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Satbayev University

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ИЗВЕСТИЯ

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PREREQUISITES FOR THE CONSTRUCTION OF A CLOSED SYSTEM OF OPENING AND DEVELOPMENT OF GROUNDWATER DEPOSITS

Abstract. Population growth and economic development have dramatically increased the demand for fresh water. The result of these trends is high rates of groundwater depletion around the world.

The traditional practice of opening and developing groundwater with vertical wells is morally obsolete, since the drilling is mainly on waste rocks with a small area of opening aquifers by the value of their thickness. It is necessary to revise the methods of opening and developing aquifers from the perspective of protecting the bowels of the earth and the groundwater system, with a focus on increasing water recovery in relation to the physical scope of drilling wells.

A closed system has been formed, structurally consisting of downward injection and ascending water-lifting wells, connected by multi-level intermediate shafts drawn along the strike of aquifers.

The system is based on the calculation of water intake from manifolds by the ejection effect, implemented by pumping water through a downhole well and lifting an increased volume of water through an upward well.

The geological and technical prerequisites for the construction of a closed system, the sequence and scope of the work performed, measures to preserve the reservoir properties of aquifers, requirements for the method of drilling wells and intermediate wellbores without complications are outlined.

Developed and tested in practice - the layout for kickoff and the formation of intermediate wellbores, a core set equipped with a multi-chamber downhole hydraulic machine and a rock cutting tool with a hydrodynamic effect of rock destruction. The characteristics and results of testing are given.

Key words: Drilling, well, closed system, layout, aquifers, wellbores, filterless.

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ЖЕР АСТЫ СУЛАРЫН ЫДЫРАТУ МЕН ИГЕРУДІҢ ТҰЙЫҚ ЖҮЙЕСІН САЛУДЫҢ АЛҒЫШАРТТАРЫ

Аннотация. Халық санының өсуі мен экономикалық даму тұщы суға деген сұранысты күрт арттырды. Бұл тенденциялардың нәтижесі бүкіл әлем бойынша жер асты суларының сарқылуының жоғары қарқыны болып табылады. Тік ұңғымалармен жер асты суларын ашу және игерудің дәстүрлі тәжірибесі моральдық тұрғыдан ескірген, өйткені бұрғылаудың негізгі көлемі олардың қалыңдығының мәні бойынша ашылатын сулы горизонттардың шағын ауданы бар бос жыныстарда жүзеге асырылады. Бұрғылау ұңғымаларының физикалық көлемдеріне қатысты судың қайтарымдылығын арттыруға баса назар аудара отырып, жер асты сулары жүйесін қорғау призмасы арқылы сулы горизонттарды ашу және игеру әдістерін қайта қарау қажет.

Құрылымдық жағынан төмен қарай айдалатын және көтерілетін су көтергіш ұңғымалардан тұратын, сулы горизонттардың соғуы бойымен тартылған көп деңгейлі аралық шахталармен байланысқан жабық жүйе қалыптасты. Жүйе ұңғыма арқылы суды айдау және көтерілу ұңғымасы арқылы судың ұлғайған көлемін көтеру арқылы жүзеге асырылатын ағынды эффекті бойынша коллекторлардан суды алуды есептеуге негізделген.

Жабық жүйе құрылысының геологиялық-техникалық алғышарттары, орындалатын жұмыстардың реттілігі мен мазмұны, сулы горизонттардың қабаттық қасиеттерін сақтау шаралары, ұңғымаларды және аралық ұңғымаларды қиындықсыз бұрғылау әдісі мен құралдарына қойылатын талаптар көрсетілген. Практикада әзірленген және сыналған – аралық ұңғыма оқпандарын бұрғылау және қалыптастыру схемасы, көп камералы ұңғылық гидравликалық машинамен және тау жыныстарын бұзудың гидродинамикалық әсері бар тау жыныстарын кесетін құралмен жабдықталған керн жинағы. Тестілеудің сипаттамалары мен нәтижелері келтірілген.

Түйін сөздер: бұрғылау, ұңғыма, тұйық жүйе, макет, сулы горизонттар, шахталар, сүзгісіз.

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ПРЕДПОСЫЛКИ СООРУЖЕНИЯ ЗАМКНУТОЙ СИСТЕМЫ ВСКРЫТИЯ И ОСВОЕНИЯ ЗАЛЕЖЕЙ ПОДЗЕМНЫХ ВОД

Аннотация. Рост населения и экономическое развитие резко увеличились потребности в пресной воде. Результат этих тенденций – высокие темпы истощения подземных вод по всему миру.

Традиционная практика вскрытия и освоения подземных вод вертикальными скважинами морально устарела, поскольку основной объем бурения осуществляется по пустым породам при незначительной площади вскрытия водоносных пластов на величину их толщины. Необходим пересмотр методов вскрытия и освоения водоносных пластов через призму охраны недр земли и системы подземных вод, с ориентиром на повышение извлекаемости воды по отношению к физическим объемам бурения скважин.

Сформирована замкнутая система, структурно состоящая из нисходяще нагнетательной и восходяще водоподъемной скважин, связанных многоуровневыми промежуточными стволами, проведенными по простиранию водоносных пластов.

Система строится в расчете отбора воды из коллекторов эффектом эжекции, реализуемой закачкой воды по нисходящей скважине и подъему увеличенного объема воды по восходящей скважине.

Установлены геологические и технические предпосылки сооружения замкнутой системы, последовательность и содержание выполняемых работ, обозначены меры по сохранению коллекторских свойств водоносных пластов, требования, предъявляемые к способу и средствам проводки скважин и промежуточных стволов без осложнении.

Разработаны и опробованы на практике – компоновка для зарезки и формирование промежуточных стволов, колонковый набор, оснащенный многокамерной забойной гидромашиной и породоразрушающим инструментом с гидродинамическим эффектом разрушения горных пород. Приведены характеристики и результаты отработки.

Ключевые слова: бурение, скважина, замкнутая система, компоновка, водоносные пласты, стволы, бесфильтровые.

Introduction. The construction of a closed system for opening and developing deposits of water lenses can be successfully implemented if the initial geological and technical prerequisites are established, which consists in the sequence of work performed in order to obtain reliable, highly informative geological materials. The objects of study are the terrain, the state of the mountain environment, the intervals of the location of aquifers and water-resistant rocks, the occurrence elements and the direction of water movement, the calculated parameters: filtration coefficient, water conductivity, power, presence or absence of pressure.

On this basis, the choice of the layout of the descending and ascending wells, their designs, the place of kickoff and the routes for the passage of intermediate wellbores along the strike of aquifers in the direction from the descending well to the ascending one, design features and technological capabilities of the means of constructing wells and shafts are determined.

The tasks to be solved are to ensure accident-free kickoff and waste of intermediate wellbores from the downhole, maintaining the stability of their walls and maintaining the natural porosity and permeability, and the possibility of their expansion. Of interest are filterless intermediate wells, which are perfect in terms of opening aquifers, since they work stably with high flow rates for a long time.

Due to an increase in well injectivity and a decrease in drilling through empty rocks due to a reduction in the number of vertical wells, a closed system for penetrating and developing groundwater deposits can become an effective means of subsoil conservation.

Tasks

Determining the initial geological and technical prerequisites for the construction of a closed system for the opening and development of groundwater deposits;

Substantiation of the structural scheme of the construction of a closed system, the choice of the design of wells and intermediate wellbores;

With regard to the state of the mountain environment, the development of facilities for construction and technological modes of drilling wells, approbation in practice.

Research methods. In works (Kruzhilin, 2017:4), (Naomi, 2019:1605), (Viossanges, 2017:5), (Molle, 2018:13), (Guppy, 2018:1), (Velis, 2017:11), (Marc, 2019:6) a review and analytical analysis of the conditions for the development of groundwater and their optimization is presented. The methods used to assess groundwater depletion are presented, the key causes and countermeasures are indicated. Ideas for the preservation of the life support system of groundwater are proposed.

In the “water-roc” system, the capacitive properties of rocks are of the greatest importance, by which they mean the ability of rocks to contain, retain and release the water contained in them. Capacitance properties determine the total groundwater reserves.

When studying the movement of groundwater, it is important to know the filtration processes, which are expressed by the filtration coefficient, which depends on the properties of the constituent elements of the “water-rock” system.

The permeability coefficient is related to the filtration coefficient:

$$К = К_{ф} ⍰ (\rho q), \quad (1)$$

where is the filtration coefficient; – coefficient of dynamic viscosity; – is the liquid density, - is the free fall acceleration.

The rocks that make up aquifers, according to reservoir properties, are porous, porous-fractured and fissured-vein type.

The capacity of a fractured reservoir is a system of fractures, voids and caverns connected to each other and to the well.

The opening of cracks sometimes reaches 100 mm or more. With an increase in the depth of wells above 100–150 m, the fracturing of rocks decreases (Mendebaev, 2021 c:6). This circumstance must be taken into account when choosing the route for the passage of intermediate shafts.

The main condition for the prudent development of groundwater deposits is the use of methods for opening and developing aquifers, which ensure the preservation of their porosity and permeability, contribute to their expansion in the bottomhole part of the well (Gorelikov, 2019:3) (Petkina, 2018:1).

For the construction of a closed system of opening and development of groundwater, pressure and high-pressure horizons that occur in various structural and geological conditions are of the greatest interest: artesian and fissure-vein, limited by aquicludes from above and below. This is explained by the fact that groundwater deposits with non-pressure and pressure regimes differ in the boundary conditions of the surface of horizons (layers). The difference lies in the fact that with the beginning of the operation of the water intake in non-pressure conditions, the reservoir thickness decreases, while during operation under pressure conditions, the reservoir thickness remains constant for a long time (John Tracy, 2019:19).

The source of reliable geological information is columns of a structurally solid core containing information about the properties of rocks that make up aquifers - fracturing, porosity, moisture capacity, water permeability, water loss, strength, brittleness and abrasiveness (Edigenov, 2017:10), (Eliseev, 2022:9).

This information is the starting material for the development of technical means for constructing a closed system for opening aquifers, preserving the natural porosity and permeability of rocks.

In addition, the aquifer must be in a stable state by the well being drilled, especially by intermediate wellbores. When drilling wells for water, to fix their walls in unstable rocks, solutions of bentonite clays are used, which leads to clogging of the pores and cracks of the reservoir, reduces water yield by 10-20 times, since the clay particles trapped in the pores and cracks of the formation swell and pinch, creating a waterproof screen.

The most common are polymeric aqueous solutions that have an inhibitory ability, which is important when drilling unstable clayey rocks. Being adsorbed on clay particles, the polymer prevents their hydration and transition into solution.

In this form, polymer solutions are effective in drilling wells in host rocks, but are not acceptable in aquifers due to the possibility of contamination with toxic elements.

The best polymer base for drilling fluids are natural celluloses and starches, which exhibit high performance properties, are easily degraded at the same time and thus retain the natural permeability of reservoirs and do not pollute the environment.

Researchers in China have studied the chemical effects of oil-based drilling fluid on shale through laboratory experiments. They found that compared with water-based drilling fluid, oil-based drilling fluid has such advantages as good inhibition, high ability to resist pollution, reusability (Dewei, 2021).

The problems of improving the removal of drilled rock cuttings from the bottom and strengthening the walls of wells in the process of deepening can be solved by creating turbulence in the flow of drilling fluid (Khuzina, 2019:1). For this, rotating turbulizers with polar ledges on the outer surface are developed, which form cavities with the borehole expanding in the direction of rotation of the turbulizer. When drilling wells, due to the shape of the outer surface, the diagram of the distribution of velocities and pressures of the rotational-upward flow in the cavity, the turbulator under pressure drives the cuttings into cracks and pores, strengthening the well wall.

The turbulizer, tested in practice, can be used when drilling wells with continuous bottomholes in empty host rocks up to the roof of aquifers. At the same time, drilling of intermediate boreholes must be carried out with core sampling, where the tasks are solved - obtaining representative core samples for studying the aquifer, and the formation of a minimum amount of sludge.

The tasks, as well as ensuring the safety of a given route and the stability of the walls of intermediate wells, can be solved using the method of drilling without rotating the drill string, and a core set with thin-walled rock cutting tools, aimed at obtaining a core column of increased diameter, more resistant to destruction and erosion.

The creation of conditions for the manifestation of the internal resources of aquifers should be understood as the formation of a pressure directed laminar flow in intermediate wells, water withdrawal through the physical effect of ejection (Giorgio, 2019:6).

A significant way to improve the reservoir properties of aquifers is the construction of filterless wells.

The efficiency of filterless hydrogeological wells is as follows:

- increase in specific debits;
- possibility of water intake from fine-grained and clayey sands;
- reduction in the number of exploration wells;
- lack of colmatation;
- increase in the service life of the well by 5-10 times compared to wells with a filter column;
- ease of restoration of the water intake part of the well by pumping;
- reduction of the production cost of extracted water.

From the design features of filterless wells, it follows that they can only be built in pressure aquifers.

A feature of a closed system for opening and developing groundwater deposits is that the pumping of the working water flow into intermediate shafts is carried out by a flush pump from the earth's surface, thereby creating a pressure flow, which makes it possible to construct filterless intermediate shafts in free-flowing aquifers.

When constructing a closed system, the following sequence of work is observed. Drilling of a descending and then an ascending well, taking into account the direction of water movement, is carried out using a universal drill head with a stepped matrix, designed for drilling with a solid bottom and with coring. In the case of the latter, a serial HQ core set with a diamond core diameter of 95.6 mm is integrated into the drill head (Figure 1). According to the results of the study of core samples taken from the descending and ascending wells, the intervals of the location of the aquifer and water-resistant horizons, the physical and mechanical properties of the rocks that make up the geological section are determined. According to them, the intervals for landing the filter column, the place of kickoff and the routes for the passage of filter-free intermediate wells along the strike of aquifers, connecting descending and ascending wells are established.

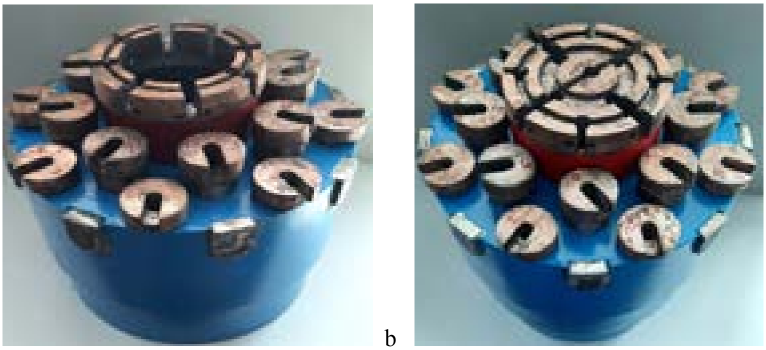
For the purpose of high-quality performance of work, the intervals of deposits of aquifers and water-resistant horizons are additionally refined using borehole telemetry SSV-01 with an accuracy of 10 mm.

Figure 2 shows the layout of the intermediate wellbore kickoff. Preliminarily, on the walls of the filter column of pipes 1 along its generatrix at the calculated distances, windows tapering to the periphery are cut, where the reciprocal-shaped liners are hermetically fixed from an easily destructible material, for example, from a polymer with a recess on the side of the axial line of the filter column 1. Then the filter column of pipes 1 lowered into a downhole, placing liners in the area closer to the bottom of the aquifers.

After that, inside the filter column 1, a deflector 3 with a guide cavity is placed and held on weight at the level of the liner 2, a core set 4 with a rock cutting tool 5 is introduced into it on the pipe string. Further, by jointly turning the deflector 3 and the rock cutting tool 5, the latter rest against the recess of the liner 2, the deflector 3 is fixed in a fixed position, the liner 2 is pierced by rotation and flushing fluid and the intermediate shaft is drilled along the aquifer. Kick-off of filterless intermediate shafts and their driving along the strike of aquifers is carried out from the bottom - upwards, where the diverter additionally performs the function of a packer, excluding the possibility of communication between aquifers, the formation of excess pressure in the downstream intermediate shaft, which, by expansion, protects the walls of the shaft from collapse.

After driving an ascending well at a calculated distance, and casing it with a filter column oriented to the direction of water movement, the intermediate wells are drilled from the descending well to the stop in the ascending well. Figure 3 shows a diagram of the construction and equipment of a closed system in relation to the Tolagay field (Aktobe region), where 1 is aquifers, 2 is an aquifer.

The principle of action. When the valve 6 is opened and the pump 4 is turned on, the working water from the tank 3 through the pipeline through the flow meter 5 enters the internal cavity of the filter column 7, where the flow is divided, partly through the intermediate shaft 9 along the upper aquifer 1, the other part through the intermediate shaft 10 the lower aquifer separated by water-resistant horizons 2, entraining by means of ejection of the mass of water from them enters the ascending well 11, where they merge with an increase in speed and pressure. Rising along the ascending pipe 12, the total flow flows into the tank 3 through the flow meter 13. The difference in water consumption according to the readings of the flow meters 5 and 13, through the pipe 14 is sent to consumers.



a b

Figure 1. Universal drill head: a - with core sampling; b - with solid bottom hole drilling

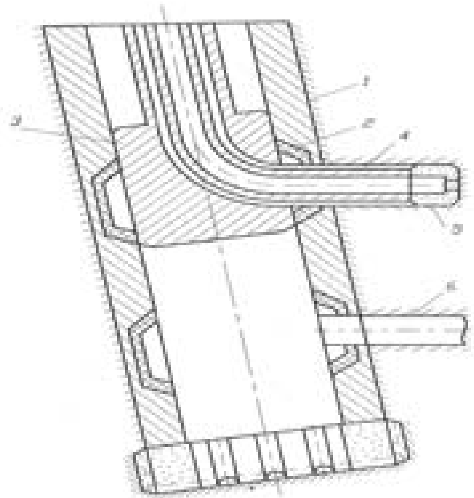


Figure 2. Layout of kickoff of intermediate wellbore

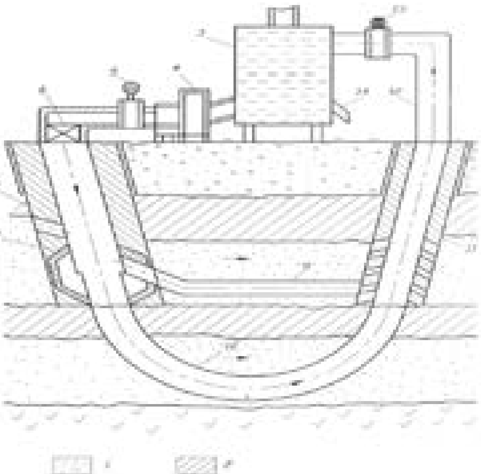


Figure 3. Scheme of a closed system for the opening and development of groundwater deposits

Thus, the volumes of water loss from aquifers and the efficiency indicator of a closed system are determined.

The success of the construction of a closed system for the opening and development of groundwater deposits is due to the design features and technological capabilities of the well drilling technology used. For drilling filterless intermediate boreholes with coring without rotation of the drill string, a core set was developed equipped with a power drive in the form of a multi-chamber downhole hydraulic machine, including a rotor 1, on which a stator 2 is installed with the possibility of rotation. On the rotor 1, inclined holes 3 and 4 are made, oriented to the bottom working chambers, respectively, 5 and 6 of the stator 2, in the direction of rotation of the stator.

The stator 2 is connected through the expander 7 to the body of the diamond crown 8 with a thin-walled matrix 9, longitudinal holes 10. In this case, the stator 2 has peripheral holes 11 linearly directed to the holes 10. The rotor 1 is connected to the drill string (not shown) from above, to the core pipe 12 with the core extractor 13 from below, and is centered by the bearing assembly 14 in the stator 2 (Fig. 4). Table 1 below shows the comparative technical and energy characteristics of serial downhole hydraulic motors and a multi-chamber downhole hydraulic machine.

In such a combination of the constituent elements of the core set, by the implementation of the effect of hydrodynamic destruction of rocks by a directed flow of working fluid, the formed core and the walls of intermediate shafts are reliably isolated from erosion and destruction (Patent, 2018), (Mendebaev, 2019 a:3), (Mendebaev, 2019 b:7), (Mendebaev, 2021 d:5).

Table 1

Reference characteristics of serial downhole hydraulic motors and the results of laboratory studies of a multi-chamber downhole hydraulic machine

Type of machine	Technical				Energy		
	Stator diameter, mm	Changeable bits diameters	Length, mm	Wei-ght, kg	Working fluid flow, l/min	Moment of force, N•m	Power, MPa
1. Multi-chamber rotary type downhole hydraulic machine with experiment	196	215,9-374,0	560	48	200-300	3500-4300	3,5-4,5
2. Screw downhole motors : DRU195S	195	215,9-269,9	6250-8750	1021-1403	1500	4450-8400	3,0-7,0
3.Turbo-drills TS5B	195	215,9-250,0	14035	2425	1500-1680	1000-1300	5,0
TS5B	240	285,8-660,4	15030	3730	2280-2400	2300-2600	5,0
Type of machine	Technical				Energy		
	Stator diameter, mm	Changeable bits diameters	Length, mm	Weight, kg	Working fluid flow, l/min	Moment of force, N•m	Power, MPa
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TS5B	240	285,8-660,4	15030	3730	2280-2400	2300-2600	5,0

Results and discussion. The development of a prototype core set equipped with a multi-chamber downhole hydraulic machine with a stator diameter of 196 mm, an impregnated diamond crown with a diameter of 215.6 mm was carried out in fractured sandstones, gravel stones and jasper-like rocks. Category of rocks according to drilling capacity is 9-10. Well inclination angles 750C. Drilling intervals - 150-300 meters.

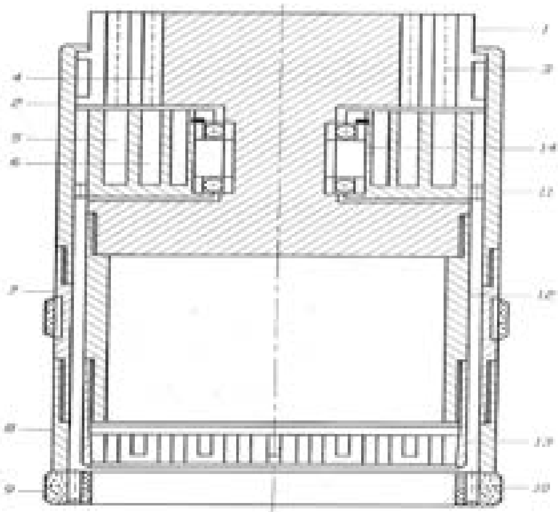

Figure 4. Core set for drilling wells

The basis of comparison is the performance of drilling wells with a rotating drill string with a serial core barrel HQ in comparable geological and technical conditions. Comparative results are listed in Table 2.

Table 2

The results of testing a prototype core set

Core retrieving barrel	Drilling diameter, mm	Drilled, m	Core diameter, mm	Specific lump size of the core, pcs/LM	Mechanical speed, m/h	Energy costs kW/h	Drilling modes		
							Water flow, l/min	Axial load, given	Rotation frequency, rpm
1.HQ	95,6	80	63	5-7	2,8-3,4	1,6-2,2	40-60	80-1000	400-500
2. Prototype of core retrieving barrel	215,9	53	172	2-3	3,0-3,7	0,7-0,9	210-230	1200-1400	200-250

Thus, it provides a solution to the main problem of constructing a closed system of wells, namely: in relation to the standard size of drilling hydrogeological wells, obtaining a solid core column of increased diameter, reducing energy costs and roughness of the well walls. Video recordings of borehole telemetry SSV-01 have established that when the outer surface of the diamond bit matrix is saturated with small diamonds, the borehole walls are polished to a smooth state, excluding possible zones of delay and turbulence of the flow, creating conditions for a laminar mode of water movement, less energy-consuming than turbulent.

Another advantage of using a thin-walled matrix diamond bit is the small amount of cuttings carried by the upward flow along the smooth surfaces of the well walls without delay and the possibility of getting into pores and cracks, which makes it possible to preserve the reservoir properties of aquifers. Practice has confirmed that a core of increased diameter with a lower specific lumpiness is more resistant to destruction and erosion, is a highly informative geological material for studying the state of the mountain environment, and for making informed decisions on the construction of a closed system for opening and developing groundwater deposits.

The arrangement of kickoff of intermediate wellbores is used when drilling multilateral wells, often when eliminating accidents in hydrogeological wells, and is reliable in operation. From the scope of the work, it follows that the main conditions for the success of the construction of a closed system, the presence of a connection between geological and technical prerequisites, the choice of method and means of drilling wells and shafts with minimal impact on the mountain environment, conducting intermediate shafts in the contour of aquifers, ensuring a laminar regime of water movement in them.

When laying downward and ascending wells inclined in the opposite direction, the elements of occurrence of aquifers and the direction of water movement in them are taken into account. According to preliminary calculations based on the operation of hydrogeological wells, a closed system in terms of volume of water loss can replace 4-5 vertical wells drilled using traditional technology. The introduction of a closed system for the opening and development of groundwater deposits in the field of hydrogeology can make a significant contribution to solving the problems of subsoil conservation and water security, and provide an economic effect due to:

- savings in drilling footage and tubular products, energy and labor costs while reducing the labor intensity of work;
- reduction of technogenic loads on the soil, reduction of ground infrastructure;
- reduction of terms of development of groundwater deposits, reduction of production costs during the operation of wells.

Conclusion.

Initial geological prerequisites for the construction of a closed system for opening and developing groundwater deposits - capacitive properties of rocks, intervals for the location of aquifers and water-resistant horizons, occurrence elements and direction of water movement, conditions of the mountain environment, design parameters: filtration coefficient, water conductivity, power. On the basis of geological, technical prerequisites were determined - methods, means of opening and development of aquifers, which ensure the preservation of the stability of the walls of aquifers, natural porosity and reservoir properties.

Structurally, the closed system consists of a descending and ascending well, inclined in the opposite direction and connected by multi-level intermediate shafts, drawn along the strike of aquifers. The descending and ascending wells to the roof of the upper water-resistant horizon are cased with a conductor, then the wells will be passed under the filter column with a reference to the intersected aquifers to the roof of the lower water-resistant horizon.Along the strike of aquifers, there are filterless intermediate wells connecting downstream and upstream wells. Ground infrastructure of the system is tank, pump, pipeline, flow meters, valve, riser pipe.

A layout design was developed for kickoff intermediate wells extending from a descending well, a core set containing a diamond bit with a thin-walled matrix and a hydrodynamic effect of rock destruction, an outer pipe, a core receiver and a multi-chamber downhole hydraulic machine, the rotating stator of which is attached to the outer pipe, the rotor to the core receiver.

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