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Geological and Field Justification of Yuzhno-Vyintoyskoye Field Development Process Based on Dynamic Marker Monitoring in Horizontal Wells

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Summary

Effective management of oil and gas field development is impossible without employing an integrated approach to well and reservoir studies, well interference assessment, and analysis of the reservoir pressure maintenance system effectiveness. To make hard-to-recover reserves development effective, the key objective is to develop and substantiate recommendations for stimulating oil recovery and increasing the oil recovery factor.

This paper dwells on a new approach to the geological feasibility study of the field development management and inter-well influence evaluation, which involves predictive modelling. Such an approach implies studying the field geological structure, analysing the current recovery status, dynamic quantum tracer-based production profile surveillance in horizontal wells, as well as using Spearman rank correlation analysis to evaluate the performance of the reservoir pressure maintenance system.

The subject reservoir is represented by a series of wedge-shaped Neocomian sandstones that are marked by a complex geological structure, lateral continuity, non-uniform distribution of reservoir rocks, and an extensive water-oil zone. At the moment, the subject field is in a production increase cycle (Dulkarnaev et al., 2020).

An integrated approach was used in this study to provide an extra rationale to the starting points of the reservoir pressure maintenance system impact at new drilling sites to improve oil recovery and secure sustainable oil production and the reserve development rate under high uncertainty.

Introduction

This paper presents the results of the use of the method for geological and field feasibility study of field development management at two fields of the Yuzhno-Vyintoiskoye field using geological and reservoir modelling and dynamic tracer-based production profile surveillance in producing horizontal wells.

The first field shows an increased water content. Therefore, the key focus of the field development plan was on the justification of measures aimed to reduce water content and achieve the target oil recovery rate.

For the second field, measures were developed and justified to prevent premature water breakthroughs. Data on the current state of the well stock at the target fields are presented in Table 1.

Table 1—The current state of the well stock in the subject fields

Parameters	First field	Second field
Producing wells in operation	25	13
Average fluid production, m^3/day	43.4	43.8
Average crude oil production, ton/day	11.5	17.7
Water cut, %	62.8	20.5
Reservoir pressure, MPa	21.6	22.0
Bottom-hole pressure, MPa	10.4	12.0
Injection wells in operation	6	5
Average injectivity of well 1, m^3/day	71.7	76.6
Average wellhead pressure, MPa	28.0	13.4

At the current development cycle, continuously increasing oil production is observed according to the production performance dynamics due to active drilling at the field and the commissioning of new wells.

For a deeper investigation into the degree of well interference, as well as to optimise the development process, an integrated approach has been implemented. It consists of dynamic tracer-based production profile surveillance providing information about the inflow profile and composition in horizontally drilled wells over a long time span without costly well interventions. In addition, Spearman correlation analysis was conducted to further substantiate the starting points of the reservoir pressure maintenance system.

Horizontal well marking method

Horizontal drilling with multi-stage hydraulic fracturing (MHF) is an effective oil field development method widely used in Western Siberia. However, assessment of each port's contribution to the overall horizontal well production, needed for decision-making purposes, poses a challenge. To complete such objectives, a well marking technology is used.

It consists of injecting marked proppant into each of the frac stages. First, the proppant is marked with high-precision quantum dot inflow tracers enclosed in a polymer cover. A unique code is used to mark each interval of the frac port (Guryanov A.V. et al., 2017).

Then the marked proppant is added to the bulk of the unmarked proppant and injected as a propping material into the formation during hydraulic fracturing (Fig. 1). When contacting the target reservoir fluid phase in the course of production from the well, the marker-reporters are released from the polymer matrix and washed out by the fluid flow to the surface. Reservoir fluid samples are collected at the wellhead during the production from the subject well as per the pre-approved schedule. These samples are then analysed to quantify each interval's contribution to the overall well production for each fluid phase (Ovchinnikov, 2019).

The use of the dynamic tracer-based production profile surveillance method in horizontal wells is becoming increasingly widespread. The data obtained due to its application make it possible to control the production profile, regulate the flooding system, and evaluate well interference not only on the basis of integral parameters but also by individual ports of marked horizontal wells.

Surveillance conducted over several years has yielded a large amount of information and enabled building a substantial database that is used to support a prompt decision-making process in the area of field development monitoring and management. The tracer-based studies were conducted in the subject fields not only on a single marked well. Instead, all wells were marked with inflow tracers.

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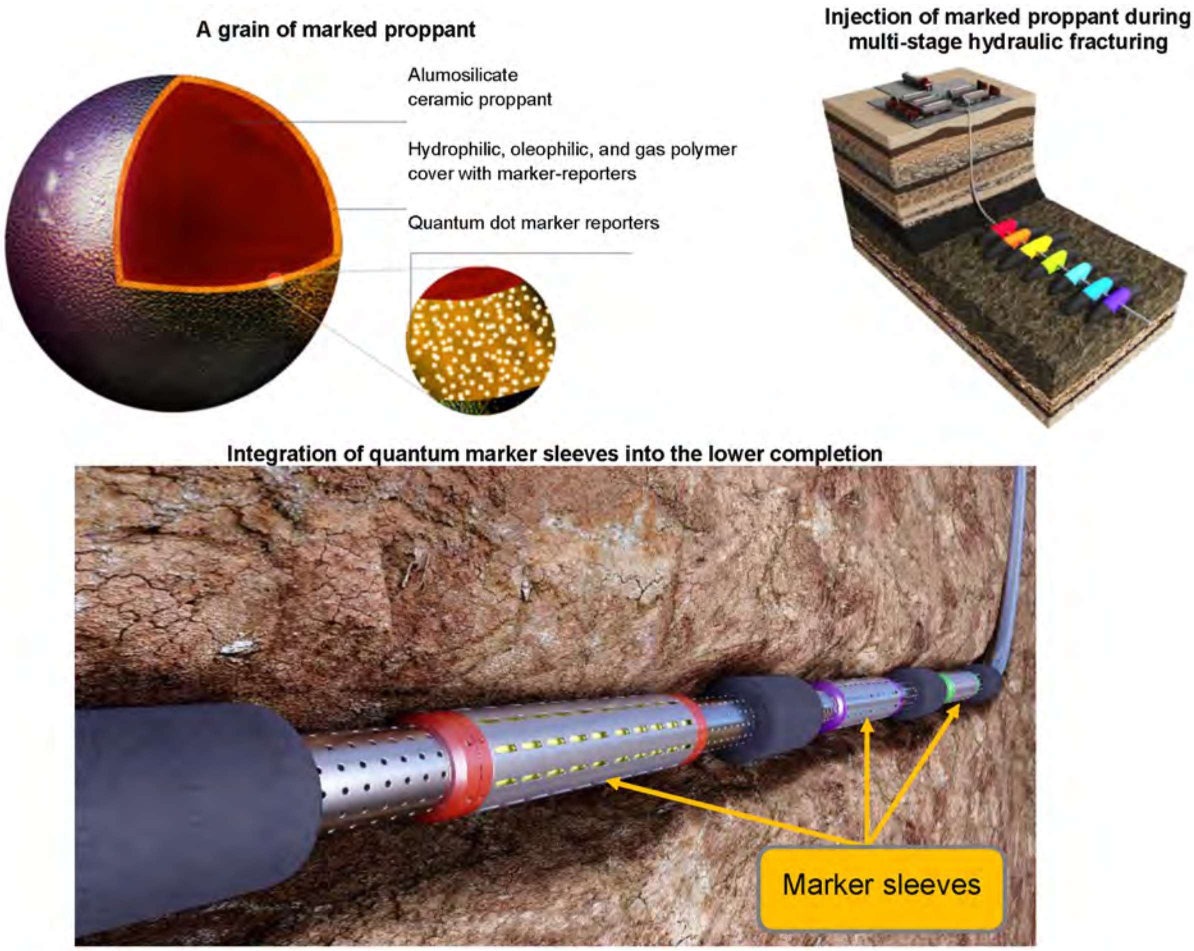

Figure 1—The use of the dynamic tracer-based production profile surveillance method

A method for a comprehensive geological feasibility study of the field development management

The geological and field feasibility study of the development system control is quite an ambitious task to complete. The implementation process consists of the following main stages:

1. Identification and update of the geological structure of the fields, including lithological and facies analysis as well as geological and reservoir modelling;
2. Analysis of the current resource recovery status (recovery dynamics; reservoir pressure analysis; analysis of the well flooding factors);
3. Analysis of the flooding system performance and the calculation of the degree of flow communication between wells using the Spearman's rank correlation method;
4. Geological and field analysis of the dynamic tracer-based production profile data and analysis of the factors responsible for the changing dynamics of flow profiles over time; analysis of interference and the presence of a single flow communication system;
5. Development of a set of recommendations for managing the development process and improving the efficiency of the reservoir pressure maintenance system;

Lithological and facies analysis

The geological model was updated for the two subject fields. The lithological and facies analysis revealed three main sedimentary facies commonly occurring in the subject field (A1 — massive sandstones of

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distribution channels; A2 — deformed sandstones that are landslide process products; A3 — siltstones interbedded with sandstones, i.e. products of offchannel deposits of intermittent turbidity flows) (Figure 2).

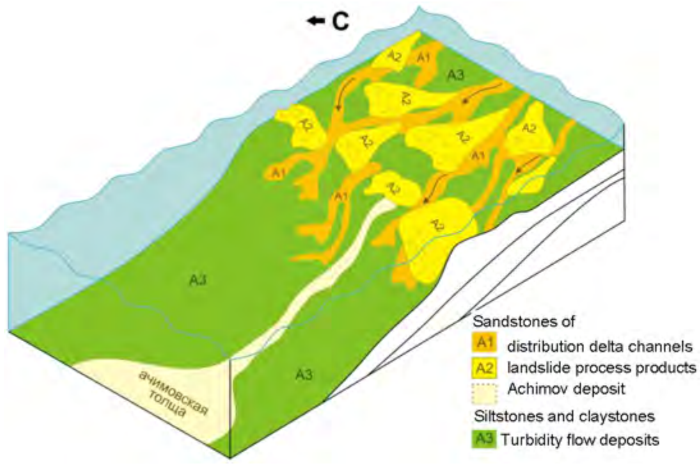

Figure 2—The use of the dynamic tracer-based production profile surveillance method

Based on the results of the electrometric curves and their comparison with the Muromtsev curves, facies zoning near the first (Figure 3. a) and second (Figure 3. b) sites was performed and the target facies zone maps were built. The lithological and facies analysis has shown that the most intense production is observed in high flow rate wells located at fields A1 and A2. The lowest flow rates are seen in the zone of occurrence of turbidity flow deposits, i.e. facial zone A3.

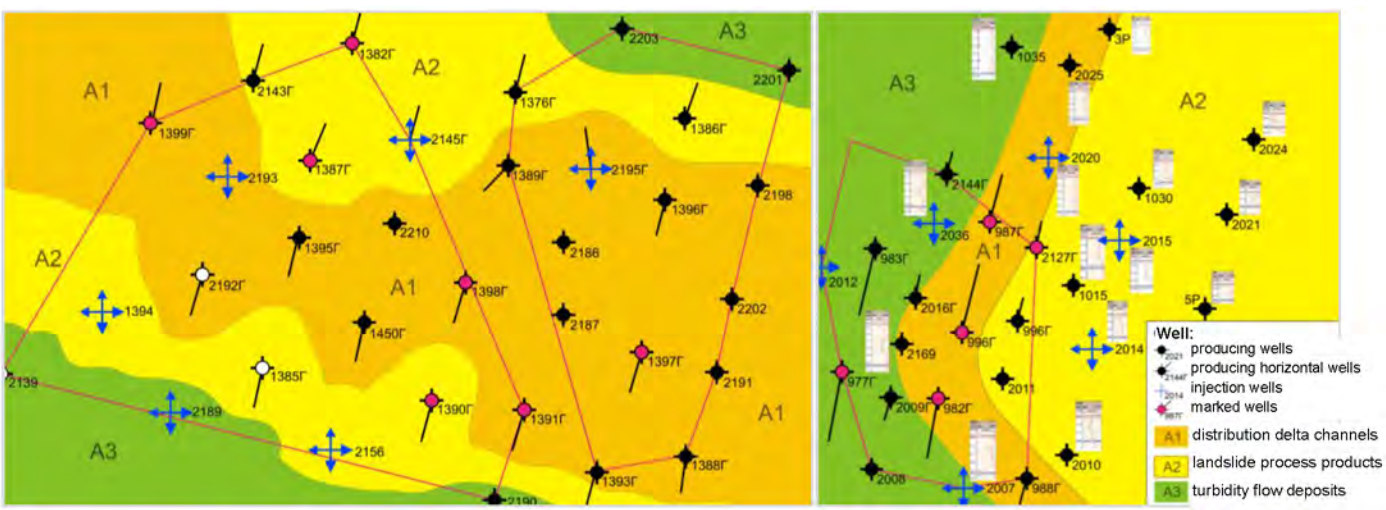

Figure 3—The contour map of the facies zone distribution: a — for the first field; b — for the second field

Effectiveness of the reservoir pressure maintenance system

The Spearman's rank correlation method was used to evaluate the areal effects of the interference between injection wells and surrounding producing wells in order to identify the reservoir flows for two sites of the Yuzhno-Vyintoiskoye field.

Correlation analysis is used to find relationships between the behaviour of two objects. In practice, the degree of flow communication between wells is commonly expressed through such indicators as well interference coefficient or coefficient of association. To assess the degree of association between the studied parameters (production and injection), the Cheddock scale is used. This scale suggests that the association

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degree between the two production parameters in question is very high if Spearman's rank correlation coefficient is 0.9, high — if it falls within the range from 0.7 to 0.9; significant — from 0.5 to 0.7; moderate — from 0.3 to 0.5; and weak — from 0.1 to 0.3 (Udintsova, 2016).

Well interference degree is estimated for the second field on the basis of the developed procedure for calculating the Spearman's rank correlation coefficients. Assessment of the reservoir flow communication not only between wells, but also between the ports of marked horizontal wells was done by combining the results of dynamic tracer-based production profile surveillance and calculation of the Spearman rank correlation coefficient.

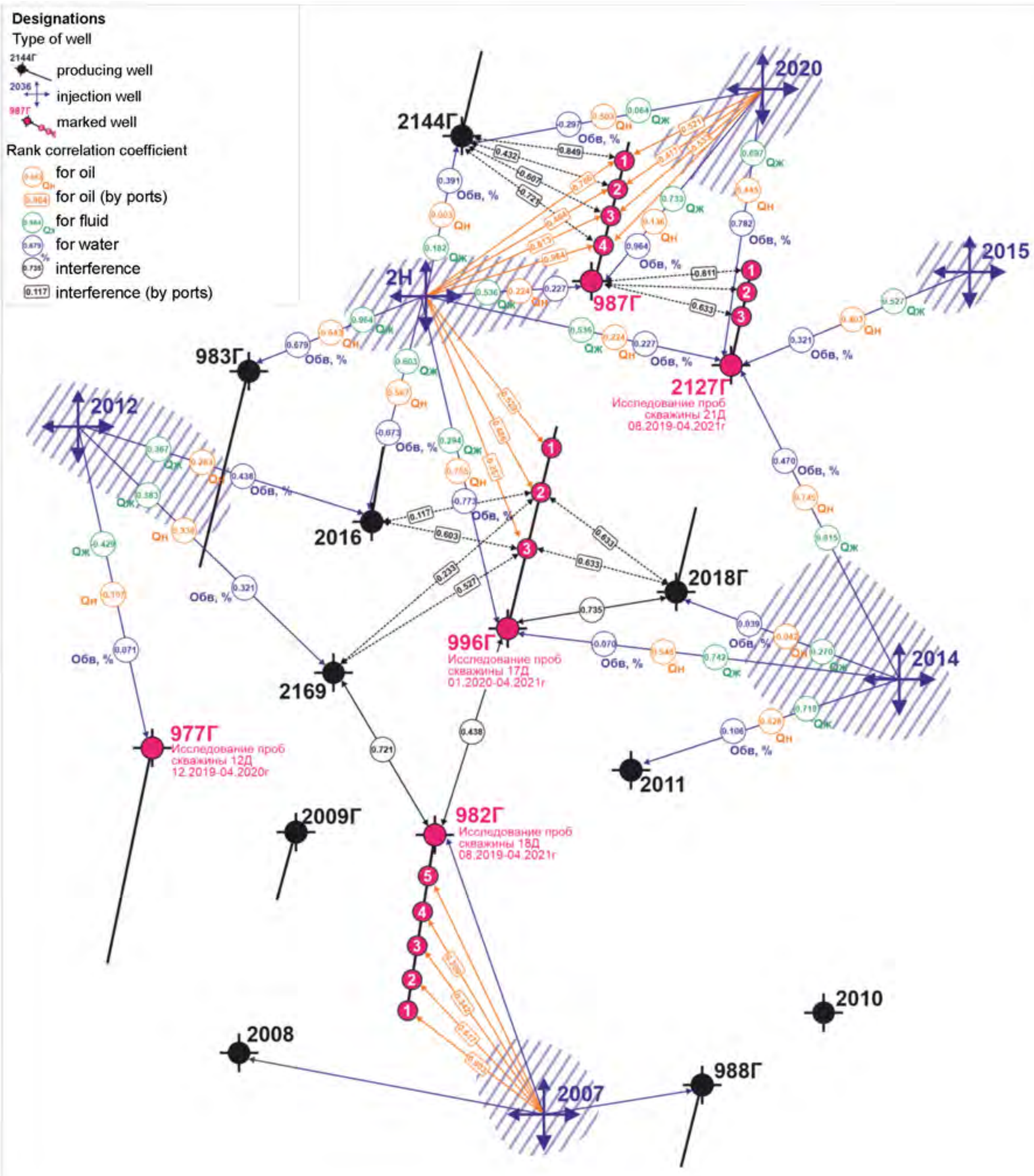

Figure 4—A map of Spearman's correlation coefficients. Estimating the interference between injection and production wells

The calculated data was used to develop a Spearman rank correlation coefficient map with arrows pointing at the dominant flow directions and reveal the degree of interference between the neighbouring

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injection and producing wells. The calculation revealed a tight reservoir flow communication between the producing wells in the northeastern area of the field. In the central and southern parts of the formation, the reservoir pressure maintenance system is still evolving (Figure 4).

In addition to the statistical calculations, the effectiveness of the reservoir pressure maintenance system was evaluated using an updated reservoir model of the field by the flow pathways. The implemented flow pathways are a visualisation of the dynamic system of the medium and show the well seepage directions.

For the first field, according to the distribution obtained, reservoir flows well represented in different directions have a direct impact on neighbouring producing wells (Figure 5a). For the second field, the main reservoir flows are clearly pronounced in the north-eastern part of the field (Figure 5b). By comparing the results of the integrated rank correlation method and dynamic tracer-based production profile surveillance with the assessment of the reservoir pressure maintenance system as per the updated reservoir flow model, high convergence of the results was revealed, which indicates the effectiveness of the proposed analytical tool combined with tracer-based studies.

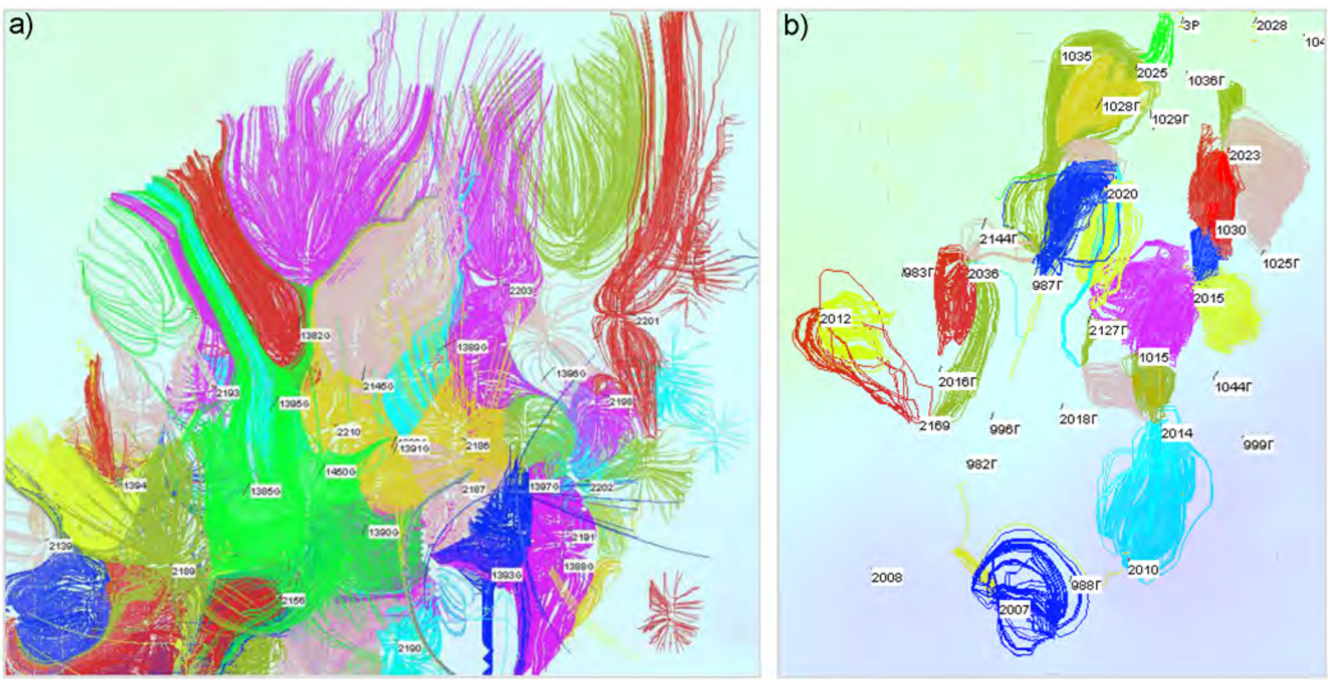

Figure 5—Flow paths of injected water for wells of the BV72-4 reservoir fields

The analysis of the reservoir pressure maintenance system effectiveness yielded information on the degree of injection influence on the production at individual flood sites, which was used to identify zones for conformance control measures for the first field.

Improving the reservoir pressure maintenance system effectiveness

As noted earlier, the first field initially has a high water content. In this regard, there emerged a need to introduce methods for improving oil recovery, aimed at curbing the uncontrolled growth of flooding, as well as to stabilise oil production and increase the oil recovery rate.

Upon the analysis of the dynamics of flooding starting points, the effect of water injection on the operational parameters of wells was revealed. The hydrodynamic communication is detected between injection well No. 1394 and production well No. 2192, and — by the flooding starting point — with injection well No. 2156 and neighbouring production wells Nos. 1385G, 1450G and 1390G. Based on the results of

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dynamic tracer-based production profile surveillance and evaluation of the reservoir pressure maintenance efficiency, it was decided to take conformance control measures in injection wells (Andreev et al., 2010).

The analysis of the reservoir pressure maintenance system effectiveness helped identify the degree of injection influence on the production for individual flooding areas. Based on the results of earlier studies, two flooding sites with injection wells Nos. 1394 and 2156 were selected for implementing conformance control measures in order to increase the vertical flooding area of the reservoir and reduce the water content in producing wells (Figure 6). The list of candidate wells and the characteristics of well operation indicators are given in Table 2.

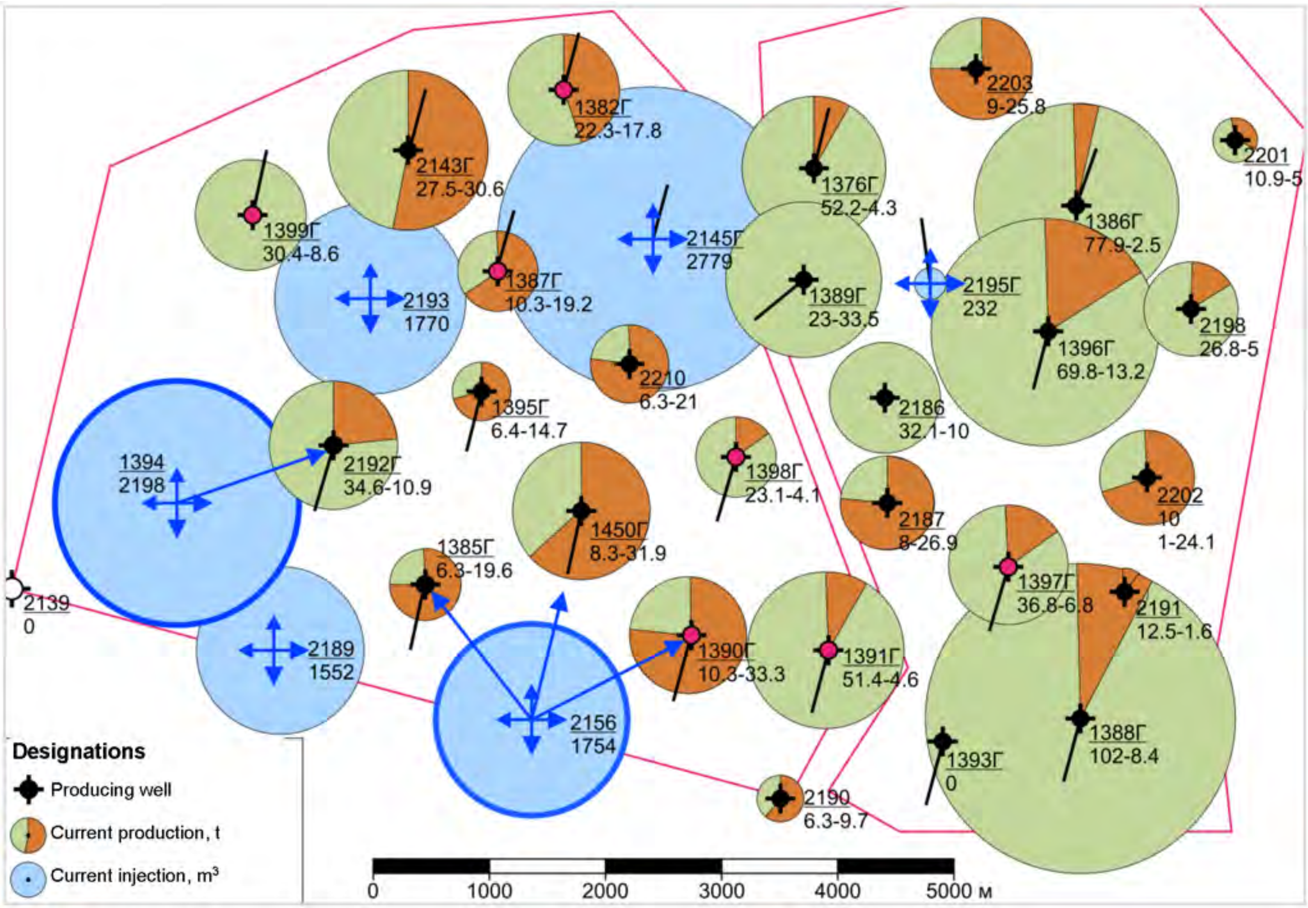

Figure 6—A fragment of the current development state map as of March 01, 2020 for the Yuzhno-Vyintoiskoye field

Table 2—Characteristics of the observation well production performance to implement conformance control measures.

No. injection well	No. producing well	Flow rate		Water cut		Water-oil ratio cum., %	Cum. oil production, t	Remaining recoverable oil reserves, thousand t.
		fluid, m3/day	oil, t/day	current %	cum., %			
1394	2192G	67.2	3.35	92.8	69.1	224	7.01	187.1
2156	1385G	20.1	14.5	26.3	18.3	22.4	8.87	189.5
	1390G	25.6	18.7	22.2	21.4	27.3	11.84	49.8
	1450G	64.9	1 1	97.7	64.1	178.7	13.3	7.9

Conformance control measures were implemented at the first field in January 2021. The graph (Figure 7) shows the effect of injecting the diverting agents. The increment in the total oil flow rate and a lower water content in the subject fields can be clearly seen.

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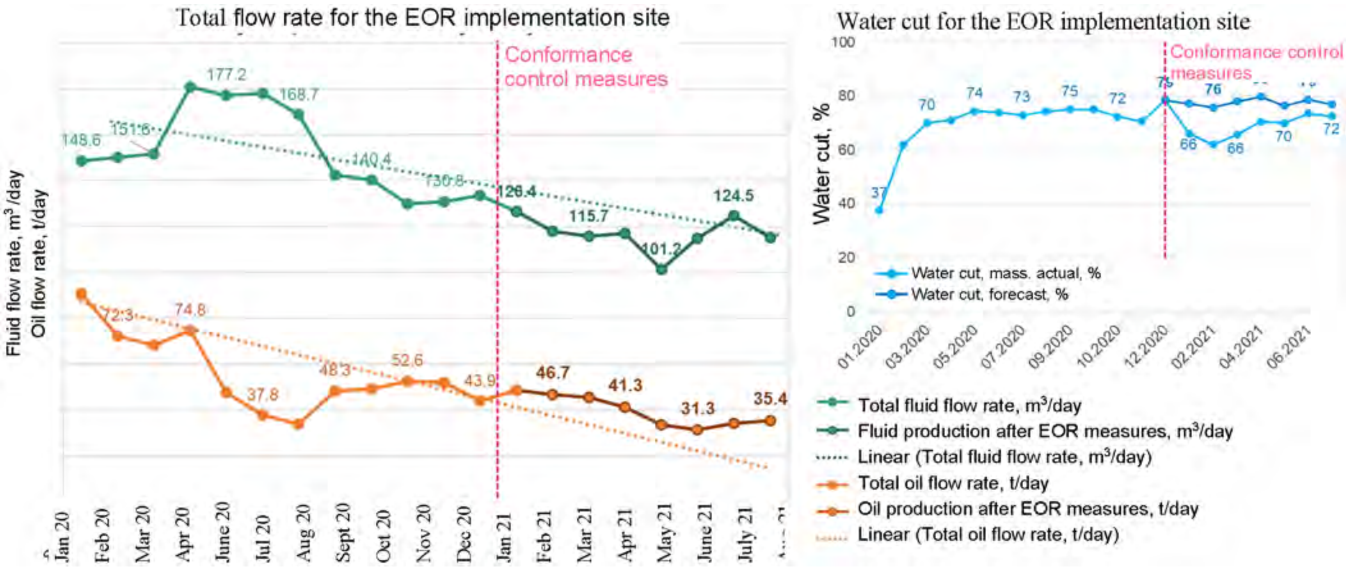

Figure 7—Effectiveness of the measures taken

Survey results

The implementation of an integrated approach to geological and field feasibility study of the Yuzhno-Vyintoiskoye field development management using tracer-based production profile surveillance enabled prompt decision-making to adjust the site development system at the current stage.

After implementing conformance control measures for the first field of the reservoir, the water content has stabilised at 68% without significant growth. The conformance control measures enabled slowdown in oil production decline. The assessment of the effect from implementing the technology showed that a positive economic effect was obtained in the target field; thus, the cumulative additional oil production amounted to 1,739 tons. The effect continues.

For the second field, recommendations are issued for early actions to prevent the injected water breakthroughs to producing wells, as well as to further substantiate flooding areas in order to boost the production and achieve better inflow conformance along horizontally drilled wells. Based on generalisation, systematisation and analysis of the results of dynamic tracer-based production profile surveillance in horizontal wells, an algorithm for monitoring and consistent decision-making was developed for managing the HC reserves recovery process at the site (Kotenev et al., 2004).

Thus, the provided set of recommendations based on the results of the geological feasibility studies to substantiate the field development system helped achieve stable dynamics of development indicators, increase flooding areas by blocking high permeability intervals and involving previously undrained interlayers in the development.

References

1. Andreev V. Ye., Kotenev Yu. A., Chizhov A. P., Chibisov A.V., Fedorov K. M., Galimov Sh. S. Substantiation of the Integration of Physical and Chemical and Reservoir Methods for Oil Recovery Improvement at the Vatyegansky Field // *Problems of Collecting, Preparing and Transporting Oil and Petroleum Products*. 2010. No. 3. pp. 5—14.
2. Guryanov A.V., Katashov A. Yu., Ovchinnikov K. N. Production profiling surveillance using quantum dot tracers // *Time of Coiled Tubing*. 2017. No. **2** (60). Pp. 42—51.
3. Dulkarnaev M. R. Geological and field feasibility study of field development management using marker-based production logging in horizontal wells: the case study of the Yuzhno-Vyintoiskoye

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field. / Katashov A. Yu., Ovchinnikov K. N., Malyavko Ye. A., Buyanov A.V. //*Oil. Gas. Novations*. 2020. No. 10. pp. 58—63.

4. Kotenev Yu. A., Nugaybekov R. A., Kaptelinin O. V. Improving the efficiency of hard-to-recover oil reserves recovery. M.: Nedra (Mineral Resources), 2004. p. 236.
5. Muromtsev V. S. Electrometric Geology of Sand Bodies Constituting Lithological Oil and Gas Traps. L.: Nedra (Mineral Resources). 1984. p. 260.
6. Ovchinnikov K.N. Challenges in Field Development and Drilling Resolved by the Use of Tracer Diagnostic Procedures in Well Inflow Profiles // *Oil gas and Innovations*. 2019. No. 2. pp. 71–77
7. Udintsova N. M. Econometrics. 2016. Multiple Regression and Correlation in Econometrics, Part 2, 73. Azov-Black Sea Engineering Institute, Zelenograd.

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