

PAPER • OPEN ACCESS

Research on Deep Profile Control Technology of Water Flooding in Lamadian Oilfield

To cite this article: Chunyan Liu 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **384** 012134

View the [article online](#) for updates and enhancements.

You may also like

- [Determination of minimum miscible pressure in CO₂-crude oil system of Changqing Oilfield](#)
Li Liu, Yingxue Ma, Xiao Liu et al.
- [Daqing Oilfield Cable Controlled Intelligent Separate Injection Technology Process Optimization](#)
Weichao Zhang, Mingri Guo, Jinghui Li et al.
- [Research and Application of the Fourth Generation Stratified Water Injection Technology in Daqing Oilfield](#)
XingLiang Song, Yin Tong, Zhendong Jin et al.



ECS
The
Electrochemical
Society
Advancing solid state &
electrochemical science & technology

DISCOVER
how sustainability
intersects with
electrochemistry & solid
state science research

Research on Deep Profile Control Technology of Water Flooding in Lamadian Oilfield

Chunyan Liu *

Geological Brigade of the Sixth Oil Production Plant of Daqing Oilfield Co., Ltd.
Daqing, 163000, China.

*Corresponding author e-mail:66853136@163.com

Abstract. After Daqing Lamadian Oilfield entered the stage of development of ultra-high water cut, the ineffective circulation of various oil layers was serious, which restricted the development benefit of oilfields. To this end, the research on deep profile control of water flooding is carried out, and the combination of polymer microsphere flexible diverting agent and bulk expanded particle slug is used to exert a slower blocking speed of polymer microspheres, and a certain resistance is established in the deep pores of the reservoir. To provide the main slug with aggregating residence time; to exert the superior advantage of flexible steering agent deformation and adhesion ability, to form a dynamic path-distributing mechanism in the deep cavity of the reservoir; to play the advantage of faster blocking speed of the bulk-expanding particles, to prevent the main section The plug was flushed by subsequent water injection. Through the multi-segment combination indoor core experiment, it is shown that the front section is filled with microspheres, the main section is filled with flexible agent, and the post-segment is filled with expanded particles, which can well block the invalid circulation part, improve the displacement effect and improve The recovery rate can reach 3.12 percentage points. On October 16, 2013, Daqing Lamadian Oilfield carried out a deep liquid flow steering test study on the 9-injection and 16-hole water-flooding group. The comprehensive water content of the affected oil wells decreased by 7.8 percentage points, and the cumulative oil increase was 5,435 tons. The rate is 2.7 percentage points, and the input-output ratio is 1:4.0, which has achieved better mine results.

Keyword: High water content; Flexible diverting agent; Deep profile control.

1. Basic summary of the test area

1.1. Test area selection

The test area selects the La 6-PS2004 well area in the northwest block of Lamadian Oilfield. The area of the test area is 0.216km². Three sets of oil layers of Saertu, Grape Flower and Gaotaizi are developed from top to bottom. The test target horizon is Sa III1-7 oil layer, geological reserves of 37.14×10^4 t, pore volume of 65.53×10^4 m³. The well in the test area was returned to the well on the newly drilled



polymer flooding in 2010. There are 25 oil and water wells, including 16 oil wells and 9 water wells. The production is produced by a 106m well spacing five-point area injection well network.

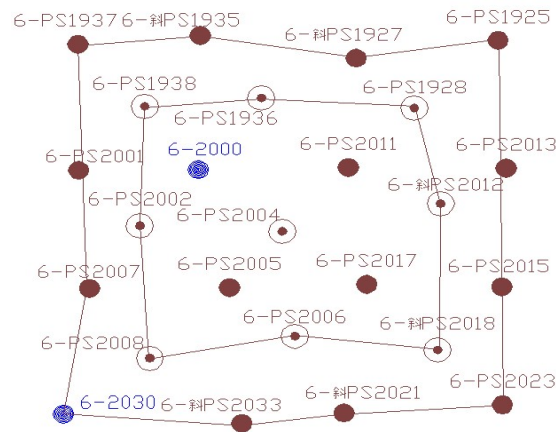


Figure 1. Well flow diagram of deep liquid flow steering test area

2. Test area development profile

Invalid loop recognition technology

There are 25 oil and water wells in the test area, including 9 injection wells. Among them, 9 injection wells currently have an average single well water injection pressure of 8.2 MPa, a daily injection of 76 m³, and a daily injection of 76 m³. 13 production wells, with an average daily production of 42 t of single well, 1.6 t of daily oil, and 96.1% of comprehensive water.

2.1. Invalid loop identification method based on logging curve variation characteristics

2.1.1. Analysis of response mechanism of ineffective loop layer electrical measurement curve. Through the analysis of the characteristics of core wells and reservoir parameters that meet the criteria for flooding efficiency, the response characteristics of corresponding logging curves after the formation of invalid cycles are clarified.

1)The natural potential curve rises. After the formation of large pores, the diffusion adsorption potential is mutated, and the filtration potential is increased, which leads to an increase in the amplitude of the natural potential curve. The oil layer is in high-intensity water injection for a long time. When the water saturation is more than 55%, it is close to the oil-water transition zone or the nature of the water layer. The wettability changes to hydrophilicity, causing an increase in the natural potential amplitude.

2)The amplitude of the deep lateral curve decreases. The resistivity curve mainly reflects the resistance of the oil layer far from the wellbore. After the inefficient loop is formed, the oil in the pore fluid is replaced by injected water, which reduces the resistivity of the rock skeleton, so the amplitude of each resistivity curve is severe. reduce. For thick oil layers, it is reduced to about 70%, and the amplitude difference almost disappears. It is the most obvious change in the identification curve.

3)The amplitude value of the acoustic time difference curve increases. As the water saturation increases, the acoustic velocity of the core gradually increases. In the inefficient and ineffective circulation part, the acoustic time difference increases, mainly because in the water injection development, the clay minerals and shale components are dissolved and washed away by the injected water, and the formation pressure rises above the original formation pressure to form pore expansion. Therefore, it is often caused that the acoustic wave time difference at the portion where the inefficient loop is ineffective is larger than the acoustic wave time difference at the portion where the inefficient loop is not formed.

4)The amplitude of the microelectrode curve is reduced. After the oil layer is flooded, especially after the inefficient and ineffective circulation is formed, the infiltration of the drilling mud filtrate is

increased, the wettability turns to be hydrophilic, and a highly conductive water film is formed on the surface of the rock particles, and the current is more likely to be near the well wall. Diffusion causes a decrease in resistivity.

2.1.2. Invalid loop layer electrical measurement identification standard. On the basis of the preferred identification curve, in order to match the development status of the current invalid circulation layer as much as possible, the criteria for discrimination are appropriately relaxed. The criteria for judging are as follows:

One is the three lateral curves, the depth of the deep oil curve of the thick oil layer drops below 35 Ω m; the second is the microelectrode curve, the thickness of the thick microelectrode curve is more than 4 Ω m; the third is the natural potential curve, the thick layer diffusion adsorption point The increase is above 10mv; the fourth is the acoustic time difference curve, and the curve amplitude rise is generally greater than 12 μ m/ft.

Considering factors such as reservoir properties, water washing characteristics, dynamic changes, etc., the relevant parameters of comprehensive judgment were finally determined.

$$P_{DKD} = \frac{Sp \cdot K \cdot Sw \cdot Pore}{Rlld \cdot Rlls \cdot Vsh} \quad (1)$$

Where: PDKD, SP, K, SW, Pore, RLLd, RLLs, Vsh are invalid loop judgment parameters, natural potential, permeability, current water saturation, effective porosity, deep three lateral values, shallow three lateral directions Value, mud content

Studies have shown that there is an ineffective loop if $PDKD > 3$.

2.2. Invalid loop recognition method based on multidisciplinary ideas

In the absence of new drilling blocks, multi-disciplinary means are used to identify the ineffective circulating well layers of old wells. The structural interface identification and the liquid volume in the layer are divided into foundations to realize the dynamic identification invalid cycle. Based on the results of multidisciplinary research, the parameters of water absorption and liquid production multiple are introduced to comprehensively identify the ineffective circulating well layer.

2.2.1. Oil and water well water absorption multiple identification invalid circulation layer. The well is the starting end of the ineffective circulation, and the results are compared with the results of the new drilling flooding interpretation. The identification of the ineffective circulation layer is performed using the water absorption multiple. It can be seen from the scatter plot of the water absorption multiple that when the water absorption multiple is greater than 0.8, it is identified as an ineffective circulation layer. Since the production volume of the oil well is affected by the water injection volume of the surrounding injection well and the connection condition of the injection-production well group, it is the end of the invalid circulation. It can be seen from the scatter plot of the production liquid that when the production multiple is greater than 0.6, it is recognized as an invalid cycle. Floor.

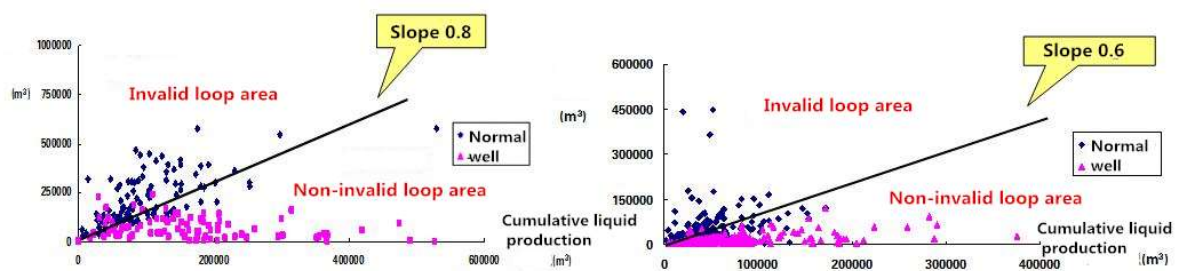


Figure 2. Dynamic identification of the scatter plot of the invalid circulation layer of the well
Dynamic identification of the refractory map of the invalid circulation layer of the well

2.2.2. Invalid loop dynamic identification standard. In order to realize the quantitative identification from point to cycle field, improve the recognition accuracy of both ends of injection and production, according to the invalid cycle judgment standard, comprehensively consider the parameters such as water absorption, liquid production multiple and oil saturation, and determine the comprehensive recognition coefficient of invalid cycle.

Cumulative production factor multiple determination coefficient:

$$P_o = \frac{\text{Oil efficiency} \cdot \text{Water multiple}}{\text{Oil saturation}} = \frac{E_D \cdot Q_l}{S_o \cdot P_{ore} \cdot S \cdot H} = \frac{E_{or} \cdot Q_l}{H_l \cdot S_o \cdot P_{ore} \cdot S \cdot H} \quad (2)$$

Cumulative water injection multiple determination coefficient:

$$P_w = \frac{\text{Oil efficiency} \cdot \text{Water multiple}}{\text{Oil saturation}} = \frac{E_D \cdot Q_w}{S_o \cdot P_{ore} \cdot S \cdot H} = \frac{E_{or} \cdot Q_w}{H_w \cdot S_o \cdot P_{ore} \cdot S \cdot H} \quad (3)$$

Where:

P_o --oil well invalid circulation judgment parameters; P_w --water well invalid circulation judgment parameters; E_D --oil displacement efficiency; Q_l --cumulative production liquid volume; E_{or} --production degree; S_o --oil saturation; P_{ore} --effective porosity; S --single well control area; H --single hole perforation thickness; H_l --liquid production thickness; H_w --water absorption thickness

The research shows that the comprehensive judgment coefficient parameter $P_o \geq 1.2$ or $P_w \geq 1.6$.

2.3. Invalid loop distribution

2.3.1. Vertical invalid loop distribution status. Vertically divided into three types of invalid cycles according to river type and different prosodic features:

The first is the sand body deposited by the Meliu River. The ineffective circulation is mainly distributed on the meandering ring belt of the point dam sand body. For the multi-period composite sand body, multiple invalid circulation layers can be developed, and the thickness is one-half of the thickness of the sand body.

The second is the low-bend diversion channel sand body. The ineffective circulation is mainly distributed on the main belt of each branch channel; for the single-stage channel sand body, the ineffective circulation layer is located at the bottom, and the thickness is one-third of the thickness of the sand body.

The third is the straight-line distributary channel sand body. The inefficient circulation distribution characteristics are similar to those of the low-bend diversion channel; even if the single-stage channel thickness is large (effective thickness is more than 3m), an ineffective circulation layer is mainly developed, and the thickness is the thickness of the sand body. One third of the.

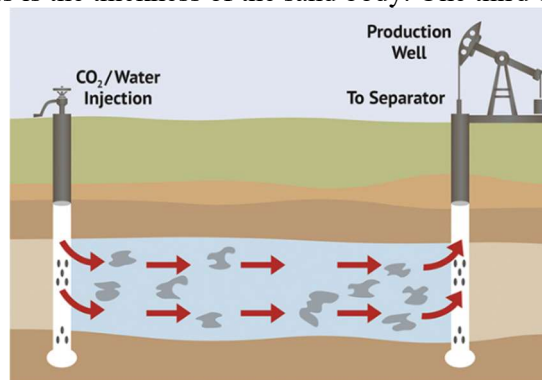


Figure 3. Oil control water injection in profile control area

2.3.2. Plane invalid loop distribution. The plane distribution of the ineffective circulation layer is mainly controlled by two factors: the injection direction and the sand body distribution. The injection and the flow lines are connected and extended, and the sand bodies are mutually occluded and pinched, so that the plane shape of the invalid circulation layer is mainly distributed as strips. Four types of branches, nets, and sheets.

Strips: The distribution of sand bodies in sedimentary units is relatively narrow (close to one well spacing, ie below 200m). The direction of injection and injection from the injection well to the production well is single, mainly from north to south, and relatively rare from east to west. .

Branches: The distribution of sand bodies in sedimentary units is relatively narrow (1 to 2 well spacings, ie around 200 to 300 m), and the direction of injection and production is less (two or less), and they are not on the same line, north-south and east-west. The streamlines are connected to each other and are branched.

Mesh: The sand body of the sedimentary unit is relatively wide (more than 2 wells, ie more than 300m), and there are more injections (more than two). The flow lines are connected to each other, and the plane of the ineffective circulation layer is mesh-like.

Flaky: The distribution of sand bodies in the sedimentary unit is relatively large (more than 2 wells, that is, more than 300m). The direction of injection and production is difficult to distinguish. The direction of injection and production is difficult to distinguish clearly. The flow lines cross each other and overlap, which cannot indicate the injection and production. Direction, the sand body is complete, the deposition is relatively uniform, and the internal boundary of the invalid circulation field is not drawn, and the invalid circulation distribution of this type is defined as a sheet.

3. Deep profile control and slug design method

3.1. Optimization of profile control agent type

According to the matching properties of various profile control agents and oil layer parameters, body expansion particles, polymer microspheres and flexible diverting agent were determined as the main agents for this profile control by comparison.

Table 1. Table of each profile control and oil layer matching

Formation parameters	Lamadian oilfield	Body expansion		Inorganic	Body granule	Polymer microsphere
		flexible	Gel class			
Porosity (%)	28.3	>15	>10	>15	>15	>10
Permeability	611	>400	>10	>100	>100	>100
Formation water	7150	<100000	<200000	<300000	<6000	<10000
Formation (°C)	48	<120	<125	<130	<60	<45
Chloride ion (g/L)	2270	<10000	<20000	<90000	<2000	<4000
Stability		Half a year	1 year	Long-term	1 year	Long-term

3.2. File Control Performance Evaluation

The microspheres can block single or multiple sealing channels, have strong stability, good injection performance and can enter the deep sealing pores of the formation, and the polymer microspheres have good sealing effect. The flexible diverting agent has good temperature and salt resistance, long-term stability in the formation, deformation and creep characteristics, and can adapt to different radius channels and deep block the high permeability channel deep in the formation. The swelled particles have high hydration expansion ratio and variable particle size. They are made into particles of different particle sizes by colloid mill. The particle size is 1-6mm, and the expansion time can be adjusted (3h-5d). Control the expansion agent content to adjust the expansion time. The expansion ratio is large, and the volume expansion ratio is 15-20 times, which can block large holes.

3.3. Segment plug design optimization method

The multi-segment combination indoor flooding experiment shows that the front section is filled with microspheres, and the main section is filled with flexible agent and bulk granules, which has the highest recovery factor and can reach 3.12 percentage points.

Table 2. Table of results of enhanced multi-segment combination recovery

Core	Front slug	Main slug	Enhanced oil recovery (%)
1	flexible diverting agent	microspheres	body expansion
2	flexible diverting	body swelling	microspheres
3	Body granule	Flexible agent	microspheres
4	Body granule	microspheres	Flexible agent
5	microspheres	Flexible agent	Body granule
6	microspheres	Body granule	Flexible agent

Through the indoor test, the front plug combination is preferred, in order to enhance the anti-scour ability of the profile control agent, prevent the profile control agent from returning, and add a protective slug (wood calcium plugging agent). The front slug makes the microsphere penetrate deep into the deep part of the high permeability layer to temporarily block the high permeability layer, and slow down the migration rate of the main agent slug. Main slug (flexible diverting agent + bulk granules) The flexible diverting agent particles migrate through the formation or block through the throat through their own deformation, thus moving to the deep part of the formation, relatively quickly reducing the permeability of the high permeability zone of the formation, improving Formation heterogeneity. The bulking particles block the residual high-permeability tunnel and improve the sealing effect. The protective slug can enhance the flushing resistance of the profile control agent to ensure the water flooding effect of the subsequent injection of water. Meanwhile, when the concentration of the polymer microspheres is more than 0.5%, the blocking ratio can reach 90.0% or more, so the profile adjustment concentration of the polymer microspheres is determined to be 0.3-0.8%. After the soft diverting agent injection concentration is greater than 1.3%, the effective sealing rate is above 90%, and the profile control concentration is determined to be 1.3%. When the concentration of bulk granules is more than 6000mg/L, the plugging rate is above 85%, and the profiled concentration of selected bulk granules is 6150mg/L.

4. Depth profile control plan design optimization method

4.1. Profile control area optimization and horizon determination

According to the water distribution of the water drive well, the high-water well area is identified, and the profile control area is clearly defined. At the same time, the main channel has the best physical properties, and the injected water preferentially rushes along the main line of the channel sand body, resulting in the flooding degree of the channel sand body. High, the river sand production level reached 40.5%, and the overall profile control is required. Through single well analysis, the profile control layer in the test area is mainly the Sa III1-7 oil layer, and the profile control thickness of the 9 wells is 27.3m.

4.2. Optimization of the profile control site design

The design ratio of the three sections of the profile control section is: the crude oil price is calculated at 5234 yuan/t, the crude oil cost is 420 yuan/t, the injection water cost is 5.58 yuan/m³, and the sewage treatment cost is 1.32 yuan/m³. Calculate the input-output ratio of the first set of schemes is 3.72, calculate the input-output ratio of the second set of schemes is 4.07, and calculate the input-output ratio of the third set of schemes is 2.46. For this reason, this survey is preferred.

Table 3. Comparison of design scheme effects

Program	Validity period (month)	Oil increase (10 ⁴ t)	Reduce ineffective water (10 ⁴ m ³)	Reduce water (10 ⁴ m ³)	Pure oil revenue (ten thousand yuan)	Reduce invalid water costs (ten thousand yuan)	Control water injection (ten thousand yuan)	output(ten thousand yuan)	Input cost (ten thousand yuan)	Input-output ratio
Option One	24	1.2704	9.5359	8.1156	6115.7	12.6	45.3	6173.6	1660.6	3.72
Option One	20	1.3175	5.5658	4.0928	6342.4	7.3	22.8	6372.6	1565.4	4.07
Option One	16	0.7409	3.6114	2.7831	3566.7	4.8	15.5	3587.0	1458.9	2.46

4.3. Design optimization of profile control single well plan

According to the profile of the oil layer, such as the profile control thickness and the profile control direction, the injection volume of the single well was designed, and the total injection of the profile control agent was 43180m³. Among them, the injection amount of the pre-stage plug is 12,408 m³, the injection amount of the main agent is 29,872 m³, and the sealing agent is 900 m³.

Table 4. Single plugs

Well number	Front slug	Main agent slug		Sealing	Total (m ³)
	Microspheres (m ³)	3-5mmSR-3+polymer (m ³)	Body granule(m ³)	wood calcium	
L6-PS1938	1402	2785	453	100	4740
L6-PS2002	1356	2420	254	100	4130
L6-PS2008	1368	3065	677	100	5210
L6-PS1936	1067	2230	423	100	3820
L6-PS2004	1589	3065	456	100	5210
L6-PS2006	1336	2510	334	100	4280
L6-PS1928	1413	2695	382	100	4590
L6-AS2012	1064	2420	546	100	4130
L6-AS2018	1814	4180	977	100	7070
Total	12408	25370	4502	900	43180

5. Mine test results

After the profile control, the profile of the injection well was obviously improved. The relative water absorption of the high permeability layer decreased by 28.6% on average, and the water absorption of the low permeability layer increased by an average of 32.0%. Comparing the effect of oil and precipitation in the surrounding 16 production wells: As can be seen from Figure 4, the comprehensive water content in the test area decreased from 96.7% before the adjustment to the current 88.9%, a decrease of 7.8 percentage points; the daily oil production was 15.7t before the adjustment. Increased to the current 46.7t, the average daily oil increase of 1.9t per day; the daily production liquid volume decreased by 56t compared with before the profile adjustment, the decline rate was 11.7 percentage points. The estimated cumulative oil increase was 5435 tons, and the recovery rate was 2.7 percentage points. The ratio is 1:4.0, and the mine has a good effect.

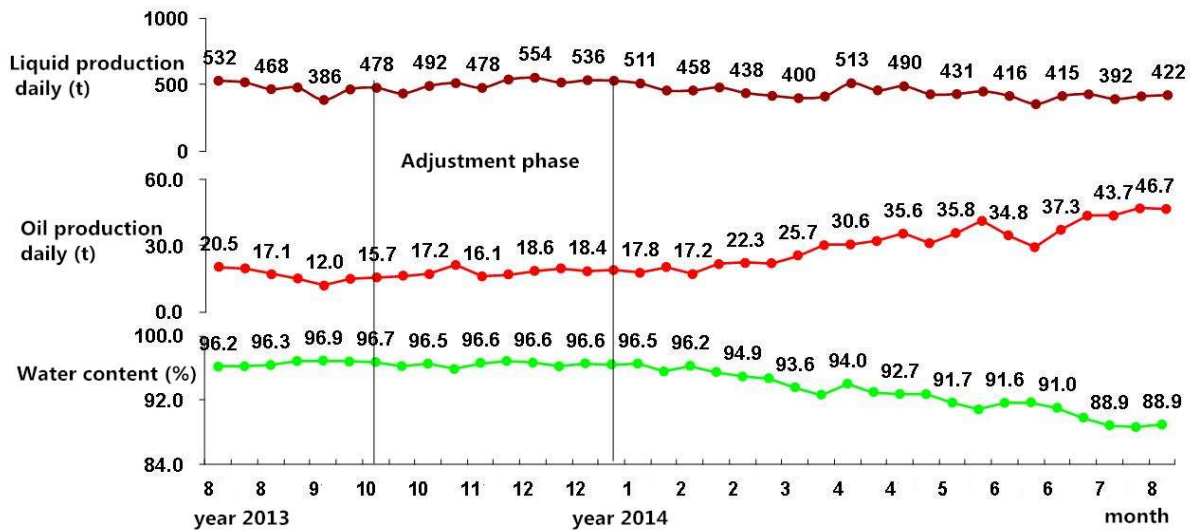


Figure 4. Mining production curve of 16 production wells around the profile control well

6. Conclusions and understanding

(1) The invalid loop recognition is performed by multi-dimensional method, and the location and thickness of the invalid loop are comprehensively judged, and the design of the profile control scheme is further guided. With the preferred slug combination, it is expected that the enhanced oil recovery can reach 3.12 percentage points.

(2) Using the numerical simulation to predict the three sets, the best benefit plan is preferred, and the input-output ratio is 1:4.07.

(3) The deep profile control agent has better performance, expands the sealing radius, improves the sealing efficiency, has certain adaptability to the profile control of thick oil layers, can improve the water absorption condition of the oil layer, and has better profile control effect. The mine test can increase the recovery rate by 2.7 percentage points, and the economic benefits are considerable.

References

- [1] J. van der Geer, J.A.J. Hanraads, R.A. Lupton, The art of writing a scientific article, *J. Sci. Commun.* 163 (2000), pp. 51-59.
- [2] Luo Pei, Zhang Lizhen. Well selection method for increasing production measures. *Oil and Gas Well Testing*, (2006).
- [3] Li Yanli, Li Yanchun. Treatment of water-driven low-yield wells in extra high water cut period. *Oil and Gas Field Surface Engineering*. (2004).
- [4] Zhao Wei, Zhao Yunfei. The utilization status and comprehensive adjustment direction of reservoirs in Lamadian Oilfield. *Daqing Petroleum Geology and Development*;
- [5] China National Petroleum Corporation Science and Technology Development Bureau, Development and Production Bureau. An example of improving the effect of water injection development in high water cut period oilfield. Beijing: Petroleum Industry Press, (1993).