Appraising the Performance of Cyclic Production Scheme through Reservoir Simulation, a Case Study
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Abstract
Oil wells in mature fields with strong aquifer influx and the first row of producers near peripheral water injectors experience very high water cuts (above 80%), which cause lower oil production and increasing disposal costs.

To mitigate this situation, various production strategies have been implemented in this simulation study to reduce water production, optimize oil production and revive dead wells. One strategy is to implement a cyclic production scheme (CPS). The CPS requires alternate shutting and flowing of wells with high water cuts over predetermined time cycles. The main objectives of the cyclic strategy is to reduce water production by optimizing oil production, minimizing coning effect and having a better control of the uniform waterflood front to the up-dip producers. This strategy enhances the sweep efficiency, improving pressure maintenance and minimizing water production.

This simulation study assesses the effectiveness and the performance of CPS implemented in a reservoir simulation model of a mature oil field. Simulation runs with several scenarios were conducted to understand and optimize the impact of CPS. The simulation results provided the best cyclic production/shut-in period and showed significant advantages of applying CPS over the regular noncyclic production in all scenarios. In this study, more than 93 wells have been evaluated and most of these wells showed good overall oil recovery after applying the CPS strategy.

Introduction
Water management has become a key strategy in the fields that have entered into a high water cut development period. As fields mature, there is a natural trend for water volumes to increase while aquifer and injected water advances towards the producers. Furthermore, increasing levels of water production can impair oil production rates, in some cases to the point where the well ceases to be economical to produce.

Although injected water is an enabler for improved hydrocarbon recovery, it is essential to control water production volumes and flood front. High water production may limit oil production in a rate limited well, increase water treatment and disposal costs. In general, excessive water production in mature fields is a serious issue in effective reservoir management.

One option to reduce water production from high water cut wells is to convert the well into a cyclic producer. Cyclic wells are alternated between shut-in and producing phases that normally last for six months each. The results of closing these wells are high water reduction with minimal impact on oil field production. The main benefit of the cyclic strategy is to reduce water production, which allows optimizing the water injection process, minimizing recirculation and allowing a better displacement of the water flood front to the up-dip offset producers. In terms of economics, since less injected water is recirculated, the operational handling costs decrease and the economic efficiency of the water injection project improves.

This study was implemented in a mature field as a part of the water management effort to reduce water production. In this study, a reservoir simulation model was developed based upon very fine geological characterization, and the field performance history was matched. The model has been constantly updating its history matching by using the latest reservoir surveillance data, pressure, water saturation for flood front detection, and new infill well data. The predictability of the
reservoir simulation model is very good. Simulation runs with several cyclic production scenarios (CPS) were conducted to analyze and optimize the impact of CPS on the production performance of the field.

**CPS Concepts**

*Figure 1* illustrates the CPS with a certain period of shut-in time. In a cyclic production mode, the mechanism of fluid movement is different than a normal production mode. During the shut-in period, heavier density water is segregated and separated from oil and settles down towards the lower portion of the oil column. Water coning and fingering will smear back to the lower part of the reservoir, and therefore, the well can produce oil at a reasonable rate during the production period.

![Fig. 1—CPS.](image)

One main advantage of cyclic production is less water coning (and lower water cut) during the production phase because gravity segregation restores the oil column in the wellbore region during the shut-in phase. Another advantage is that cyclic production is particularly applicable to dead wells that have been revived but have marginal pressure potential. The shut-in period allows the build up of pressure potential as well.

The main objectives of CPS are to save reservoir energy by keeping water in the reservoir, and by this, reservoir pressure will be maintained to enhance sweep efficiency, by disrupting the streamlines around the injection wells that direct the injected water to the un-contacted areas, and to recover the bypassed oil. Also, there are other benefits by CPS that related to gas-oil separation plant operations to minimize surging conditions after reducing water productions, to control water handling capacity for disposal wells and to optimize demulsifer consumption.

**Selection Criteria and Implementation**

The key parameters used in the selection of CPS candidates are well production performance with water cut above 60% and up to 99% with minimum oil production, normally below 1 thousand barrels of oil per day (MBOD) and sometimes as marginal as 0.2 MBOD. The designation of a producer well as a cyclic is done after other water control methods, such as water shut-off and workovers have been considered. Cyclic producers are selected in areas of thin oil columns and near to peripheral water injectors.

This strategy was first implemented in 2005 with 22 wells, mostly located in a thin oil column of less than 20 ft and spread throughout the entire area of the field. No evaluation through reservoir simulation has been done to assess the performance of these wells before this study. The results of CPS wells under these conditions are a significant water reduction with minimum impact on oil field production.

**Reservoir Simulation Model Description**

The model used in this study is based on the latest geological models developed with detailed reservoir characterization. It offers fine layering (49 layers) with a grid size is of 250 meters, totaling 3 million cells. It includes detailed fracture modeling and petrophysical rock typing. The permeability distribution for this model is validated by transmissibility (KH) values obtained from pressure transient analyses. The main history match parameters include new enhanced permeability distribution, vertical transmissibility reduction, lower aquifer permeability, and localized fracture lineaments.
History Matching

History matching is a critical step in simulation model calibration because it allows the static geological model to be rationalized with production data. It has a critical role in monitoring displacement processes; understanding the insight of reservoir flow dynamics, and the predictability of future production performance.

In this model the historical production and pressures were calibrated and matched for the CPS wells used in this evaluation. The accuracy of the history matching was very high reflecting the good quality of the reservoir simulation model. Figures 2 and 3 show good history match quality for two wells, and the cyclic mode is captured clearly in these wells. With this good quality, the model can be used to simulate the future reservoir performance with a higher degree of confidence.

Evaluation Parameters

Two main parameters have been evaluated very closely, and they are: (1) duration of shut-in intervals, and (2) production performance. The main constrains used in this study are shown in Table 1. The total number of wells evaluated in this study is 93 wells.

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Table 2—Cyclic periods used in the study

After many simulation runs and evaluations, all well results showed that the best cyclic period is 8 months on followed by 4 shut-in months, based on the reduction of water and improving in oil rate. Figure 4 shows all the prediction cases of water cut, oil rate and cumulative oil production for all the four different production cycles for one of the cyclic wells. The green
line representing the best cyclic case (8 on/4 off) showing the water cut reduction and oil rate improvement. **Figure 5** shows an advantageous performance by the 8/4 case, where the green line is the base case (wells without cyclic mode) and the red one is the cyclic cases for all the wells. Based on these results, the 8/4 cycle has been used in the actual field production optimization of cyclic wells.

**Fig. 4**—All prediction cases in one well.

**Fig. 5**—The best cycle time.

**Production Performance**

The second parameter evaluated in this study was the production performance by assessing following four major outcomes that attributed to a reasonable judgment on CPS performance and they are: (a) oil production, (b) water production, (c) sweep efficiency, and (d) offset wells performance. The following sections evaluate the impact of CPS on these areas:

**Oil Production:** This is the first key parameter to evaluate in this study. **Figure 6** shows the production performance of the cyclic group compared to the normal case, and it clearly shows an increase in oil rate when the wells were put on production. This increase in oil rate occurred due to the build up of pressure and the oil accumulation in the top of the wellbore during the shut-in period. **Figure 7** shows a single well performance. Cyclic wells improve the oil production when compared to continuous production.
Fig. 6—Increase in oil rate for the cyclic wells group.

Fig. 7—Increase in oil rate in one cyclic well.

**Water Production:** This is the major key objective in this study to reduce water production. A reasonable correlation can be developed between the number of cyclic wells placed on production and the decrease in the amount of water production. Water production decreased by about 20%. Fig. 8.

Fig. 8—Water production reduction in the cyclic group.
The closing CPS wells provide a high water reduction with minimal impact on oil field production. Figure 9 shows oil and water reduction for some cyclic wells. It has been found that a greater reduction in produced water can be achieved using CPS.

![Fig. 9—Pie chart for some cyclic wells showing water reduction.](image)

**Sweep Efficiency:** In the cyclic process, the incremental production effect is reached due to the interplay of different production mechanisms: capillary and viscous forces, gravity segregation and compressibility effects, which lead to improved fluid cross flow and better reservoir sweep efficiency.

In this study, sweep efficiency improvement from flow pattern redistribution has been observed and it could make an additional contribution. This happened due to the re-alignment of streamlines that has been established in the field. Figure 10 shows the improvement in the sweep in some parts of the field.

![Fig. 10—Sweep improvement after cyclic mode.](image)

**Offset Wells Performance:** In this study, the effect of this CPS process has been evaluated also for the offset wells around the cyclic wells. Cyclic wells have a significant impact on the offset well’s performance. Figure 11 shows the performance of one of the offset wells with and without cyclic process around it, and it is clearly shown that the oil rate has increased in the CPS case. Improved performance of offset wells is observed in many areas and goes beyond the cyclic period and into the future.
Conclusions
There was a big impact of the implementation of this CPS water management strategy in the optimization of the oil production from the reservoir. Significant water productions from CPS wells were considered one of the most important factors in effective reservoir management. The oil production was reduced slightly though due to eight months on four months shut-in cyclic time compared to continuous production of these wells. Subsequently, instantaneous increased in oil rate and reduction in water were observed in all reservoir simulation cases. Due to gravity effects, cyclic production enhanced oil rate and reduced total water production during the flow period cycle. The study results showed that CPS was a viable option for water production management in oil fields. The cyclic production continues to be an effective practice to reduce water production and conserve reservoir energy in the mature field areas.

References

