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Identify Possible Clusters on Marine Hydraulic Structures and their Content for the Development of Offshore Hydrocarbon Deposits

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Abstract

In the article the design of cluster drilling of one hypothetical offshore oil field is considered. Based on the development project for this field, 91 wells are required to be drilled. According to the adopted coordinate system, the coordinates of the faces of all wells were measured with a ruler in the structural map, and the parameters of the wellbore profiles were also determined as the vertical depths of the faces of the wells, their deviations from the vertical, and others. Based on these parameters, the total lengths of the boreholes of all wells and the total costs of their full construction were calculated. The rational coordinates of the stationary platforms, the total area of the work sites, as well as the total costs for their construction at sea, were also calculated; in each variant, optimal flyover schemes were chosen, their total lengths, as well as total costs, were calculated. Based on all the data obtained, the total costs for cluster drilling of all wells were determined, as well as the costs for the construction of all hydraulic structures. Among all the accepted 8 options, only one II option turned out to be the most rational, requiring minimal investment.

Keywords: Hydrocarbon field; Cluster and maintenance; Marine hydraulic structure; Vertical and inclined wells; Development; Resources; Economic feasibility

Introduction

The operational experience of offshore hydrocarbon deposits shows that there is a wide variety of methods for assessing the cost indicators of hydraulic structures designed and installed with a large number of functional and cost characteristics for the development and withdrawal of their resources on commodity exchanges. The cost indicators and the functional availability of these structures are interconnected and their capabilities are determined by the presence of all kinds of technological lines and devices necessary for the development of field resources in the sea. Depending on the technological support of the structure, metric characteristics are formed that affect its corresponding weight indicators. Weight indicators are adjusted depending on the design stage, starting from the stage of the technical proposal and subsequently at the stages of outline, technical and working design. Moreover, in this process, at each design stage, the relevant geological and geographical conditions for the location of the structure are refined and the characteristics of the reservoir and floating facilities involved in these activities are taken into account. The last place here is also given to the characteristics of the drilling complex and the modules supporting this complex and the corresponding drilling programs. Of no small importance for the price of the structure as a whole is the availability of connections and interaction with neighboring platforms, the number of production lines, its provision with systems for performing the necessary technological operations, including systems for performing water and gas impacts on wells, energy supply, and re-injection of drilling waste into specially drilled for this purpose, wells, submarine pipelines for access to the terminal, etc. All this is shown in Figure 1, from which it is seen that how the existing structures installed in the offshore are interconnected.

Figure 1: Development option of marine deposit resources.

The drilling program at one of these structures is shown, which affects the design cost of this installation. As can be seen during the construction of offshore structures [1,2], the cluster drilling program is not provided for in the drilling program, and therefore, according to the data on the implementation of offshore field development technologies, the cost of these structures is much more expensive for the adopted scheme for its implementation.

Therefore, in this paper, we consider an implementation option for a drilling program for cluster execution, for which evaluation work on the construction of hydraulic structures is given.

Problem Setting

The method of cluster drilling is currently recognized as the most rational and widely used method for developing resources of offshore oil fields [3-8]. The proposed article describes a project for drilling producing wells using cluster drilling for developing resources from a hypothetical field [4-6,9-10], a structural map of which has an anticlinal tectonic structure is shown on Figure 2a:

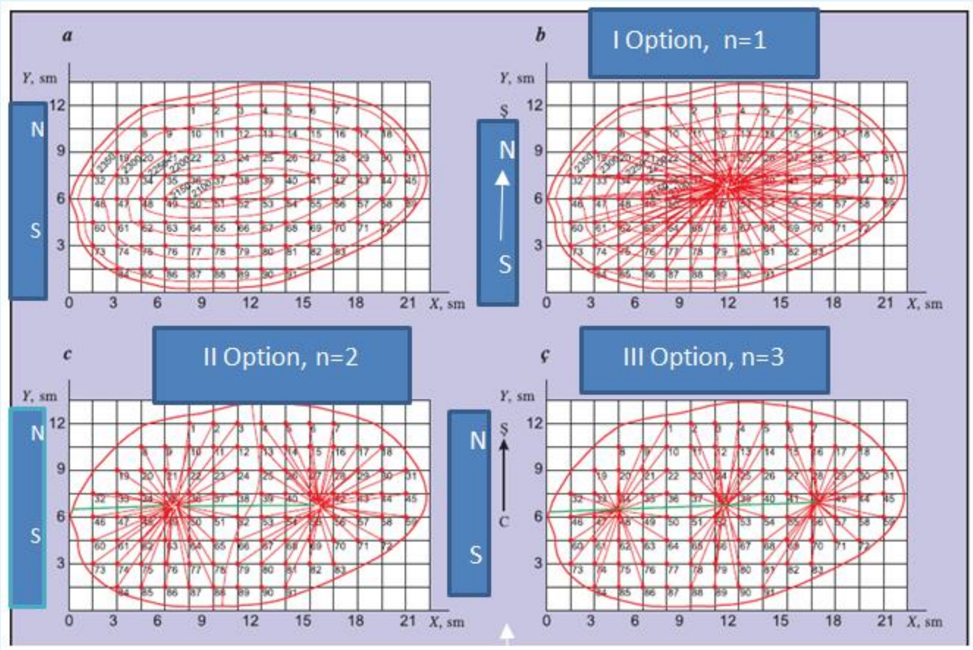

Figure 2: Structural map of a hypothetical offshore field with anticline tectonic structure.

Case Study

The longitudinal and transverse dimensions of the field are assumed equal, respectively, up to 2973 and 1707 m. It is assumed that due to the uniform distribution of the natural energy of the field, the well grid of its development is four-point, i.e. the faces of four producing wells are located at the nodal points of a square with a side length of 200m. This means that the area of the oil zone of the wells location is equal to the area of the square with the side length equal to 400 m. = 160000 m^2, which means the density of the wells is well / 4g. Thus, on the structural map of the field (see Figure 2), the faces of 91 wells are shown and 6 closed curves are indicated on its roofing part. The vertical difference in the depths of two adjacent closed curves in comparison with sea level is -50 m. The depth of closed curves in the upper part starts from 2100 m. And on the deepest parts of the slopes (near the oil contours) it reaches a depth of 2350 m. Work on the design of well drilling of a hypothetical offshore field, shown in Figure 3 [11], must be performed in the sequence below.

At the beginning, on the structural map of a given offshore oil field, the Cartesian XOU coordinate system is selected as close as possible to the field, the ordinate axis of the system is directed north-south, and the abscissa axis is directed east-west. After this, the values of the X and Y coordinates of all the mine faces of the field in centimeters are measured in this coordinate system and are placed in the table. The numbers of wells are numbered from 1 to 91. To convert the values of coordinates into meters, their values in centimeters are multiplied by a coefficient equal to 133.33. This is a scale factor in which a structural map is constructed that has a unit of measurement of 133.33 m / cm Therefore, after determining the coordinates of the borehole from the structural map, it is necessary to really reflect these coordinates for the field conditions in order to determine its location under these conditions. Therefore, it is necessary to multiply the obtained coordinate values by a scale factor, i.e., by 133.33, which makes it possible to determine these coordinates in meters.

Under sea conditions, hydraulic structures are not allowed to be set arbitrarily, and their number should receive an appropriate justification. In the scientific substantiation of solving the above problems, the main limiting factor is investment and CAPEX, directed to their construction and the volume of drilling operations on platforms. It should be noted that well drilling programs on offshore platforms for the development of reserves of the offshore field should be implemented on the condition of a minimum of capital investments. Failure to comply of this condition may cause an increase in prices for the implementation of relevant programs and unreasonable loss of a large amount of funds.

Decision Method

To determine the optimal variant of drilling a given hypothetical offshore field by core drilling, 8 different options are offered, shown in Table 1. As can be seen from the table, the first option envisages the construction of one platform from which all 91 wells with holes will be drilled on this platform. The bottom of all 91 wells are shown on the structural map. Calculated rational coordinates of the platform projection on the structural map, equal respectively to X = 10.86 sm. and y = 6.69 sm [12].

Version	The Number of Fixed Platforms, N	Number of Wells Drilled from One Platform
I	1	91
II	2	45;46
III	3	30;31
IV	4	24;19
V	6	15;16
VI	8	12;7
VII	16	6;1
VIII	91	1

Table1: Consideration of construction options.

According to these coordinates, the optimal location of the platform projection on the structural map is determined. To simplify the solution of the platform, all the wells are connected to the center of the platform by straight lines (Figure 2b). These lines are projections of directional wells on the structural map. The angles between these lines and the north-south direction are azimuth angles for drilling inclined wells. In this case, the location of all wells to be drilled coincide with the center of the platform. Actually, the layout of the well locations on the platform is represented by the scheme shown in Figure 2c. Here, small points characterize the tower support points of the drilling rig, and circles - the location of the wellheads on the platform. The distance between the wellheads is equal to the distance between the tower supports of the drilling rig, i.e. is assumed to be 8 m. In the second variant, it is planned to build two platforms, and out of 91 wells, 45 wells will be drilled and located on platform I, 46 wells - on platform II (Figure 2c). The coordinates of the platform are presented respectively: Platform I – X_1 = 6.27 and Y_1 = 6.43 sm; Platform II – X_2 = 15.6 and Y_2 = 6.95 sm. Thus, the optimal location of both platforms are determined. In Figure 3 shows the layout of the wellheads and tower supports of the derricks on the working site of each platform.

The third option provides for the construction of three platforms. In this option, from 91 wells drilling of 30 wells is supposed to be placed on platform I, 31 wells -on platform II and 30 wells - on platform III (Figure 2c).

The coordinates of the platform are represented respectively: Platform I – X_1 = 4.74 and Y_1 = 6.2 sm; Platform II – X_2 = 10.79 and Y_2 = 6.82 sm; Platform III – X_3 = 17.05 and Y_3 = 7.05 sm. The layout of the wells and derrics tower supports on the working site of each platform is shown in Figure 3. On the structural map, all the bottom holes of the wells corresponding to individual platforms are connected by the central points of the each platforms projections by straight lines, and for the third option, well clusters drilling outline are obtained (Figure 2c). According to the procedure described above, the necessary calculated data for each of the IV, V, VI and VII options were provided. Due to the limited volume of the article, schemes for these options were not presented. For the VIII-th option, due to the verticality of all the provided drilling wells, for each well of a separate platform construction is planned, in which case their number will be equal to the number of wells being drilled, i.e. n = 91. In this case, the platforms projections coincide with the bottoms of the wells being drilled and they do not deviate from the vertical. In each option, to calculate the total costs of well drilling for all wells, it is necessary to start determining the total length of their wells. The location of the vertical bottom hole and only one wellhead outline on the platform working site is determined by the structural map (Figure 2). There may be three different cases: the bottomhole of the wells are on one of the iso-hoop (or close to it) curves of the structural map (wells number 1, 10, 17, 25, 26, 30, 34, 49, 53, 55, 58, 65, 73, 84); - the bottomhole of the wells are between the adjacent (or in the middle) iso-hoop curves of the structural map (wells number 3, 12, 15, 19, 36, 42, 46, 54, 61, 76, 86, 89); - the bottomhole of the wells are located between adjacent iso - hoops at different distances from them (this includes all other wells). For bottom holes that correspond to the first case, their vertical depths are not calculated for the definition of their depths, since these depths are assumed to be equal to the depths of the iso-hoops. Due to the equality of the vertical distance between the neighboring iso-hoops is 50 m. in the second case, when calculating the vertical depths of the bottom hole well locations, it is necessary either to add -25 m to the depth of one of the iso hoops, or to take it away from the depth of the other iso-hoops -25 m. The number of wells corresponding to the third case in this field is quite large, which is why the determination of their vertical depths is considerably difficult. For this case, the interpolation method is the most acceptable, using which a straight line is drawn from the bottom of the well to two neighboring iso-hoops. Then this line is measured in mm-ah, which the bottom of the well divides into two parts. By measuring most of this line in mm, the lengths of the obtained sections are determined. For example, the measured length of the line passing through the bottom hole of well No. 5 (the distance between the end points of this line located on adjacent iso-hoops) was 14 mm. On the other hand, the distance measured from this bottom to isohoops, equal to 2350 m, was 9 mm. Thus, the vertical depth of the bottom hole well № 5 was 2336 m. The vertical depths of all wells, calculated according to this procedure, are presented in Table 2 (Table 2). The values of H in all variants are the same

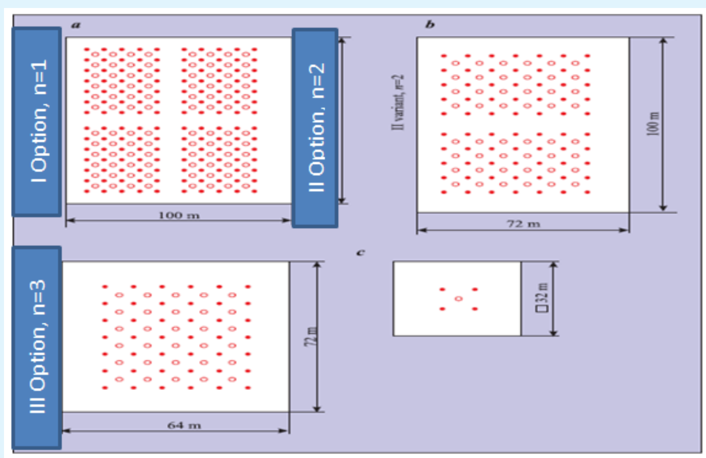

Figure 3: The layout of the wellheads and derrick tower supports on the platform.

Wells №	H, m	A, m	B, m	l2, m	L, m	Wells №	H, m	A, m	B, m	l_2, m	L, m
1	2354	847	2154	2315	2515	49	2150	647	1950	2055	2255
2	2343	760	2143	2274	2474	50	2112	453	1912	1965	2165
3	2328	720	2128	2247	2447	51	2130	253	1930	1947	2147
4	2321	727	2121	2242	2442	52	2110	100	1910	1913	2113
5	2325	800	2125	2271	2471	53	2140	167	1940	1947	2147
6	2328	900	2128	2310	2510	54	2175	373	1975	2010	2210
7	2336	1040	2136	2376	2576	55	2202	560	2002	2079	2279
8	2332	993	2132	2352	2552	56	2234	773	2034	2176	2376
9	2311	827	2111	2267	2467	57	2264	960	2064	2276	2476
10	2296	680	2096	2204	2404	58	2300	1147	2100	2393	2593
11	2290	573	2090	2167	2367	59	2339	1353	2139	2531	2731
12	2275	513	2075	2137	2337	60	2328	1273	2128	2480	2680
13	2264	533	2064	2132	2332	61	2275	1073	2075	2336	2536

14	2267	627	2067	2161	2361	62	2235	882	2035	2218	2418
15	2276	753	2076	2208	2408	63	2213	670	2013	2122	2322
16	2284	913	2084	2275	2475	64	2209	533	2009	2079	2279
17	2307	1080	2107	2368	2568	65	2205	380	2005	2041	2241
18	2336	1253	2136	2476	2676	66	2209	293	2009	2030	2230
19	2332	1087	2132	2393	2593	67	2222	327	2022	2048	2248
20	2291	900	2091	2282	2482	68	2241	460	2041	2092	2292
21	2261	713	2061	2181	2381	69	2265	627	2065	2158	2358
22	2242	547	2042	2114	2314	70	2283	807	2083	2234	2434
23	2239	400	2039	2078	2278	71	2309	993	2109	2331	2531
24	2220	320	2020	2045	2245	72	2337	1180	2137	2441	2641
25	2206	347	2006	2036	2236	73	2346	1333	2146	2146	2346
26	2202	467	2002	2056	2256	74	2310	1147	2110	2402	2602
27	2220	633	2020	2117	2317	75	2286	973	2086	2302	2502
28	2230	813	2030	2187	2387	76	2273	807	2073	2225	2425
29	2240	1000	2054	2284	2484	77	2271	660	2071	2174	2374
30	2296	1187	2096	2409	2609	78	2268	547	2068	2208	2408
31	2339	1380	2139	2546	2746	79	2273	487	2073	2129	2329
32	2343	1253	2143	2482	2682	80	2280	513	2080	2142	2342
33	2295	1047	2095	2342	2542	81	2293	587	2093	2174	2374
34	2250	847	2050	2218	2418	82	2313	740	2113	2239	2439
35	2210	653	2010	2113	2313	83	2333	900	2133	2315	2515
36	2179	453	1979	2030	2230	84	2350	1233	2150	2478	2678
37	2167	267	1967	1985	2185	85	2335	1080	2135	2393	2593
38	2142	120	1942	1946	2146	86	2325	933	2125	2321	2521
39	2114	187	1914	1923	2123	87	2319	813	2119	2270	2470
40	2128	380	1928	1965	2165	88	2321	733	2121	2240	2440
41	2142	567	1942	2023	2223	89	2325	693	2125	2235	2435
42	2174	767	1974	2118	2318	90	2332	707	2132	2246	2446
43	2219	960	2019	2236	2436	91	2343	773	2143	2278	2478
44	2268	1153	2068	2368	2568						
45	2321	1347	2121	2513	2713						
46	2323	1253	2123	2465	2665						
47	2368	1033	2168	2402	2602						
48	2213	847	2013	2184	2384						

Table 2: Determination of the option 1 parameters: I Option: n=1: l_1 = 200m.

Note: H - is the vertical depth of the well; A-distance deviations of the bottom hole from the vertical; B-vertical height of the curved part of the well bore; l_2 - inclined (straight) line, replacing the length of the curved part of the wellbore; L_2 - is the length of the borehole model. Due to the difference in the number of platforms in the considered options for the development of field resources by drilling programs, the deviation of the "A" well heads from the vertical is different. To determine "B" - the vertical height of the curved section of the wellbore from the distance "H" - the vertical depth of the well is subtracted l_1 = 200 m (Table 2). The values of L_2-were determined according to the Pythagorean theorem.

It was taken into account that for wells drilled in the conditions of the Caspian Sea, the cost of one meter of penetration in the SOCAR system a cost of 1,775 $ is estimated. According to this indicator, for various variants of cluster drilling of 91 wells, the total cost of each of them was determined by the following sequence: For option I (n = 1), the total length of all boreholes was 219842 m. Taking into account that the total cost N_1 = 219842 * 1775 = 390219550 $; -For option II (n = 2), the total penetration rate for all wells was 213146 m., Taking into account that the total cost N_2 = 213146 * 1775 = 378334150 $; - For option III (n = 3), the total penetration in all wells amounted to 211345 m., Taking into account that the total cost N_3 = 211345*1775 = 375137375 $. Similar calculations were performed for all options, and the results are shown in Table 3, from which it follows that for various well drilling programs, with an increase in the number of platforms, the total length of the planned wells and their total cost decreases.

Version	Number of Platforms, N.	Total Length of All Wells, M	Total Cost of All Wells, $
I	1	219842	390219550
II	2	213146	378334150
III	3	211345	375137375
IV	4	210189	373085475
V	6	208643	370341325
VI	8	208128	369427200 369427200
VII	16	207011	367680600
VIII	91	206144	365905600

Table 3: Determination of design and cost characteristics of wells.

For various variants of cluster drilling, the total area of the platform working site and their total cost was calculated by the following sequence.

For the first option, 96 wells can be drilled from the platform, but according to the development project for a given field, 91 wells have to be drilled. The working area of the platform is divided into 4 equal parts with a distance of 12 meters between them, and empty distance for 12 meters length are left at the edges of the platform. 24 wells can be drilled from each part of the platform, but one of them needs to be drilled 19 wells for getting the total number of 91 wells. Due to the presence of the distance between the drilling tower supports and the distance between the well heads are 8 m. the area of the working site of platform will be S_1 = 13200 m^2. According to statistical data on the Caspian Sea, the average cost of one m^2 of the working site of stationary platforms is 10930$. Thus, for the first option (n = 1), the cost of a single platform will be N_1 = 144276000$. For the second option (n = 2), the working area of each platform is divided into two equal parts for drilling 24 wells from each of them. But from one part 24 wells and on the other 22 or 21 wells will be drilled. The area of one platform is S_1 = 6336 m^2, and the two platforms – S_2 = 12672 m^2. The total cost will be equal to N_2 = 138504960 $. For the third variant (n = 3), out of 91 wells, 30 wells from the first, 30 wells from the second and 31 wells from the third platforms have to be drilled. The area of the one platform working site is S_1 = 4608 m^2, and the three platforms S_3 = 13824 m^2. The total cost of the three platforms will be N_3 = 151096320 $. The same method was used for calculations for other options and the results are presented in Table 4:

Option	Number of Platforms, N	Total Area of Platforms, M2	Total Cost of All Platforms, Manat.
I	1	13200	144276000
II	2	12672	138504960
III	3	13824	151096320
IV	4	16128	176279040
V	6	18432	201461760
VI	8	21504	235038720
VII	16	30720	335769600
VIII	91	93184	1018501120

Table 4: Determination total cost of platforms.

As can be seen from the table, for various well drilling programs as the number of platforms increases, their total area of working sites increases 7 times and therefore the total cost of platforms under construction increases in accordance with the implemented options. Below the sequence of determining the optimal designs of sea pier, (determining metric dimensions) and their costs for various types of cluster drilling is shown. The length of the overpass (sea pier) connecting the location of offshore field with the mainland supposed to be known. We assume that this distance is equal to L_1 = 2000 m and for the all implemented well drilling options is constant. The remaining parts of the overpass (sea pier), i.e. its main part and extensions are located on the offshore field expectation area and attached to the main area of the platform. On Table 5 the lengths of the overpasses (sea pier) and their cost for all options of the cluster drilling are shown:

Option	Number of Platforms, N	Total Length of All Trestles, M	Total Cost of All Trestles, $.
I	1	3447	37675710
II	2	4080	44594400
III	3	4300	46999000
IV	4	5367	58661310
V	6	6247	68279710
VI	8	6967	76149310
VII	16	9313	101791090
VIII	91	20213	220928090

Table 5: Total cost of all trestles with platforms.

For the first two options, the extentions to the trestles are not made, but its main part consists two sections, namely: the distance from the offshore field to the first I platform and the straight section connecting the I and II platforms. For the third option, additional extentions are also not foreseen, but its main part includes only 3 sections, namely, up to the first platform I, the section connecting platforms I and II, as well as the section connecting platforms II and III. On the fourth option, the main part of the overpass (sea pier) consists two sections and two additional extentions.

Results & Discussion

As can be seen from table 5, with an increase in the number of platforms, for drilling clusters various variants the length and, accordingly, the cost of building the required trestles are increased. The total costs for the construction of marine hydraulic structures (platforms and trestles) for implementation of drilling clusters for various drilling programm options are determined by the below mentioned formula [4]:

$$N = N_w + Np + N_t \quad (1)$$

N_w, Np, N_t - respectively, there are costs associated with drilling wells, with the construction of platforms and trestles accordingly, and N - there are total cost (CAPEX) associated with the development of the offshore field. Usually the option with a minimum total investment as an effectiveness option is accepted. The dependence N = N(n), reflecting the change of total expenditures with the number of platforms in Figure 4 is shown.

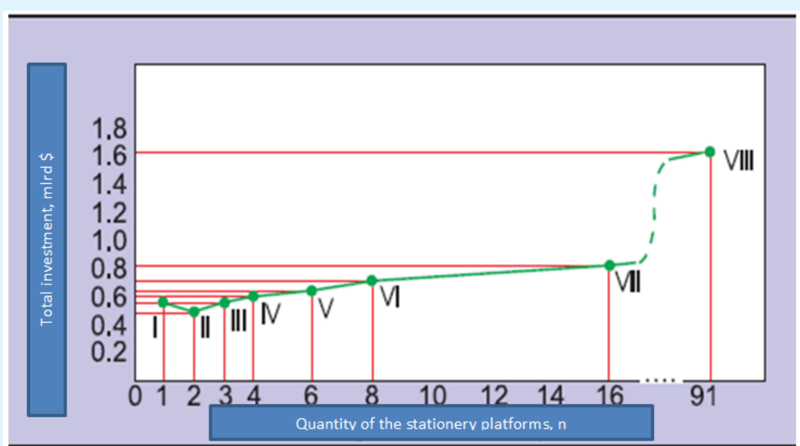

Figure 4: The curve of dependence of total investments on number of platforms.

It should be noted that if for the development of reserves of a given field, all 91 wells from three platforms are drilled using the cluster method (n = 3), i.e. if one extra platform is built, then it will require capital investments in the amount of N_3 = 573323695 $, i.e. extra costs will amount to 195 mln. $. If all 91 wells for a given field will be drilled from one platform under a well drilling cluster program, then this will require total investments of N_1 = 572171200 $, i.e. in this variant of field reserves development (n =1) expenses will be exceeded by the amount of 194 mln $.

Conclusion

1. For the adopted 8 options of a given field reserves development using cluster drilling technology with an increase of platforms number , the total length of all wells and their costs decreases.
2. In the considered options of a given field reserves development, due to the increase of fixed platforms number, the areas the platform working sites and length of trestles and their extentions, capital investments for the construction of hydraulic structures in sea conditions are usually large.
3. With an increase of the number of platforms, total investment for the implementation of cluster drilling and the construction of hydraulic structures, depending on the number of platforms, initially decreases and then increases. This dependence has one minimum, which corresponds to the option of developing the reserves of a given field with a minimum total investment.

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