

Increasing of Oil Field Productivity by Implementation of Re-entry Horizontal Injection Well, Case study

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Abstract

Water flooding is one of the most important methods used in enhanced production; it was a pioneer method in use, but the development of technology within the oil industry, takes this subject toward another form in the oil production and application in oil fields with all types of oils and oil reservoirs. Now days most of the injection wells directed from the vertical to re-entry of full horizontal wells in order to get full of horizontal wells advantages.

This paper describes the potential benefits for using of re-entry horizontal injection wells as well as combination of re –entry horizontal injection and production wells. Al Qurainat productive sector was selected for study, which is one of the four main productive sectors of South Rumaila oil field. A simulation model – named as SRFQ was used in the present work to predict the re-entry horizontal wells performance.

Four scenarios were suggested to cover the full scope of the study; those scenarios are different in manner of wells combinations. Cumulative oil production, ultimate recovery percentage are two criteria were used to predict the performance and comparison of scenarios.

Results from simulation model (SRFQ) runs revealed that the productive sector can be continue to gain 1564.331 MMSTB till 2020, without changing to any existing injection and production wells status, which is called the base scenario. While scenario no.1 needs some of work over and remedies jobs, which gives more cumulative oil production reaches to 1698.481 MMSTB till 2020.

On another side, scenarios no. 2 and 4 are the most important scenarios because re-entry horizontal injection wells were implemented. Very good and encourage results were gained over the bas scenario from the sector under study.

At last, scenario no.3 was suggested just to predict the production capacity of the Al Qurainat sector with re-entry horizontal production wells and existing vertical injection and production wells, while the cumulative oil production reaches 3398.481MMSTB.

Key words: horizontal, reservoir management, increasing production, re-entry.

Introduction

It is well known that water injection is the most common method for increasing oil recovery and pressure

maintenance applications, where water injection is often used as a recovery method for light oil reservoirs, then latterly was used for viscous oil

reservoirs by Martini, R.F. et al.(2005)¹.

This oil recovery technique becomes an increasing important issue in the management of produced fluids, including disposal or produced water as well as oil from production or field. Water flooding technology was developed along the time from the forties of the previous century up to now. Now a days the use of horizontal wells within EOR applications becomes traditional and have been increasing very rapidly through the oil industry as advances in drilling techniques continue to overcome water flooding problems like sweep efficiency, oil production with high WOR, front shape, injection flow rate,...etc.

Most of the recent reports or publications appeared the interesting of horizontal-well water flooding starting from the nineties decade of the last century, although there are relatively little published information about the using of horizontal water injection wells in comparison with another recovery methods. The need for injection patterns of both horizontal injection and production wells, opposed vertical fractures well placement, are necessary for increasing the rate of flooding in EOR processes. However, in spite of the tremendous increase in literature reference, little information is available on horizontal well application for EOR methods. A survey of extensive horizontal well literature is beyond the scope of this paper, but reviews of books, SPE reprint series and published articles, show that horizontal wells are still used primarily to solve specific production problems, which includes²:-

- Low permeability formation, specially fractured formations.
- Low permeability gas reservoir.

- Unusual gas resources such as coal-bed methane or Devonian shale.
- Gas or water coning.
- Thin formation.
- Viscous oil.

The development of oil and gas fields take a variety of pictures and forms, depending on the circumstances and productivity associated with hydrocarbon reservoirs. In addition to that, the method and the application ways of strategy plans that were developed by engineers, responsibility of production techniques and reservoir management of oil and gas field.

With more planning and management point of views, using of different ways and advanced technology in the implementation of production plans, the goal will be clear and deliberated with less losing and cost risk. Therefore, emerged as the importance of implementing plans and reservoir management processes," which are practically relies on use of financial, technological, and human resources, while minimizing capital investments and operating expenses to maximize economic recovery of oil and gas from a reservoir" 3. The purpose of reservoir management is to control operations to obtain the maximum possible economic recovery from a reservoir on the basis of facts, information, and knowledge (4, 5, 6).

This paper describes potential benefits of using re-entry horizontal injection as well as production wells for water flooding purposes in case of production enhancement and field development. Incremental of cumulative production and sweep efficiency are the criteria used for comparison and improvement.

Southern Rumail Oil Field ⁷

The dimensions of Southern Rumail oil field are about 38 Km long and 14 Km wide. The field is associated with large gentle anticline

fold of sub meridional trend; dip angles on the flanks do not exceed 3° whereas in the crested parts they are about 1° . The field main pay reservoir is divided into four production sectors, also the reservoir consists of five production units according to the differences between the porosity and the permeability, which are from top to bottom R1, R2.1, R2.2, R3.1 and R3.2 respectively.

The field is surrounded by a large aquifer and the predominate production driving force is the natural water drive which is active as driving force and contribute up to 90% ^(8,9,10) of the production energy. The problem in the reservoir under study is the asymmetric rising of oil water contact on east & west flanks, which means that the reservoir has a tilted OWC because of unequal water influx advancement in both sides of the field. In accordance to that, the water will spill over from the west flank to the east part of the reservoir. To prevent the spillover phenomenon, the Reservoir Engineering Directorate executed the water injection project along the east flank of the field in order to support the reservoir pressure decline and balance the fast water advancement from the west side of the field.

Many development stages had been carried out along the production life of the field since exploration, which were executed in sequence of development stages. The wells have a high production potential, some of them reach up to 50,000 STB/D at the early time of production life.

Many reservoir studies ^(11, 12) outlined that the recovery factor for all reservoir units (R1, R2, R3) in Southern Rumaila field could not be below 50%. Therefore, the most reasonable value of recovery factor in the field is 54% and the OOIP will be 1458 MM tons.

The production from the field reaches to 65 MM tons/ year and can be held on this level of production by water injection in addition water drive. The reservoir behavior (production, injection, pressure, water advancement) is directly and frequently investigated by the engineers in order to ensure that the application of production plan to reach high production rates with good depletion strategies.

Geological Description

The main pay reservoir in South Rumaila oil field is one of the most important and prolific oil producing reservoirs in southern area of Iraq. This reservoir constitutes the upper sandstone member of the Zubair formation that is called main pay zone of South Rumaila Oil Field. The Zubair formation in south of Iraq found in (Rumaila, West Qurna and Zubair Fields), which belongs to the depositional cycle of Lower Permian of Lower Cretaceous age. The formation is generally, composed of sandstone and shale. The ratio of sand in the formation decreases significantly toward the east while this ratio increases toward the west and it may reach to 100% in the west of South Rumaila Oil Field. The sand ratio also decreases toward the north while it increases to the south.

Zubair formation has been divided into five members on the basis of sand to shale ratio.

The main pay (upper sand stone member) comprises three dominated sandstone units, separated by two shale units. The shale units act as good barriers impeding vertical migration of the reservoir fluids except in certain areas where they disappear. For more details with geological description of main pay reservoir can be found in reference [7].

The main pay is an important producing horizon; even though, it is considered being in a mature stage of depletion due to highly water advancement over some parts of it. In spite of that a large cumulative production from the main pay reservoir still continue, and the oil recovery during the primary production stage affected by the un balance water drive from the both sides of the field.

Water Flooding in South Rumaila Oil Field

In an attempt to increase the production of oil from the main pay reservoir and maintain the reservoir pressure by achieving better water injection plan, a water flooding project was implemented from 1980 up to now, through multi stages of completion along the field life. Problems have been appeared at the beginning of water flooding project like un stable water injection flow rate, decreasing of formation ability to receive the injected water quantity with the time, diminished and lack in amount of water injected to the producing layers ...etc.

Therefore, one can see unfavorable water flooding operations within the field and much oil still remaining in reservoir, especially in the upper parts of main pay reservoir.

Why Horizontal Well Water Flooding? ⁽¹³⁻¹⁸⁾

In the last few years, the number of horizontal wells drilled has substantially increased worldwide. The gained field results published in papers and reports are revealed, that the application of horizontal wells are encourageous, so that the major advantages of using horizontal wells are increasing productivities, minimizing gas and water coning, extending areal sweep, and connecting vertical fractures.

Martkitell and Huang(1993) ¹⁴ stated that to drill a successful and economical horizontal well for a specific reservoir requires state-of-the-art for drilling/completion techniques, a detailed geologic/reservoir description study, and an optimal well design.

The horizontal well design involves many aspects such as well length, location relating to GOC/WOC, spacing, and performance prediction compared to a vertical well, in addition to the technical objective of the horizontal well is to expose significantly more reservoir rocks to the well bore surface than can be achieved via drilling of a conventional vertical wells, so the desire to achieve this objective stems from the intended achievement of others. More important technical objectives that relate to the specific characteristics of the target reservoir are related to the more objectives (avoidance of water production for example) achieved by desire horizontal wells which provides an economic benefits. The drilling, completion and production techniques have been modified for the horizontal environment; this lead to the average cost is going down.

Additionally, the key issues in correct application of horizontal wells technology pivots around achieving desired production/ injection of the project wells and the cost associated with drilling horizontal wells without damaging the depleted and low pressure reservoir.

Southern Rumaila - Field Development

Most of the explored oil and gas fields, after completing of the exploratory drilling phase to identifying the reservoir limits, and make sure the hydrocarbon inventory. The professional engineering staff of the reservoir management and fields

development directorate, beginning to prepare the reservoir studies for the development purposes in order to put the reservoir under commercial production with optimum exploitation of its natural energy by using of optimum production methods. Hydrocarbon fluids must be withdrawal from the reservoir without loosing of reservoir energy, so the complete process seems like balancing between fluids withdrawal and reservoir pressure drops. With progressing of oil field production, there are many production plans were suggested, discussed and implemented according to the production of H.C quantities and accompanied reservoir pressure draw down.

The main pay reservoir in South Rumaila oil field was developed since early times of production up to now with different stages ⁽¹⁹⁾, these stages are out of the scope of the present work.

This work presenting, a new idea of development for the Qurainat production sector by suggestion of a new re-entry horizontal injection wells project. Principally every project success depends on careful monitoring/surveillance and through going evaluation of its performance toward the reactive agreement with the expected performance, unless the original plan should be revised and recycle again.

Traditionally, translating of any idea to the application phase, a process of comprehensive management plan which involves depletion and development strategies, data acquisition and analysis, geological and numerical model studies, production and reserves forecasts, knowledge of facilities requirements, economic optimization, and management approval should be performed. Therefore the whole concept idea of the present work and

the results derived from them, are submitted to the executive operators of the South Rumaila oil field, as an application of horizontal well technology for the both of the discovery and production development stages of oil reservoir, which becomes a frequent worldwide event over the past few years, and becomes the needs for the enhancing recovery from the vast amount of the remaining oil and gas in place around the world, and to complete globally requirement of better reservoir management practices.

Suggestion of Horizontal Water Flooding Wells in Southern Rumaila Oil Field

The South Rumaila Field is divided into four production sectors. From the north to the south, the sectors are Qurainat, Shamiya, Rumaila, and Janubia as in Fig.1.

The selection of this productive sector is due to the following reasons:-

- The amount of original oil in place still huge in comparison with other productive sectors.
- There is a possibility in the development of this production sector from the field in terms of:-
 - The type and the number of wells.
 - The quality of their high productivity as in the rest of the production sectors in the field.

Horizontal water injection wells for water flooding applied in the present work includes re-entry horizontal injection wells, besides the existing of vertical injection and production wells operate in the same productive sector.

Also a re-entry horizontal producing wells were suggested for production boosting from the same productive sector in some suggested cases.

Practically, the concept is that large volumes of water can be injected at pressure below the fracturing pressure

of reservoir. Using of horizontal well is attempting to demonstrate the economic impact of horizontal well for water flooding in an area adjacent to a pre-existing vertical water flood.

In addition to that, thinking of horizontal water injection project needs to understand the available and adequate surface and subsurface infrastructure construction facilities, also balancing between the expenditures for equipment upgrade, drilling and completion of re-entry horizontal injection wells, injected water treatment process and volumes with how much oil can be produced?.

That is, what had said before, is the view point of the field development, specially for the productive sector – Qurainat of the considering field. This development perspective preceded by a descriptive study of the considered region, as well as the collection of data from the vertical wells that were currently operation within the field, to identify a suitable un-flood area within the field, then all the information are plugging in the simulation model to study the horizontal water flooding performance over the existing conventional wells.

SRFQ - Simulation Model

The results of the present work was obtained from the reservoir simulation model called (SRFQ), these are classified in to two main groups, simulation results and predicted results, where the second one divided into four scenarios. Simulation model building and matching are out of the scope of the present work, just taking of simulation results to help with the prediction phase of the study.

Runs were conducted to confirm the suitability of re-entry horizontal water injection wells for water flooding, and to verifying the main target of the present research work that is study increasing of oil productivity from

Qurainat productive sector of the Southern Rumaila oil field by proposing re-entry horizontal injection wells.

The history match phase of the study was over the period from 1954 to the end of 2006. For more details about this phase of the study, one can refer to reference [10], and then the model runs from 2007 to end of 2010 according to field production conditions and facilities founded during this period. Fluid saturation distribution map was obtained¹⁰, especially for water saturation - Sw-map of the concern productive sector. Fig. (2a, 2b), show the saturation distribution map of the concerned sector.

Predictive Phase Results

Table 1, reflects the methodology that was followed by this part of the work results, so it shows there are four main scenarios suggested with the Qurainat productive section of southern Rumaila field.

Some questions were raised through the suggested re-entry horizontal injection wells, these are:-

1. What are the lengths of the new re-entry horizontal wells?, and where will be locate in the field?.
2. How much cumulative production can be gained from each one?
3. What are the constraints for the production from the new re-entry wells?

The present study could not concern with the optimum length or location of re-entry injection wells, but studied the subject by virtue of production enhancement. Field constraints are:-

- a) Production well is plugging with maximum water cut 50%.
- b) Maximum gas oil ratio is 775 SCF/STB.
- c) Minimum bottom hole following pressure = 2660+50 Pisa, where Pb is 2660 psia, in order to avoid any free gas liberation.

d) Maximum Bottom hole injection pressure is 6000 Pisa, in order to not overcome the fracture rock pressure.

Prediction phase falls into four scenarios; each one had been run with SRFQ model from 2011 to end of 2020, so the priority of this part is to study the implementation of re-entry injection wells from existing vertical injection wells and steering them toward the right areas, also a re-entry of horizontal production wells were suggested for production boosting, taking into account the current wells status, which may be classified into:-

1. Ceased flow wells.
2. Transferred to upper shale layer.
3. Wells with fluctuation in production history due to production problems like high water cut, needs more work over jobs, low bottom hole pressure ...etc.
4. Limit and/or varying in receive amount of injected water by reservoir producing units across the perforated area of the injection wells, this reason depends on their petrophysical properties along the field, as well as the well capacity for injectivity.

Prediction Scenario	Vertical injectors	Vertical injector with remedies.	Re-entry horizontal injectors	Vertical producers with remedies	Vertical producers	Re-entry horizontal producers
Base Scenario	*				*	
Scenario No.1		*		*		
Scenario No.2			*	*		
Scenario No.3		*		*		*
Scenario No.4			*	*		*

Base Scenario

In the base scenario, the locations, production and injection rates of the existing vertical wells were fixed according to the last production schedules of 2010. Prediction runs were carried out from 2011 to 2020. This scenario was done in order to confirm the following issues:-

- Study the possibility of the Qurainat production sector in Southern Rumaila oil field continue to produce at a rate of 0.4285 MM STB/D as minimum.

- Creating a base scenario for comparison with following suggested scenarios.

General Marks

According to the following suggested scenarios, the benefit of each one will be inspecting to confirm the following items:-

- Increasing of cumulative oil production from the productive sector under study.
- Study the pressure drawdown behavior along the wells production life.

- Verifying of water injection importance for the pressure maintenance in connection with natural aquifer support.
- Water flooding behavior and sweep efficiency under the concerning condition of each scenario.

Scenario No.1

This scenario has reserved with the same vertical production and injection wells, but depends on making some remedies, for those wells suffering from fluctuation in their behavior in order to increase the injection and production flow rates for them. This scenario studied the benefits of new flow rates of the existing vertical wells to confirm the general remarks. Work over process with some of injection and production wells that were suffered from working problems, especially cease flow due to decreasing of formation permeability, or mechanical problems along well strings ...etc. figure 3a, shows the location of these wells.

Scenario No.2

This scenario introducing the re-entry horizontal injection wells with most appropriate injection flow rates - favorite injection flow rate that increasing of productivity along time of prediction with less WC% measured in production wells - and closing of all existing vertical injection wells, while the vertical production wells still producing under the same wells conditions of the scenario No.1. This scenario suggested confirming the importance of horizontal re-entry water injectors, in addition to the general marks.

Scenario No.3

This scenario is the same as scenario No.1, but with introducing of new re-entry horizontal production wells with most appropriate production rates that

make them continue in production under the constraint limit(WC=50%). This scenario depends on vertical injection wells under new conditions as in scenario No.1. It is suggested to confirm the production enhancements (dual producers view of point), by introducing of re-entry horizontal production wells accompanies with existing of vertical injection and production wells as in scenario No.1, in addition to the general remarks of suggested scenarios.

Scenario No.4

This scenario is the same as scenario No.2, but with introducing of new re-entry horizontal production wells, with most appropriate production rates that make them continue with production under the constraint limit(WC=50%). This scenario depends on re-entry horizontal injection wells under new conditions as in scenario No.2, and closing all of the vertical existing injection wells. This scenario suggested confirming the production enhancement (dual producers) with introducing of re-entry horizontal injectors as in scenario No.2, in addition to the general remarks of suggested scenarios. Figure 3b, shows the suggested location of new re-entry horizontal wells.

Discussion of the Scenarios Results

In this section, discussions of the suggested scenarios results are oriented to cover the guide line features, which are:-

1. Increasing percentage of cumulative field production.
2. The formation pressure, due to variance of pressure supporting, especially within the re-entry injection horizontal wells.
3. Well pressure variation with the time.
4. Production plateau

The final results tables presented for each scenario, reflects the final results after discard the wells with low production rates (≤ 500 STB/D), or suffering from rapid increasing of water cut during their production life and gaining low cumulative oil production.

Scenario No.1

This scenario begins with identification of locations which have high production possibility. Inspection the necessary of existing vertical production and injection wells within productive sector, considering of work over process advantages for each well in case.

Results obtained from the predictive runs of this scenario revealed that, more of oil production gaining was happen under new wells conditions. A comparison was made between scenario no.1 and base case, to inspect the validity of the production enhancement.

Fig. 4 shows these results in comparison with base scenario for the WC up to 50%. Following are some advantages gained from this scenario, these are:-

1. Significantly, there is increasing of cumulative oil production, the cumulative oil recovered during the period from 2011 to 2020 is 1698.5 MMSTB, in comparison with 1564.33MMSTB by the base scenario. The incremental percentage increase in production is equal to 15.629% with ultimate recovery percentage reach to 39.46%.
2. The block pressure of the main pay reservoir still above the bubble point pressure.
3. The pressure supporting energy in this scenario is both of aquifer and water injection wells, but they couldn't equally in response with cumulative fluid withdrawal from

the sector, therefore a pressure declination is observed with continuing production of the wells up to the end of the predictive period.

Scenario No. 2

This scenario dealing with introducing of re-entry horizontal injection wells with identification of them locations from the existing vertical wells, The suggested re-entry injectors are implemented by the model SRFQ, while the vertical production wells are still under their conditions of scenario No.1 and close all the vertical injectors. Fig. 3b, shows the new wells on gridding map of the considered productive sector (Qurainat). Many runs were carried out in order to gain more oil production. An appropriate injection rates according to sweep efficiency were applied for those injectors.

Fig.5 shows the comparison with base scenario, to inspect the validation of production enhancement by introducing those new re-entry injection wells. The gained results from this scenario revealed the following advantages:-

1. Increasing of field oil production significantly. The cumulative oil recovered during the period from 2011 to 2020 is 2118.14MMSTB, in comparison with 1564.334MMSTB by the base scenario. The incremental percentage in production is equal to 26.15% with ultimate recovery percentage reach to 49.21%.
2. High cumulative production from existing vertical wells by this scenario in comparison with base vertical production wells.
3. The block pressure of the main pay reservoir still above the bubble point pressure.

Scenario No. 3

This scenario is similar to scenario No.1 with proposing of a new re-entry horizontal production wells to boost the production concerning the same water cut limit.

Results of re-entry horizontal wells of this scenario can be seen in the Table 2, which presents the production rate and cumulative oil production for both dry and wet oil.

A comparison was made with the base scenario to insure the improvement in cumulative oil production, Fig. 6 shows these results. The final results of this scenario by introducing of new re-entry wells can explain the cumulative oil production improvement as following:-

1. Cumulative oil production recovered during the period from

2011 to 2020, is 3398.481MMSTB, in compariso

2. n with 1564.33MMSTB by the base scenario. The incremental percentage in production is equal to 23.629% with ultimate recovery percentage reach to 78.96%. It seems there was almost big difference relative to the base case.
3. High cumulative production from those new re-entry wells were gained in comparison with their existing vertical production wells.
4. Still the block pressure of the productive regions above the bubble point pressure. The pressure maintenance in this scenario is aquifer and water injection wells together.

WELL NO.	Production Rate (STB/D)	Date to end of dry oil production	Cumulative production of dry oil (MMSTB)	Well status at the end of prediction	Cumulative production wet oil (MMSTB)
400	5000	---	---	31.12.2020 49%	18.25
401	2000	6.9.2013	1.958	2.4.2017 48%	4.564
402	2000	---	---	31.10.2016	4.258
403	500	Neglected			
404	3000	16.1.2014	3.333	31.12.2020 41%	7.617
405	3000	---	---	31.12.2020 41%	10.95
406	500	Neglected			
407	2500	---	---	30.6.2020 49%	8.665
408	500	Neglected			
409	500	Neglected			
410	5000	31.10.2017	12.47	31.12.2020 46%	18.25
411	3000	31.12.2020	10.95	31.12.2020 0%	10.95
412	3000	28.7.2013	2.817	31.12.2020 42%	10.95

Scenario No.4

This scenario is similar to scenario No.2 with proposing of a new re-entry horizontal production wells. The improvement of oil production within the concerning productive sector within this scenario has been gotten with the same water cut constraint. Results of the re-entry horizontal production wells of this scenario can be seen in the Table 3, which presents the production rate and cumulative oil production for both dry and wet oil.

A comparison was made with the base scenario to insure the improvement in cumulative oil production by this scenario, Fig. 7, shows these results. The final results of this scenario by introducing of new re- entry wells can explain the cumulative oil production improvement as following:-

1. Cumulative oil production recovered during the period from 2011 to 2020 is 3364.133MMSTB, in comparison with 1564.33MMSTB by the base scenario. The incremental percentage in production is equal to 22.629% with ultimate recovery percentage reach to 78.16%. It was shown that this scenario slightly less than the third one.
2. Pressure maintenance manner, block pressure behavior ($> P_b$), cumulative oil production of re-entry production wells follows the same explanations as in scenario No.3.

Figure (7), shows the comparison results with base scenario.

WELL NO.	Production Rate (STB/D)	Date to end of dry oil production	Cumulative production of dry oil (MMSTB)	Well status at the end of prediction	Cumulative production wet oil (MMSTB)
400	4500	---	---	31.12.2020 44%	16.425
401	500	Neglected			
402	500	Neglected			
403	500	Neglected			
404	500	Neglected			
405	500	Neglected			
406	1750	---	---	31.12.2020 50%	6.3875
407	8000	---	---	31.12.2020 34%	29.2
408	500	Neglected			
409	500	Neglected			
410	4000	20.8.2015	6.768	28.2.2019 46%	11.916
411	3250	31.10.2015	5.733	14.10.2020 49%	11.609
412	3750	18.10.2012	2.46	31.1.2017 50%	8.329

Final Decision, Which Scenario is the Best?

At the end of the suggested scenarios results, Table (4), summarize the importance of the re-entry horizontal wells implementation within Qurainat production sector/ Main pay reservoir. In general, all the scenarios results are encouraging to increase the sector production by re-entry wells (injection and /or production) over the base case, and this is in fact ensuring one of the horizontal wells validations in South Rumaila Oil Field, also it can be considered as future development step point of view for this field.

The suggested scenarios have different wells locations as mentioned before and demonstrated in Fig. 3b, within the whole productive sector. These wells have different time of break through (assuming of WC equal 10%), and time of reaching the upper limit of 50% WC. There is no chance of locally free gas liberated in production wells, or the pressure still above Pb.

The present study considered as development stage view point to SOC Company, because the South Rumaila oil field is falling under its management, therefore SOC may have the following choices when put this

study in execution plane, and can expand the same idea to another productive sectors in the field.

- According to the present status of the field production with max of 50%WC, scenario no.1 can be adopted with doing some of work over and remedies jobs for the vertical injection and production wells, in order to rehabilitate them and return them to the service. Increasing of the cumulative oil production has been gotten from 1564.33 MMSTB to 1698.5 MMSTB along the time period from 2011 to 2020.
- Both of sweep efficiency and cumulative production was improved by adopting of re-entry horizontal injection wells and close all of vertical injection wells, scenario no.2.
- Implementation of both re-entry horizontal injection and production wells (dual producers), reveals that the cumulative oil production reach to 1665.652MMSTB in scenario no.4 in comparison with base scenario for the same suggested time period.

	Cumulative oil Production (2011-2020), MMSTB	Incremental Percentage in comparison with the base scenario	Ultimate recovery percentage	Re- entry Drilling and completion Coast (million\$)*
Base Scenario	1564.3314		36.35	-----
Scenario No.1	1698.481	15.629	39.46	-----
Scenario No.2	2118.14	26.15	49.21	28.8
Scenario No.3	3398.481	23.629	78.96	64.8
Scenario No.4	3364.133	22.629	78.16	72

*- Re – entry drilling and completion cost calculated according to 1.2²⁰ times vertical well cost.

**-. Vertical well drilling and completion cost reach to 6 million dollars²¹.

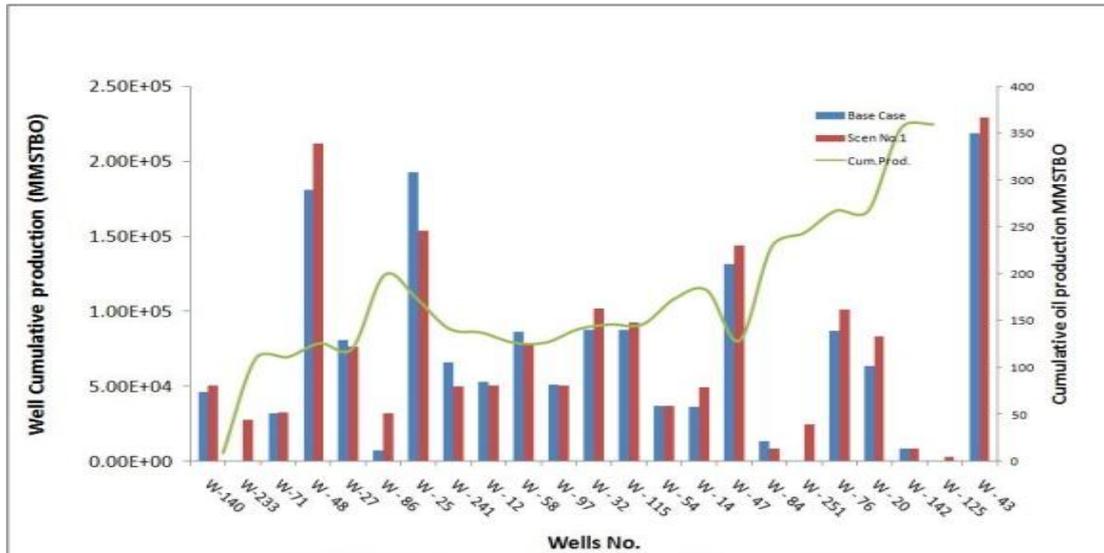


Fig.4, Comparison between Base Scenario and Scenario No.1

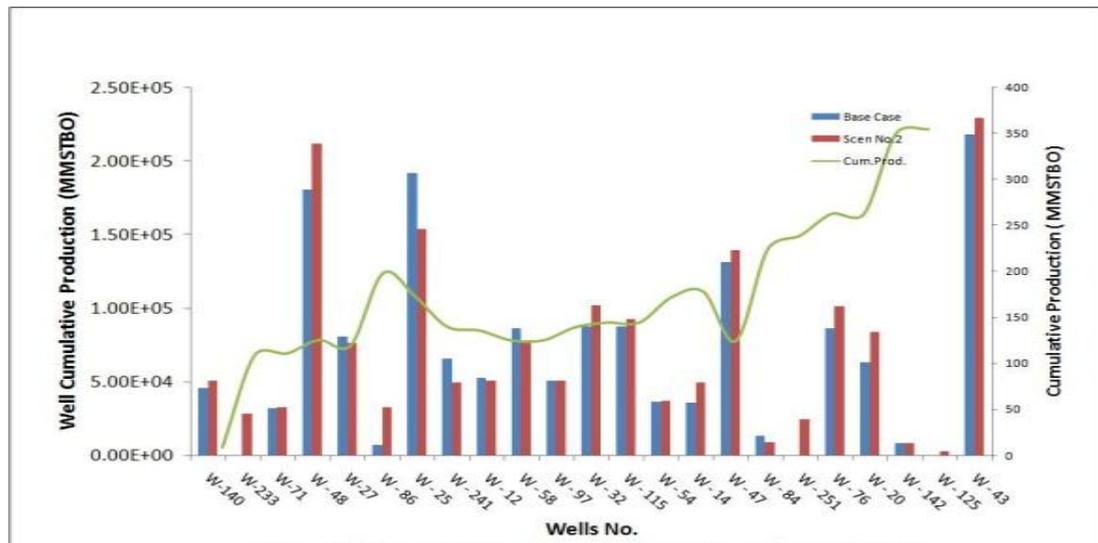


Fig.5, Comparison between Base Scenario and Scenario No.2

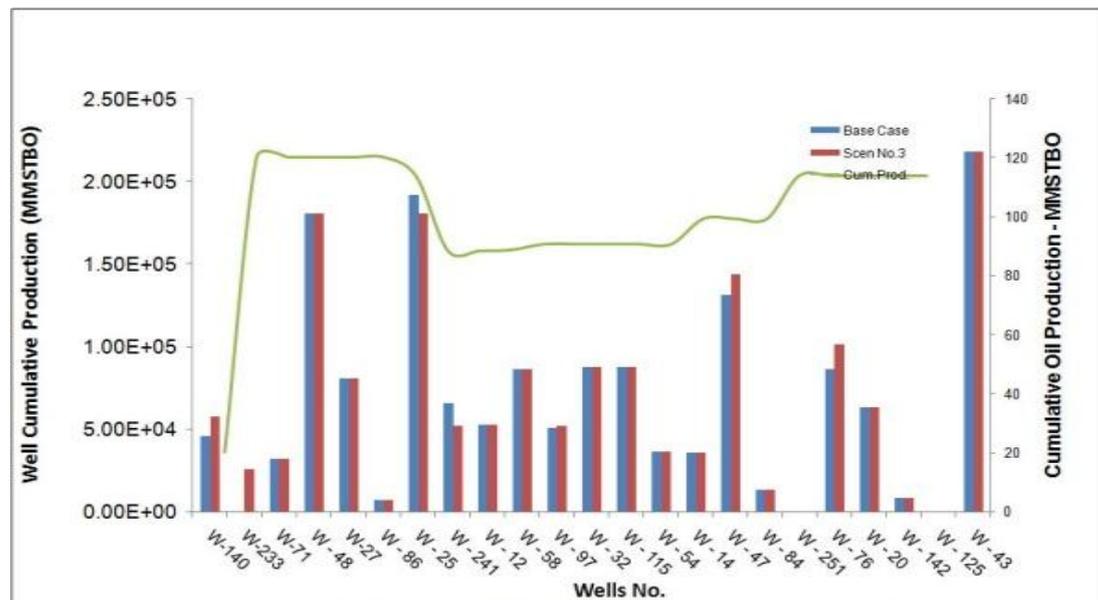


Fig.6, Comparison between Base Scenario and Scenario No.3

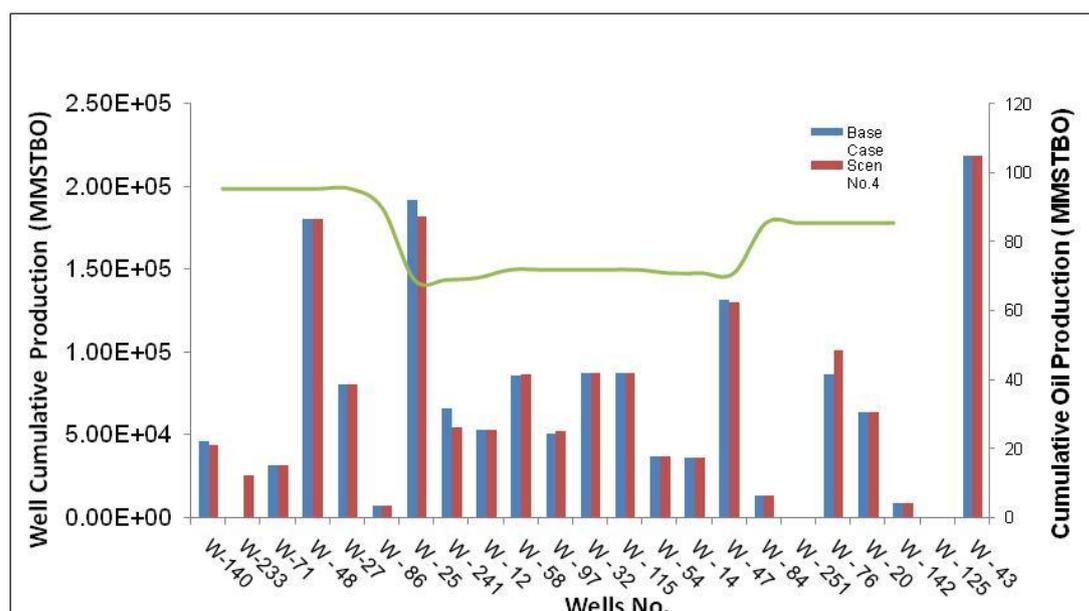


Fig.7, Comparison between Base Scenario and Scenario No.4

Conclusions

1. The final results of the suggested scenarios in the present study are courageous for executing and implementing re-entry horizontal wells project within main pay reservoir in Southern Rumaila oil field according to the predicted cumulative oil production and ultimate recovery percentage by the suggested scenarios.
2. All the scenarios reveal that the re-entry wells have higher capacity either for injection or production usage. Good and acceptable production incremental percentage in comparison with the present existing vertical wells that were launched from them to the production units (R1, R2 and R3).
3. The production from the productive sector Al Qurainate – reach to 0.465 MMSTB/D (scenario No.1), under the present field conditions, while the cumulative production reach to 1698.481 MMSTB at the end of 2020.
4. It is clear from Tables 2 and 3, the time of dry and wet oil production are different among suggested wells in each scenario or among scenarios themselves for each well, this return

to the location of the new suggested re-entry wells, the directions and their proximity from the high water saturation grids. Other factors may Play significant effects on wells behavior like:-

- a. The effect of the adjacent existing vertical production wells.
- b. The daily production rate.
- c. The flow capacity for the penetrated grids by those wells.

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Nomenclature

H.C = Hydro carbon
 H.W = horizontal well.
 EOR = Enhanced oil recovery.
 GOW = Gas oil contact.
 SOC = South Oil Company.
 SRFQ = South Rumaila Field (name of model).
 SRFQ = model name, Southern oil field.
 OWC = Oil water contact.
 WC = Water cut.
 WOR = Water oil ratio.

SI Metric Conversion Factors

STB	x	1.589873	E-01 = m ³
Ft	x	3.048	= m
Ton	x	9.071847	E-01 = mg
API °		141.5/ (131.5+ API °)	= gm/cm ³

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