Justification for the selection of distances between wells to increase the efficiency of flooding by deposits in terrigenous reservoirs of Western Siberia

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Abstract. Under the conditions of oil deposits of Jurassic deposits in Western Siberia, the influence of geological and technological parameters on the degree of response of producing wells to the injection of water into injection wells has been studied. Parameters that have a prevailing effect on the success of water flooding, as reflected by the magnitude of the cross-correlation function, are identified. Water flooding success parameter is proposed. The minimum and critical values of this parameter are established. A technique is proposed for selecting production wells for transferring them to injection, as well as for selecting the density of the grid of wells at the stage of field exit from exploration.

1. Introduction
One of the factors determining the efficiency of water injection into a reservoir is the presence of a hydrodynamic connection between production and injection wells [1–8].

Under the conditions of layered heterogeneous formations US\(_1\) and US\(_2\) of the Tevlino-Russkinskoye field, often producing wells located near injection wells do not experience injection effects, which requires studying the effect of the injection process on oil recovery efficiency [9, 10].

The solution to this problem was carried out by analyzing the time series of monthly fluid production from wells located near injection wells and monthly water injection [11, 12].

2. Materials and methods
We used geological and field data for 160 wells in which there was no effect on the bottom-hole zone to eliminate extraneous “noise.” Assessment of the degree and time of response of producing wells to water injection was carried out by analyzing changes in cross-correlation functions over time. Further, the influence of the following parameters on the water flooding efficiency was investigated:
- perforated formation thickness in the production well \(H_{per}^p\), m;
- effective oil-saturated formation thickness in the production well \(H_{e}^p\), m;
- the average thickness of oil-saturated layers in the production well \(H_{th}^p\), m;
- the standard deviation of the thickness of oil-saturated interlayers in the production well \(\sigma_{th}^p\), m;
When using this criterion, a significant differentiation of wells occurs, and measures of information parameter were obtained in the form:

\[ P_{wfe} = \frac{H_e^P \cdot a_{PS}^P \cdot H_{form}^P \cdot n^l \cdot K_S^l \cdot \rho_{IR} \cdot M_{BC} \cdot Q_{wat} \cdot F}{\rho_{2,25} \cdot Ohm \cdot m}; \]

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content increase significantly.

Four areas are distinguished, in two of which the effective water flooding is determined unambiguously: at $P_{wfe} < P_{wfe}^{\text{crit}} = 7.5 \text{m}^3/\text{month}$ the probability of effective water flooding is zero; at $P_{wfe}^{\text{crit}} \leq P_{wfe} \leq P_{wfe}^{50} = 25 \text{ m}^3/\text{month}$, effective water flooding is less than 50%; at $P_{wfe} > P_{wfe}^{50}$ effective water flooding is more than 50%; at $P_{wfe} < P_{wfe}^{\text{min}}$, effective water flooding is equal to 100%.

Using the parameter $P_{wfe}$ allows carrying out a diagnostic procedure for assessing the effectiveness of water flooding in the reservoirs of the layers US$_1$ and US$_2$, where it is planned to transfer production wells to injection. On deposits that are already drilled and exploited, the selection of foci for pumping water can be made based on the formula (1):

$$F \leq F_{\text{max}} = \frac{1}{P_{wfe}^{\text{min}}} H_e^p \alpha_{ps}^e \alpha_s^e K_s^e Q_{\text{wat}} = 2,7 \cdot 10^{-2} H_e^p \alpha_{ps}^e \alpha_s^e K_s^e Q_{\text{wat}},$$

while effective water flooding is 100%;

$$F_{\text{max}} < F < F_{50} = \frac{1}{P_{wfe}^{50}} H_e^p \alpha_{ps}^e \alpha_s^e K_s^e Q_{\text{wat}} = 4 \cdot 10^{-2} H_e^p \alpha_{ps}^e \alpha_s^e K_s^e Q_{\text{wat}},$$

while the effective water flooding vary from 50 to 100%.

If the probability $F > F_{50}$, effective water flooding is less than 50%, and the transfer of the selected well to injection is unjustified.

At the stage of geological exploration, i.e. when there are already sufficiently reliable data (in general for deposits or their individual sections) about average values of effective oil-saturated thickness, relative PS amplitude ($\alpha_{ps}$), sandiness coefficient ($K_s$), an approximate estimate of the distance between wells is possible by the formulas:

$$F \leq F_{\text{max}} = 2,7 \cdot 10^{-2} H_e^p \alpha_{ps}^2 K_s^e Q_{\text{wat}},$$

while effective water flooding = 100 %;

$$F_{\text{max}} < F < F_{50} = 4 \cdot 10^{-2} H_e^p \alpha_{ps}^2 K_s^e Q_{\text{wat}},$$

while effective water flooding = 50 ... 100 %.

In the practical use of these formulas, it is necessary to strive to ensure that the selected distance between the producing and injection wells at average values $H_e$, $\alpha_{ps}$, $K_s$ is less than $F_{\text{max}}$. If drilling wells with such a dense grid of wells is impossible for economic reasons, the distance between the wells should be less than $F_{50}$.

4. Conclusion
In the conditions of Jurassic deposits of Western Siberia, the following are established:

- geological and technological parameters that have a prevailing effect on the success of water injection into the reservoir;
- a methodology has been proposed for the selection of producing wells for transferring them to injection;
- an algorithm for choosing the density of well grids at the stage of field exit from exploration is proposed.

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