Research on well selection and layer selection methods for tapping the remaining oil at the top of thick oil layers using ultra-short radius lateral drilling horizontal wells

Guangyao Yang

The First Oil Production Plant of Daqing Oilfield Co., Ltd. Daqing, Heilongjiang, 163000 China

Abstract: The flexible drilling method of ultra-short radius sidetrack horizontal wells is an effective method to utilize the remaining oil at the top of thick oil reservoirs. By analyzing the current status of the SZ oilfield well network, development stage and sand body development characteristics, combined with the characteristics of ultra-short radius lateral drilling horizontal well technology, the areas and formations suitable for ultra-short radius lateral drilling horizontal well tapping are identified, and the criteria for selecting wells and formations for ultra-short radius lateral drilling horizontal wells are established, which is a guide for the application of this technology.

Keywords: Thick oil reservoirs; remaining oil; sidetracked horizontal wells.

1. Introduction

The Daqing oilfield has entered the late stage of high-water content [1] and after many years of exploitation in the SZ oilfield, there is still difficult-to-use residual oil at the top of thick oil reservoirs, which requires a new process of directional tapping. The flexible drilling method of ultra-short radius lateral drilling horizontal wells is an effective method to use such difficult-to-use reserves.

2. Introduction to ultra-short radius lateral drilling horizontal well technology

The ultra-short radius lateral drilling horizontal well is a process technology that uses the oil casing in the old well to drill horizontally after making a window slant at any position within the upper 30m of the target layer[2] (Figure 1), using special drill bit, guiding power motor, titanium alloy drill pipe, MWD follow-through monitoring and other tools to carry out the construction, and the radius of curvature is between 7.62m-17.4m to complete 0°-90° turning and slanting to achieve horizontal state, drilling more than 100m in the design direction with a hole diameter greater than 95mm. This technology can be used to achieve directional dredging and reconstruction, expand the drainage area, improve the production conditions of the well and increase the recovery rate.

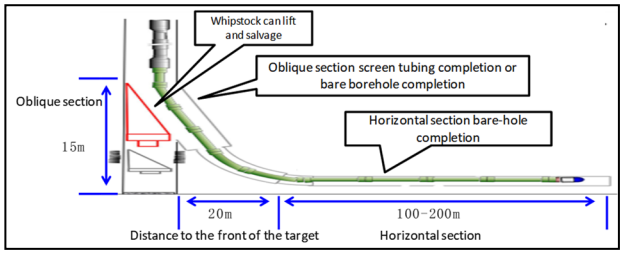

Figure 1 Schematic diagram of an ultra-short radius lateral drilled horizontal well

The following advantages exist for ultra-short radius lateral drilled horizontal wells.

(1) Short displacement in front of the target and small requirements for the size of the sand body.

(2) Locatable and orientable, capable of drilling along the top of thick oil formations.

(3) Multiple horizontal branches can be drilled in one straight well, resulting in a high degree of reserve recovery.

The following disadvantages exist.

(1) The sloping section can only be completed with bare borehole or screen tubing, and there is a high risk of water flooding in the sloping section.

(2) High requirements for well conditions, requiring a well diameter of not less than 120mm and good quality cementing.

(3) Inclined shafts can only be designed with horizontal sections in the direction of the shaft inclination.

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3. Analysis of factors for well selection and formation selection for ultra-short radius lateral drilling horizontal wells

3.1 Analysis of potential strata and potential areas

The ultra-short radius lateral drilled horizontal well has a 15m slant section, and in the slant section only bare-hole completions or screen pipe completions are allowed, so there cannot be high water-bearing formations within the upper 15m of the adjustment level.

SZ oil field compartment thickness is small (Table 1), II oil group and I oil group compartment average thickness of 12.8m, and the upper I oil group is not well-developed, high-water flooding risk is small, the main potential layers in the top thick oil layer of II oil group are unit II-1 and unit II-2. The thickness of the IV oil group and the III oil group is smaller, only 5.0m, but the oil layer at the bottom of the III oil group is poorly developed and has potential in the local area, and the main potential layers of the thick oil layer at the top of the IV oil group are unit IV-1 and IV-2.

The oil group III and V compartments are small and the upper oil layer is well developed, with little potential for ultra-short radius horizontal wells.

Table 1. Statistical table of compartment thickness in the SZ oil field

compartment	No compartment	H < 5m	5m≤H < 10m	10m≤H < 15m	15m≤H < 20m	20m≤H	Average thickness
	Proportion of wells (%)	Proportion of wells (%)	Proportion of wells (%)	Proportion of wells (%)	Proportion of wells (%)	Proportion of wells (%)	(m)
0 oil group-I oil group	0.0	0.0	0.1	0.1	53.4	46.3	21.0
IOil group-IIOil group	0.0	0.3	0.8	80.7	14.8	3.3	12.8
IIOil group-IIIOil group	5.8	66.7	23.1	3.1	1.0	0.3	3.7
III oil group-IV oil group	1.8	59.0	28.0	6.1	3.9	1.3	5.0
IV oil group - V oil group	4.1	94.1	1.8	0.0	0.0	0.0	1.7
V oil group-VI oil group	0.5	95.7	3.0	0.7	0.1	0.0	2.2

Oil Group II is currently not completed chemical drive blocks to avoid affecting the effect of agglomeration drive, chemical drive blocks are not suitable for ultra-short radius horizontal well tapping at this stage. No chemical drive is carried out in the marginal II oil group, and the upper thick oil layer can be used as a target for adjustment.

The thickness of the upper part of the IV oil group is small, and the slope making section needs to pass through part of the III oil group, only the block where the chemical drive of the III oil group has been completed can be used as the area for tapping the thick oil layer in the upper part of the IV oil group.

3.2 Analysis of measure well selection

By old well side drilling ultra-short radius horizontal wells to tap the remaining oil has a better advantage [3]. The ultra-short radius side-drilled horizontal wells are drilled using oil well casing, and the network of Class II oil formation wells will need to be returned in the future and cannot be used as measure wells for short radius horizontal wells. The only wells retained in the chemically driven well network of the IV oil group are Block D and Block Z at present, and the ultra-short radius side-drilled horizontal wells in other blocks can only be selected as measure wells for water-driven oil wells.

3.3 Analysis of well selection factors at the top of thick oil formations

The remaining oil at the top of thick reservoirs suitable for dredging in ultra-short radius sidetrack horizontal wells are mainly in 3 categories: thin injection and thick recovery, river margins and diversion line areas.

(1) In the thin injection and thick recovery injection and recovery relationship, the well end sand body is clearly developed, and the lateral drilling horizontal well is easy to enter the target and track the sand body, which is the main type of tapping (Figure 2 and Figure 3).

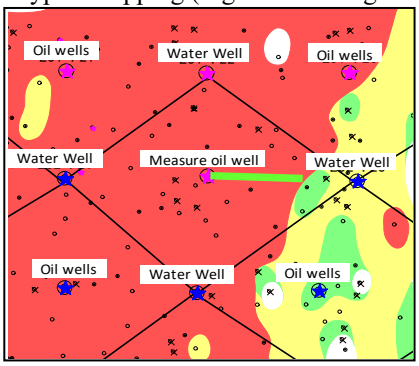

Figure 2 Thin injection and thick extraction type sedimentary phase zone map

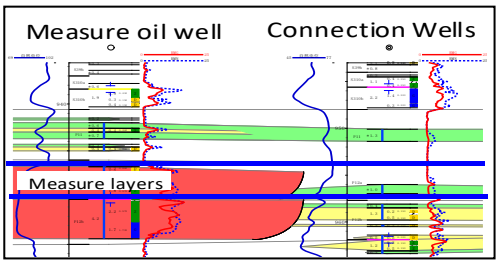

Figure 3 Thinly injected thickly mined sand body connectivity diagram

(2) The sand body at the edge of the river channel is susceptible to residual oil formation due to the existence of phase change and large physical variation, and its top interlayer is developed to prevent bottom water cone entry, which can be used as a potential site for lateral drilling of horizontal wells if the injection and extraction relationship is suitable (Figure 4 and Figure 5).

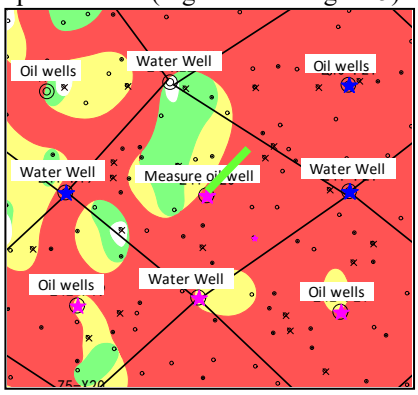

Figure 4 River margin type sedimentary phase zone map

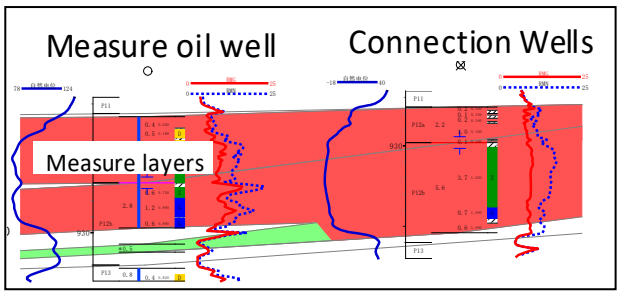

Figure 5 River margin type sand body connectivity diagram

(3) The area of the diversion line is relatively rich in residual oil and can be used as a potential site for sidetracking horizontal wells if the top of the newly drilled wells nearby are low in water flooding and the internal entrapment is developed (Figure 6 and Figure 7).

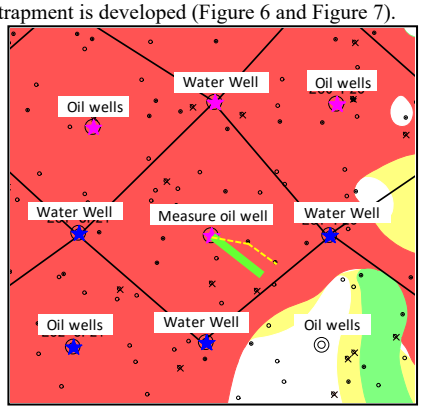

Figure. 6 Phase zone diagram of the divergent linear deposition

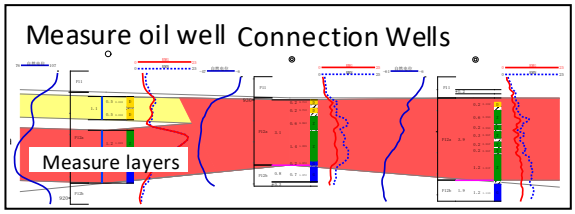

Figure. 7 Split line sand body connectivity diagram

The situations that are not suitable for dredging of ultra-short radius lateral drilling horizontal wells are mainly 7 categories: thick injection and thin extraction, small compartment, uncertain sand body, poorly developed sandwich layer, continuous layer at the bottom of thick oil layer, unsuitable well spacing and high-water flooding level of new wells.

(1) In the injection and extraction relationship of thick injection and thin extraction, it is difficult to determine whether the sand body at the end of the well is connected in the upper low flooded layer of the river or the lower high flooded layer, and is not used as a potential for ultra-short radius lateral drilling horizontal wells (Figure 8 and Figure 9).

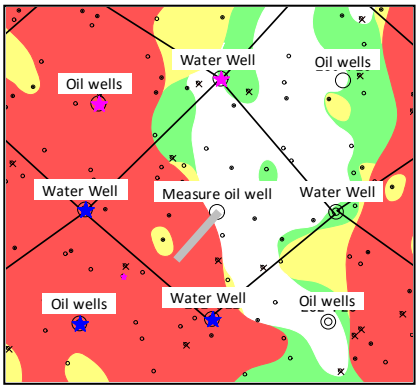

Figure 8 Depositional phase zone map for thick injection and thin extraction type

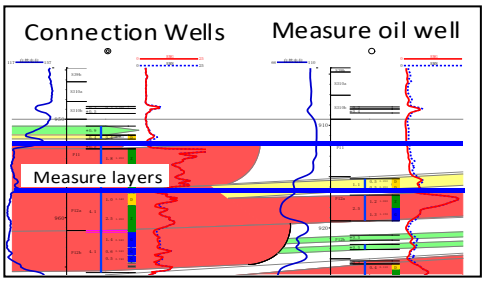

Figure. 9 Thick injection and thin extraction type sand body connectivity diagram

(2) The compartment is small and the upper oil layer is well developed, and there is a risk of water flooding when the slant-making section crosses the upper oil layer (Figure 10 and Figure 11).

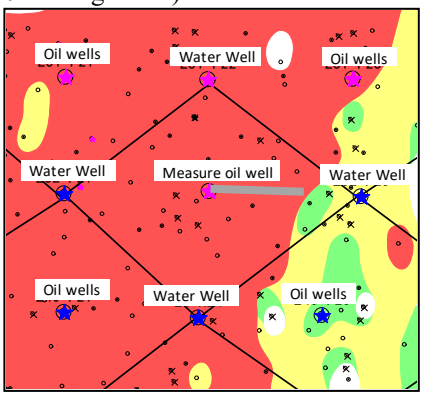

Figure. 10 Phase zone map of compartmentalized mini-sediments

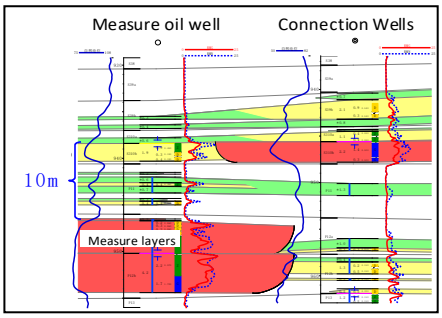

Figure. 11 Diagram of compartmentalized small sand body connectivity

(3) Sand body uncertainty and the presence of wells with sand body variability on the horizontal well trajectory make it difficult to determine the scale of sand body development and there is a risk that the sand body will not be controlled (Figure 12).

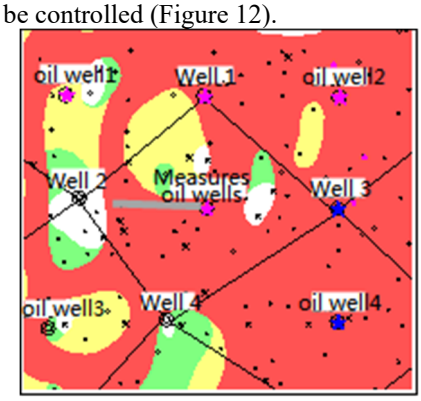

Figure 12 Map of the indeterminate depositional phase zone of the sand body

(4) The sand body is poorly interbedded and water from the highly flooded layer at the bottom will enter the upper horizontal well (Figures 13 and 14).

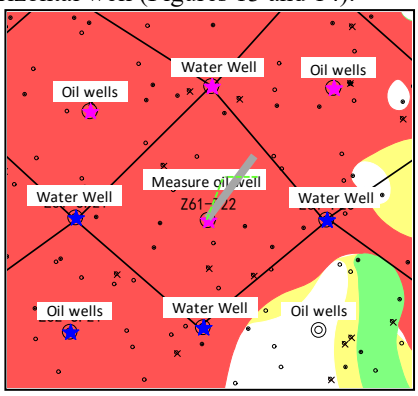

Figure 13 Map of the poorly developed sedimentary phase zone of the sand body intercalation

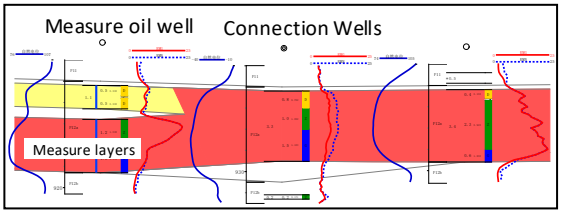

Figure 14 Sand body intercalation poorly developed type sand body connectivity diagram

(5) The continuous layer at the bottom of the thick oil layer will enter the highly flooded layer at the bottom of the river sand during the drilling of the horizontal well, and there is a risk of water flooding (Figure 15 and Figure 16).

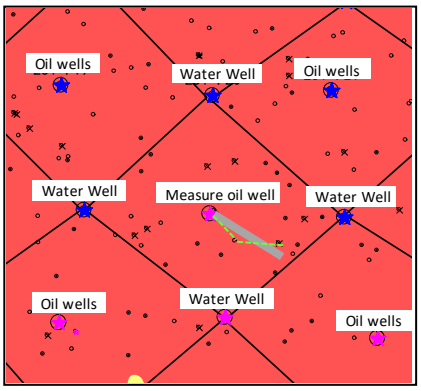

Figure. 15 Phase zone diagram of a continuous layer type deposit at the base of a thick oil layer

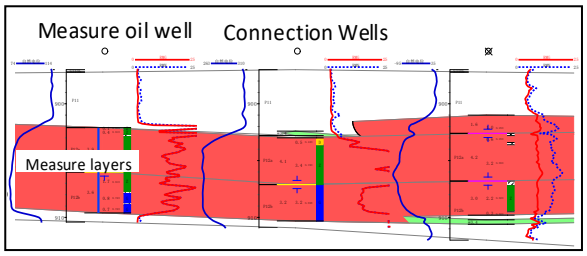

Figure 16 Continuous sand body connectivity at the base of the thick oil layer

(6) The well spacing is inappropriate and some of the horizontal sections are too close to the current well site, posing a risk of collision (Figure 17).

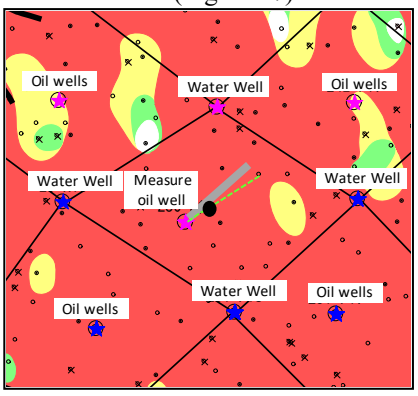

Figure 17 Well spacing unsuitable sedimentary phase zone map

(7) The new wells have high flooding levels and are at high risk of flooding (Figure 18 and Figure 19).

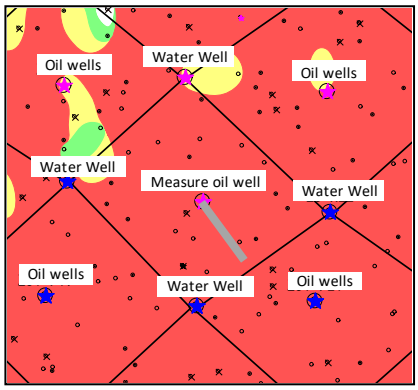

Figure 18 Sedimentary phase zone map of new wells with high water flooding level type

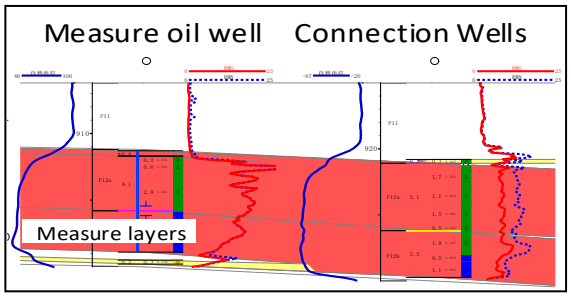

Figure 19 Sand body connectivity diagram of new well flooding level high type

Based on the above analysis, the formation selection criteria for ultra-short radius lateral drilling horizontal wells at the top of thick oil formations are established (Table 2).

Table 2 Formation selection criteria for ultra-short radius lateral drilling horizontal wells

No.	Projects	Standards
1	Spacer thickness	More than 15 meters
2	Sand body development	At least 2 wells drilled on horizontal well trajectories encounter sand bodies
3	Intercalation development	At least 1 interlayer developed at the top of the sand body
4	Sand body connection method	The sand body is not connected to the river sand on
5	Flooding of new wells	Low flooding thickness of new wells near the measure well is greater than 1m
6	Well Position Relations	Horizontal well trajectory is more than 20m from the current well site
7	Through-hole	Measure well passage diameter not less than 120mm

According to the criteria for well selection and formation selection, two wells in the water-driven well network in Block Z were selected for the ultra-short radius lateral drilling horizontal well experiment.

4. Forecast of indicators and evaluation of benefits

According to the reservoir characteristics, production situation and utilization status, it is predicted that the initial daily fluid increase of the ultra-short radius lateral drilling horizontal well will be 15.0t and the daily oil increase will be 3.0t, the evaluation period will be 5 years and the cumulative oil increase during the evaluation period will be about 1650t. The technical service fee for the ultra-short radius (the length of the horizontal section of the lateral drilling ≤ 110m) is RMB 1.15 million, and the cost of the horizontal section of the lateral drilling exceeding 110m is calculated at RMB 3,500/m; the overhaul operation fee is RMB 250,000/well; the cost of sieve pipe is calculated at RMB 170,000/well; the cost of logging is RMB 380,000/well, and the crude oil price is calculated at RMB 50/bbl, with a predicted input-output ratio of 1.40. The economic benefits are good.

5. Conclusion

(1) Residual oil at the top of thick oil reservoirs can be tapped using ultra-short radius lateral drilling horizontal wells.

(2) The ultra-short radius lateral drilling horizontal wells are more restricted in tapping the remaining oil at the top of thick oil reservoirs and need to continue to make technical improvements.

References

1. Fu Zhiming. Tapping residual oil at the top of thick oil reservoirs using ultra-short radius lateral drilling horizontal wells [J]. Oil and Gas Field Surface Engineering, 2013, 32(3): 34-35.
2. Xin Changqing. Oil & gas field surface engineering, 2013,32 (4) : 108-109.
3. Yang Erlong, Wang Jingcui, Gao Yuxin. Study on the boundaries of layer selection technology for ultra-short radius lateral drilling horizontal wells [J]. Petroleum Drilling Technology, 2012, 34(5): 33-36.