

# Research on the Development Change Law of Block A after Fine Potential Excavation

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**Abstract.** After the comprehensive utilization of well pattern and fine potential tapping based on subdivision water injection in block A, remarkable results have been achieved in water cut control and decline control. With the continuous deepening of development degree, new characteristics have emerged in water drive development, and the change law of indicators has also changed greatly. Therefore, it is necessary for us to find out the change law of fine potential tapping development indicators, so as to provide a theoretical basis for the next sustainable and high-efficiency development. Through theoretical calculation and numerical simulation, this study gives the law of production decline and water cut change in different stages before, during and after fine potential tapping; The laws of water cut and production decline in different stages are evaluated and predicted. It provides a theoretical basis for the fine potential tapping, popularization and application of other blocks.

**Key words:** Fine tapping potential; Development law; Water content change; Production decline.

## 1. Introduction

Block A has carried out fine potential tapping based on comprehensive utilization of well pattern and subdivision water injection, and achieved remarkable results in controlling water cut and decline. However, as the distribution of remaining oil is becoming more and more scattered, the adjustment potential is becoming smaller and smaller, and the adjustment is becoming more and more difficult. Therefore, the field test of water control and efficiency improvement focusing on increasing the production thickness of thin and poor layers and low efficiency circulation treatment has been carried out in block A, and the methods of further enhancing oil recovery and improving development benefits have been explored, and phased progress has been made. After more than two years of water control, efficiency improvement and potential tapping, block A has achieved a good potential tapping effect. However, compared with the fine potential tapping period, the development law will change. At present, there is a problem of unclear understanding of the development law of each stage. Although the fine potential tapping has achieved a good potential tapping effect, whether the change of water cut and decline indicators continues to be better or better, and whether there is any law to follow, we still need to improve our understanding. With the deepening of development, the adjustment difficulty of water drive development is increasing, the adjustment potential is decreasing, and the pertinence of tapping the potential is not strong. Therefore, it is urgent to find out the development law of fine tapping

potential to provide technical support for the next development, popularization and application.

## 2. Study on the law of yield change

The output of oil and gas fields and oil and gas wells is not constant, but constantly changes with the process of oil and gas exploitation or the implementation of development measures. Oil and gas production may show an upward trend in a certain period, but may tend to be stable in other periods, but it develops and changes in a decreasing trend in most of the time of oil and gas field development. The practice of a large number of oil and gas field development shows that about half of the recoverable geological reserves are recovered in the process of production decline. During the decline period, not only the amount of oil and gas recovered is large, but also the duration is long, and the decline law is very complex. Therefore, Studying the law of production decline is of great significance to do a good job in oil and gas field performance prediction and oil and gas production planning. More importantly, only after understanding the law of production decline of oil and gas fields, can we take effective measures to prevent production decline in order to improve the final recovery of oil and gas fields.

### 2.1 Optimization of yield variation model

In order to verify the accuracy of the model, the primary well pattern with relatively stable decline without major

measures is selected for calculation. By comparing the predicted production value with the actual production value, the optimal model describing the production change of block A is finally determined. According to the fitted decline model formulas, the error between the predicted production and the actual production is calculated. The error of APS formula and logistics model is relatively small, but the above error is similar. Through the calculation of the difference between the predicted cumulative oil and the actual cumulative oil, it can be found that the error of Arps decline model is the smallest. To sum up, APS decline formula has small prediction error, simple operation and wide application. It is the optimal model for studying production decline in the experimental area (Table 1).

Table 1. Error calculation of prediction results

Decline model	Instantaneous production error	Cumulative oil production error
Arps	6.19%	-0.58%
Logistics	5.93%	-0.92%
Weibull	7.11%	-1.26%

### 2.2 Yield change law before fine tapping potential

Before fine potential tapping, the production will mainly rely on well pattern infilling to achieve production replacement. The basic well pattern corresponds to the development of main oil layers. After the initial production rise period, the production enters the decline stage. After the secondary infilling, the production decline slows down and fluctuates with the production of new wells. The output of block A has fluctuated for four times. First, due to the transfer of pumping in the whole region, the decreasing trend of production has been curbed, and the production has rebounded by a small margin; The reason is that the production of the first well increases and decreases again after the first well is put into production; The third fluctuation occurred during the secondary infill period. The production of secondary infill wells increased for a short time and reached the peak in 2000. However, since the production of secondary wells increased less than that of the other two sets of well patterns in 1998 and 1999, the whole region ushered in the fourth decline in 1998; In 2007, there were three infills. The production of the three wells led to another increase in the production of the whole region. Due to the short production time, there was no significant decline.

Determine each decline time period of the whole area before fine potential tapping according to the production change curve of well pattern. According to the analysis process of Arps decline model above, analyze and calculate the phased decline of each set of well pattern before fine potential tapping through trial and error method for the whole area, basic well pattern, secondary well pattern, secondary and tertiary well pattern of block A (after three infilling, secondary and injection, and form a new well pattern with three times), Judge the production decline type of four sets of well patterns in stages. Before fine potential tapping, the overall test area follows

hyperbolic decline. With the increase of grid connection density, the decline rate gradually decreases: the classified well pattern follows hyperbolic decline before fine potential tapping, and the decline rate is based on the well pattern < primary well < secondary and tertiary combination. The fitting results are shown in figures 1-4.

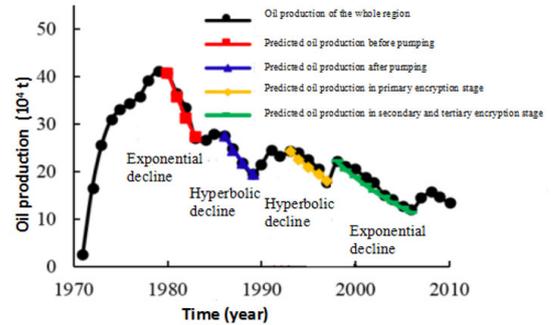


Figure 1 Oil production forecast of the whole region

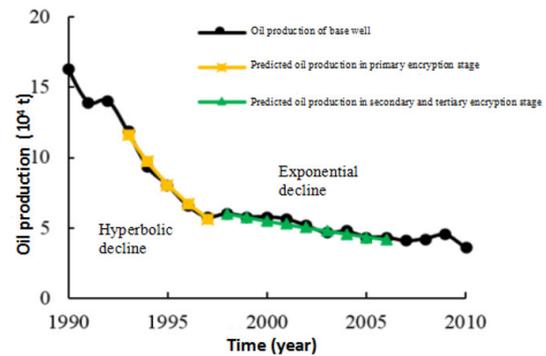


Figure 2 Oil production prediction of basic wells

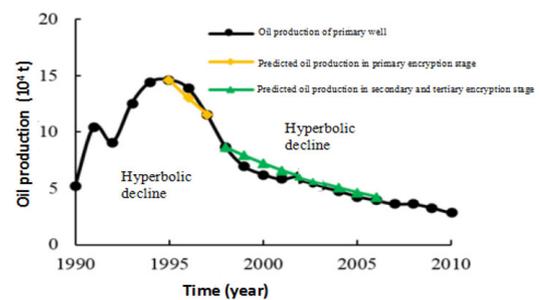


Figure 3 Oil production prediction of primary wells

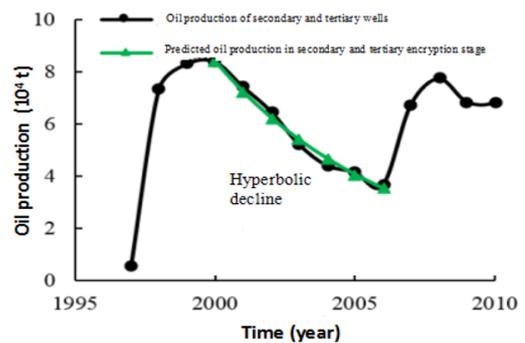


Figure 4 Oil production prediction of secondary and tertiary wells

### 2.3 Yield change law in fine tapping potential

The decline trend of output in the fine tapping stage is slower than that in the three infilling stage, and the output basically does not decline, with an average annual oil output of 133800 tons. In the early stage of the fine tapping stage, the oil production in the test area was affected by the oil increase measures, and the output maintained growth. When the effect of the measures gradually weakened, the output fell slightly in 2013. In 2014, the basic well pattern was greatly displaced and put into operation, and the output in the test area increased slightly compared with the previous year. The basic well pattern is in the decline stage at the initial stage, and the production increases after the production of extended reach wells; The primary well is less affected by the measures, and the production is in a steady decline state; In the initial stage of the second and third wells, the scale of measures is large, the oil increase is large, and the production increases. In the later stage, the effect of measures weakens and the production begins to decline. According to the change of grid connected production, determine the decline time periods of the whole region during and after fine potential tapping. According to the analysis process of Arps decline model above, calculate the phased decline of each set of well pattern in fine potential tapping stage by trial and error method. The fitting results are shown in figures 5-8.

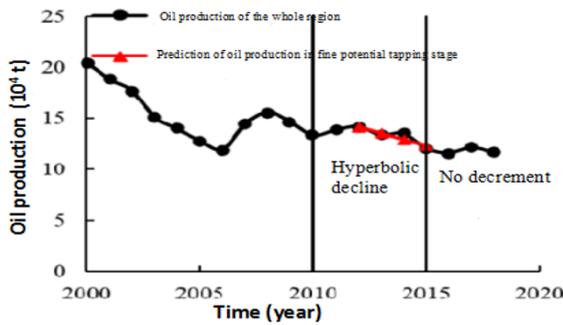


Figure 5 Oil production forecast of the whole region

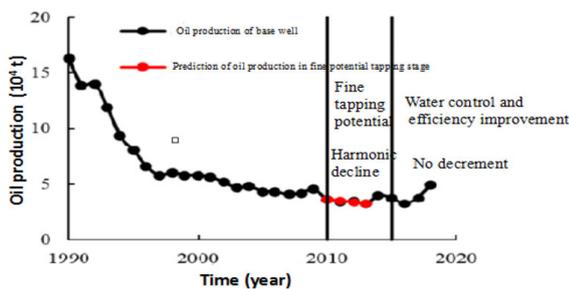


Figure 6 Oil production prediction of basic wells

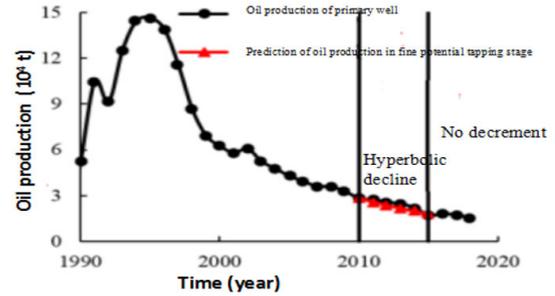


Figure 7 Oil production prediction of primary wells

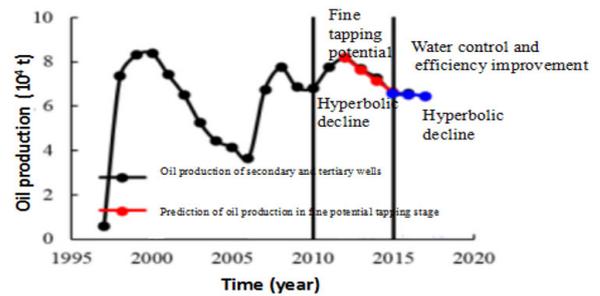


Figure 8 Oil production prediction of secondary and tertiary wells

In the stage of fine potential tapping, the decline type of well pattern changes, and the decline of the other two sets of well patterns slows down except the primary well pattern; In the stage of water control and efficiency improvement, there are only two or three times and obey the exponential decline.

Calculate the comprehensive decline rate and natural decline rate of each well pattern in the fine potential tapping stage respectively, and compare the difference of natural decline rate and comprehensive decline rate of each well pattern in the fine potential tapping stage.

There are obvious differences in natural decline and comprehensive decline among grid connected wells. The natural decline rate of basic wells < secondary and tertiary wells < primary wells, and the natural decline rate of block A in 2015 is 12.86%, while the comprehensive decline rate of secondary and tertiary wells < basic wells < primary wells, and the comprehensive decline rate of block A in 2015 is 4.55%

### 2.4 Yield change law after fine tapping potential

The natural decline and comprehensive decline of well pattern are calculated respectively, and compared with the average value in the last three years of fine potential tapping stage. The results are shown in the table below. It can be seen from the natural decline situation that the natural decline rate of block A continues to decrease in the stage of water control and efficiency improvement. At present, the decline rate is 6.54%, a decrease of 5.18% compared with the end of the previous stage. Among them, the decline rate of secondary and tertiary wells is large, and the natural decline rate in 2017 is only 2.86%; The natural decline rate of basic wells is higher than that of the

previous stage. The main reason is that the extended reach wells enter the decline period and the decline rate is high, which makes the decline rate of basic well pattern higher than that of the previous stage; The natural production of primary wells increased in 2016 with a negative decline rate, but it resumed decline in 2017. The decline rate is equivalent to that of the previous stage, reaching 15.11%. The comprehensive decline of well pattern is similar to the natural situation. The comprehensive decline of the whole region continues to decrease, the decline of secondary and tertiary wells remains at a low level, the comprehensive decline of basic wells is slightly higher than that of the previous stage, but the decline rate is decreasing, and the comprehensive decline of primary wells has little change compared with that of the previous stage.

Comparing the difference between natural decline rate and comprehensive decline rate of well pattern in 2017, compared with the previous stage, the effect of measures is weakened, and the difference between natural decline and comprehensive decline is only 1.31%; No measures have been taken for the basic wells, and the natural decline rate is consistent with the comprehensive decline rate, both of which are 9.18%. The production decline rate of primary wells is the highest among the three sets of well patterns. The decline rate of secondary and tertiary wells is the smallest of the three well patterns. Compared with the previous stage, the scale of measures is reduced, and the difference between natural decline and comprehensive decline is reduced. However, thanks to the effect of measures, the decline rate continues to decrease.

### 2.5 Results of production decline law of well pattern in block A

According to the above Arps decline model analysis process, through the trial and error method for the basic well pattern, primary well pattern, secondary well pattern, secondary well pattern and tertiary well pattern in the whole area of block A, judge the production decline types of four sets of well patterns in stages, and calculate the variation law of the production of each set of well pattern with time and the variation law of the reduction rate with time. The calculation results show that: the whole obeys hyperbolic decline; With the increase of well pattern density, the decline rate decreases gradually; The classified well pattern follows hyperbolic decline before fine potential tapping, and the decline rate is based on the well pattern < primary well pattern < secondary and tertiary well pattern; In the stage of fine potential tapping, the decline type of well pattern changes. Except for the primary well pattern, the decline of the other two sets of well patterns slows down: in the stage of water control and efficiency improvement, only the secondary and tertiary well patterns obey exponential decline, but the decline rate is only 0.99%, and the production remains basically stable.

## 3. Study on variation law of water content

The common characteristic of waterflooding oilfields is that the anhydrous oil production period is short, and there is a large amount of accompanying water production in the whole oil production process. However, the law of water cut rise is very different in different oilfields. Therefore, it is one of the important problems in the process of oilfield development to recognize the law of water cut change and take effective measures to reduce the accompanying water production.

### 3.1 Optimization of water cut fitting prediction model

Five types of displacement curves are used to fit the stage by stage water cut of the whole area and well pattern. Taking block A as an example, the fitting coefficients are compared first. Among them, the fitting correlation coefficients of convex and convex-s are higher, both reaching more than 0.95. On this basis, the error between the calculated predicted water cut value and the actual water cut is 2.83% and 3.72% respectively, Therefore, block A conforms to the convex water cut change. The water cut rises rapidly in the initial stage and slows down in the later stage. According to the fitted water cut model formulas, the error between the predicted water cut and the actual water cut is calculated. The prediction error of displacement series formulas is relatively small, simple and widely used. It is the best method to study the water cut prediction of block A (Figures 9-12).

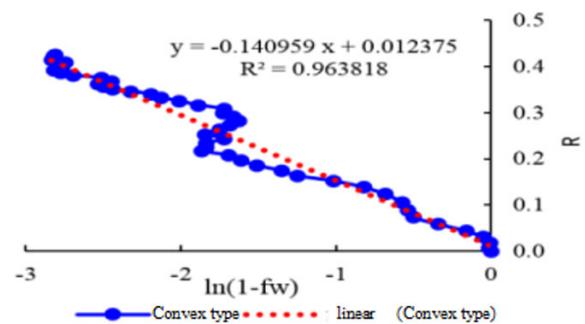


Figure 9 Convex water content change fitting curve

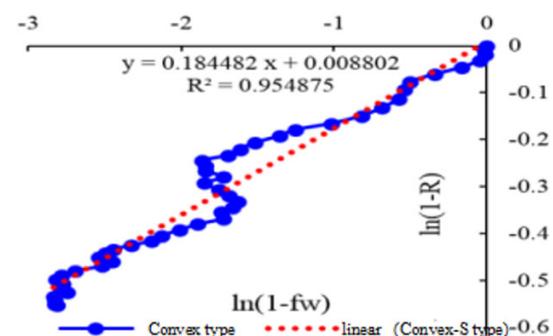


Figure 10. Fitting curve of convex-s type water cut change

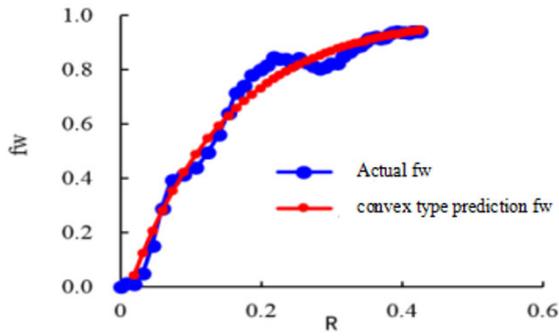


Figure 11. Convex predicted water cut curve

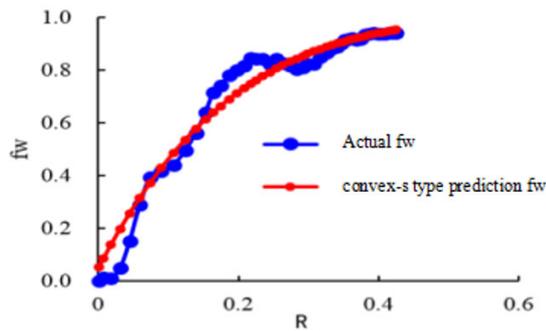


Figure 12. Convex-s type predicted water cut curve

### 3.2 Variation law of water content before fine potential tapping

The water free oil production period of the basic well before fine potential tapping is relatively short. After the initial production rise period, the production enters the decline stage, and the water cut continues to rise. In 1986, the water cut reached more than 80%. The water cut decline is mainly realized by well pattern infilling. In 1989, the primary well was put into operation and entered the primary infilling stage, and the water cut decreased to a great extent. The primary well experienced the water free period, and the water cut also continues to rise, In 1995, the water content of the primary well reached 77%, which was only 4% lower than that of the whole area. The secondary well was put into operation in 1996 and the tertiary well was put into operation in 2007. They did not experience the anhydrous oil production period, and the initial water content increased rapidly. In 2010, the water content of the whole area reached 93.8%, and the basic well, primary well and secondary and tertiary well were 95.5%, 94.4% and 91.7% respectively

The decline stage is determined by the previous oil production, and the decline of oil production will lead to the rise of water cut. Before fine potential tapping, the water cut is fitted by using the displacement series curve, and the water cut is predicted by the recovery degree. The water cut pattern of area a and sub well pattern is obtained. Before fine potential tapping, the whole area and sub well pattern obey convex and convex S-type water cut patterns as a whole, and the initial water cut rises rapidly.

### 3.3 Variation law of water content in fine potential tapping

In the stage of fine potential tapping, affected by the large-scale hole patching wells from 2010 to 2013, there were 236 wells in the region, 91 holes were patched, and the construction proportion reached 38.6%. The oil and liquid were increased in the test area, which greatly reduced the water content, and the change range of water content was very small. The water content in the region increased only 0.5% in five years: in order to exploit the non displaced crude oil at the edge of the fault, four large displacement wells were drilled at the end of 2013 and the beginning of 2014 to exploit the main oil layers, It is the same as the basic well, so it is classified as the basic well. It can be seen from the figure that the water cut of the foundation is greatly reduced due to the operation of the extended reach well.

During and after fine potential tapping (water control and efficiency improvement stage), except for the basic wells, the water content of block A and other well patterns has changed from the original convex and convex S-type to the current concave and concave S-type. The rising speed of water content has slowed down, and the measures have controlled the water content to a great extent.

### 3.4 Variation law of water content after fine potential tapping

After the fine potential tapping, in order to develop the crude oil of other faults, another 8 large displacement wells were drilled in 17 years, which greatly increased the oil production of the basic wells and the whole region, resulting in the continuous decline of water cut of the basic wells in 17 and 18 years; 16. The water cut did not rise in 17 years and decreased slightly. In 17 and 18 years, the water cut increased due to the impact of drilling shut in: the liquid production of secondary and tertiary wells accounted for 40% of the liquid production of the whole region. After the impact of drilling shut in, the water cut continued to rise. Generally speaking, the water cut was well controlled in the stage of water control and efficiency improvement

### 3.5 A block water cut mode determination results

According to the water content change curve of well pattern, determine the time period of each water content pattern in the whole area. According to the above water content pattern analysis process, predict the water content of the whole area, basic well pattern, primary well pattern, secondary and tertiary well pattern (after three times of infilling, the secondary well is transferred to injection, and a new well pattern is formed with the tertiary well), and judge the water content pattern of three sets of well patterns in stages, The variation law of the water content of each set of well pattern with time is calculated. The calculation results show that the overall water content of area a and sub well pattern follows the convex and convex S-type water content patterns. After fine potential tapping, except for the basic wells, the water content patterns of area a and sub well pattern change into concave water content curves, and the rising speed of water content

slows down, indicating that the water content is controlled in a great situation after fine potential tapping, which has played a significant effect.

### 3.6 Variation law of water cut rise

The rising rate of water cut reflects the change of water cut in the oilfield. The smaller the rising rate of water cut, the better the development effect of the oilfield. In the practical application of the oilfield, the ratio of the difference between the water cut of the current year and the previous year and the difference between the recovery degree of the current year and the previous year is often used as the water cut rise rate of the oilfield in the current year. Draw the change curve of water cut rising rate with recovery degree and the change curve of water cut rising rate with water cut in block A (Figures 13-14).

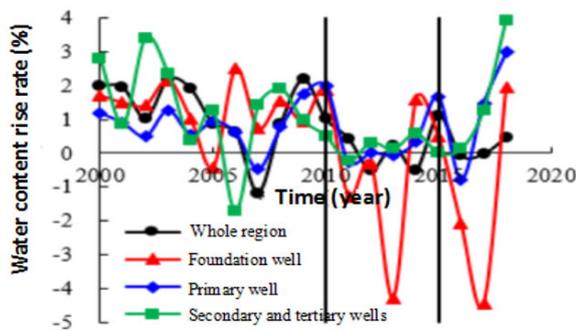


Figure 13. Curve of water content rise with time

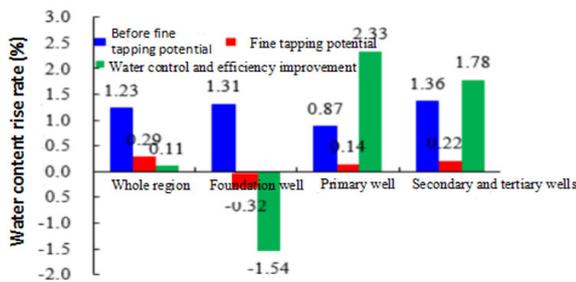


Figure 14. Phased statistical histogram of water content rise

It can be seen from the change curve of water content rise rate with time that after fine potential tapping, the trend of rapid water content rise has been effectively controlled. The phenomenon of water content rise rate less than 0 and water content decline has occurred in each year. The water content rise rate before fine potential tapping in the whole region is 1.23, the average water content rise rate in the stage of fine potential tapping is 0.29, the water content rise rate at the end of the stage is 0.11, and the average water content rise rate in the stage of water control and efficiency improvement is -0.04. In the stage of fine potential tapping, the rapid rise trend of water cut in the whole area and sub well pattern has been effectively controlled, and the maximum basic well pattern has been reduced by 1.63 percentage points. In the stage of water control and efficiency improvement, although the water

cut rise rate of primary wells and secondary and tertiary wells has increased, the water cut rise rate of the whole region and basic wells has been controlled, and the maximum basic well pattern has been reduced by 1.22 percentage points.

### 3.7 Prediction results of water content without measures

In the third encryption stage, due to the rapid rise of water content, fine potential tapping measures were taken in area a, and hole patching was carried out from 2010 to 2013; After the completion of hole patching in 13 years, the water content of the whole area increased slightly after 14 years, and water control and efficiency improvement measures were taken in area a to stabilize the water content. If fine potential tapping is carried out at the end of 10 years and water control and efficiency improvement are not carried out in 16 years, the decline change of the whole region can be obtained, as shown in the figure below:

The water cut is predicted according to the previous decreasing oil production. The decreasing oil production is used to calculate the cumulative oil production NP, and the recovery degree R is calculated through NP to fit the displacement series curve. The predicted water cut without fine potential tapping conforms to the convex curve. The fitting parameters are determined to predict the future water cut. Assuming no fine potential tapping, the water cut will reach 97.1% in 2025, In the stage of fine potential tapping and water control and efficiency improvement, the rise of water content is controlled to a great extent; Because there are few water cut rising points without water control and efficiency improvement, the displacement series formula is no longer applicable. At this time, the future water cut is predicted through the C-type water drive law curve. The water cut without water control and efficiency improvement will reach 96.1% in 2025. The water cut is controlled to a certain extent in the stage of water control and efficiency improvement. These two prediction curves further illustrate that fine tapping potential has greatly reduced the rising trend of water cut, It can play the role of water control (Figure 15).

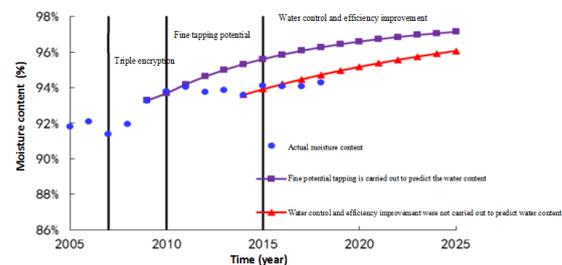


Figure 15. Water cut prediction diagram

## 4. Conclusion

1 Before fine potential tapping, the initial decline basic well pattern < primary well pattern < secondary and tertiary well pattern, the decline pattern in fine potential tapping changes from exponential decline to hyperbolic

decline, and the whole area conforms to exponential decline after fine potential tapping;

2 Before fine potential tapping, the whole area and sub well pattern obey convex and convex S-type water cut patterns as a whole. After fine potential tapping, except for the basic well pattern, the water cut patterns become concave water cut curves

3 After the fine potential tapping, the fast rising trend of water cut has been effectively controlled. In each year, the water cut rising rate is less than 0 and the water cut has decreased. In the fine potential tapping stage, the fast rising trend of water cut in the whole region and well pattern has been effectively controlled. In the stage after fine potential tapping, although the water cut rise rate of primary wells and secondary and tertiary wells has increased, the water cut rise rate of the whole region and basic wells has been controlled. Fine tapping the potential greatly reduces the rising trend of water content and can play a role in water control.

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