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**M. T. Biletskiy[1],**
orcid.org/0000-0002-4947-5686,
**B. T. Ratov*[1],**
orcid.org/0000-0003-4707-3322,
**V. L. Khomenko[2],**
orcid.org/0000-0002-3607-5106,
**A. R. Borash[3],**
orcid.org/0000-0001-6417-4841,
**S. K. Muratova[4],**
orcid.org/0000-0002-3507-3096

1 – Satbayev University, Almaty, the Republic of Kazakhstan
2 – Dnipro University of Technology, Dnipro, Ukraine
3 – Yessenov University, Aktau, the Republic of Kazakhstan
4 – Caspian University, Almaty, the Republic of Kazakhstan
* Corresponding author e-mail: b.ratov@satbayev.university

# THE CHOICE OF OPTIMAL METHODS FOR THE DEVELOPMENT OF WATER WELLS IN THE CONDITIONS OF THE TONIREKSHIN FIELD (KAZAKHSTAN)

**Purpose.** Scientific substantiation of the application of technology for the development of water wells in the conditions of the Tonirekshin field of the Mangystau Peninsula.

**Methodology.** The tasks were solved by a complex research method, which includes a review and generalization of literary and patent sources, analytical studies on existing methods for the development of water wells and their interpretation in relation to the geological and technical conditions of the Tonirekshin groundwater field.

**Findings.** The main exploitable aquifers that are part of the Tonirekshin groundwater field are considered and a critical analysis of information on the geological and hydrogeological features of the basin is made. The requirements for the process of development of water wells for the field conditions are formulated. Well-known advanced well development methods are analyzed. Their advantages, disadvantages and compliance with the requirements are revealed. The implosion method was chosen as the best method for the development of water wells in the conditions of the Tonirekshin field.

**Originality.** For the first time, for the geological and technical conditions of the Tonirekshin groundwater field, using the method of expert assessments, the choice of the optimal method for the development of water wells has been scientifically substantiated, which ensures decolmatation of the near-wellbore zone and the maximum flow rate of high-quality water for domestic and drinking water supply.

**Practical value.** For the specific geological and technical conditions of the Tonirekshin groundwater field, the most suitable method for the development of water wells was chosen – the implosion method. The application of this method will provide a significant increase in well flow rate and a solution to the problem of oasis irrigation of lands in the Beineu district of the Mangystau region (Kazakhstan).

**Keywords:** *Mangystau peninsula, Tonirekshin field, decolmatization methods, implosion method*

**Introduction.** Several groundwater horizons have been explored on the Mangystau Peninsula, which have so far been used only to a small extent. The lack of water resources is one of the most important problems hindering the industrial and agricultural development of any region [1]. This problem is very acute in relation to the Tonirekshin field [2], where a decision was made to create an oasis production of agricultural products, requiring the maximum possible flow of groundwater. In the northern part of the Alb-Cenomanian horizon, a small area was discovered – the Tonirekshin field – with a powerful complex of self-flowing slightly brackish and fresh waters. A preliminary exploration was carried out, which allowed concluding that it was possible to organize an irrigated area with a high need for groundwater. However, well production drilled in a small area of about 3 × 3 km, turned out to be very different. Since the geological and hydrogeological conditions for drilling different wells were almost the same, a hypothesis arose about the possibility of maximizing the productivity of all water intake wells by improving well development technology.

**Literature review.** The problem of well development is of great interest among specialists. This is explained by the importance of the issue and high economic efficiency if positive results are achieved.

For the high-quality development of wells equipped with gravel filters, the correct design of the size of the gravel packing and the quality of the gravel material is of great importance. New concepts for tapping the aquifer and designing the size of the gravel pack are presented in [3]. This study comparatively analyzed the grain size, bar graph, and circle methods used in applying different formulas to determine gravel filter slot size based on grain size data and evaluate how well this method predicts slot size and gravel packing. It is concluded that the circular method is well suited for estimating the gap size, effective size and uniformity coefficient compared to the grain size analysis curve. Based on the grain size analysis and results, the following conclusions can be included. For the studied sample showed a wide range of aquifer material types, the best overall estimation of aquifer parameter and well design are reached based on circle method. Circle diagram is very sensitive to shape of the grading aquifer materials. Circle method is very suitable for the estimation of the slot size, effective size and uniformity coefficient in this study in comparison to the curve of grain size analysis.

The assessment of hydraulic conductivity based on the specific power of aquifers was carried out in [4]. Transmissivity estimates can be obtained by different approaches, mainly analytical and empirical. The application of analytical methods requires checking non-linear well losses due to turbulence and vertical flow related to partial penetration. The empirical approach relates transmissivity values to specific capacity data measured in the same well. In this work, a new relationship to estimate transmissivity by specific capacity data in some Italian carbonate aquifers is proposed.

An assessment of well development using the method of air pulsation in bedrock aquifers is given in [5]. Drawdowns were reduced in the test wells, and, accordingly, the average specific discharges and transmissivities were increased. Additionally, in this process, the changes in groundwater quality were investigated, as well as the substances that caused the degradation of the well performance in bedrock aquifers. According to the results of the groundwater quality analysis conducted during the surging process and the step drawdown tests, there was no significant groundwater quality change before and after surging, but it appeared that there was an inflow of contaminants from the upper shallow strata close to the surface.

The authors of [6] proposed a method for dispersing and removing clogging deposits. To do this, a vibration effect of a powerful filtration flow of alternating direction is created in the filter cavity. This leads to multiple controlled explosions of the gas-air mixture, which allows this method to be used in a wide range of hydrogeological conditions, as well as in wells equipped with various types of filters.

Based on analytical studies, a mathematical model of elastic hydrodynamic oscillations in the aquifer has been constructed, which makes it possible to determine the magnitude of stresses at any point in the treatment of the near-filter zone of the well and, accordingly, to establish the required degree of destruction of the bridging agent. Based on the results of an experimental study on the explosion of a gas-air mixture in a piston-projectile in a wellbore, it was established that the power of the explosion determines the frequency of movement of the piston-projectile, which affects the vibration characteristics of the "filter-filter zone-aquifer" system.

Sets of cavitation generators in combination with conventional conical hydrodynamic nozzles were developed in [7]. This combination reduces the pressure in the system and makes the cleaning unit much lighter and more mobile.

A multi-level design procedure has been developed for cleaning water wells. First, the nozzle geometry was designed and CFD simulations were performed to study the development of cavitation in the flow. Test nozzles were manufactured and the erosion characteristics were experimentally verified at various ambient pressures. It was shown that cavitation nozzles could effectively produce erosion at water depths of up to 300 m. Several sets of nozzle holders were then developed for cleaning water wells.

The developed nozzles and nozzle holders were successfully used for cleaning water intake wells and showed excellent results in increasing well flow rates from 34 to 121 % of the measured flow rates before cleaning. The proposed technology makes it possible to rehabilitate water wells in 2–3 days without the use of heavy drilling equipment. The cost of rehabilitation is only 20–40 % of the cost of drilling a new well.

The theoretical foundations for controlling the cavitation-pulsating effect on rocks based on the spectrum theory are carried out in [8]. The energy distribution of the cavitation-pulsating action on the rock mass has been determined. Experimental studies on the operation of a hydrodynamic pulsator were carried out and a calculation method for optimizing the cavitation-pulsating effect on rocks was developed.

A new method for assessing well recovery at the initial stage of pumping tests was proposed in [9]. This study analyzes the unsteady flow of groundwater to a real well (with wellbore storage and skin effect), which completely penetrates into a confined aquifer. The well is located in an infinite system, so the influence of boundaries is not taken into account. The Laplace domain solution to the partial differential equation is used to describe the unsteady radial flow to the well. A new method for estimating the skin factor at the initial stage of pump testing is presented. This method can be used to estimate the skin factor when the well-known semi-logarithmic Cooper-Jacob method cannot be used due to that the second straight line is not reached on a semi-logarithmic graph of drawdown versus logarithmic time. A field example is presented to evaluate the restoration of a well in Veseli nad Lužnice using a new correlation.

The basic principles of restoring the productivity of wells plugged during their drilling and operation using acid treatments were studied in [10]. It is shown that many wells that, as a result of drilling, well workover after long-term operation, do not produce production due to complete or partial clogging. The disadvantage of acid solutions based on hydrochloric acid is the high reaction speed and the difficulty of getting the acid into the reservoir through the colmatation film.

The authors believe that it is necessary to model and study the mechanisms of decolmatation, develop an effective composition for the restoration of deep wells, enlarge the channels, and also reduce the corrosive effect. Many acidic components and cleaning materials are known, but for specific conditions of depth and rock composition, it is necessary to develop an individual formulation of process fluids and technologies for treating ROM and restoring well productivity.

Technology for well development using ultrasonic research method is considered in [11]. The authors believe that compared to other common remediation methods, the ultrasonic method is particularly effective in reducing hard mineral deposits. Its main effect extends beyond the well casing into the gravel area. After using the ultrasonic method (as well as other mechanical methods), the well can be immediately put into operation. However, the ultrasonic method cannot be used on its own, but only in combination with the pump (or airlift) method, which is used here to remove the material released by the ultrasonic effect itself.

A mechatronic system for implosion action on the bottomhole formation zone was proposed in [12]. The proposed generator makes it possible to provide multiple implosion effects on the bottomhole zone of the formation. The necessity of using an automatic generator control system is substantiated. The dependence of the pressure in the front wave of the hydraulic shock on the diameter of the implosion chamber of the generator is determined analytically – a hyperbolic dependence, and the pressure in the front wave of the hydraulic shock on the immersion depth of the generator – a directly proportional dependence.

The developed control algorithm allows you to automate the oil well treatment process and optimize the treatment time and its intensity depending on the mining and geological conditions of the productive formation.

**Unsolved aspects of the problem.** As can be seen from the above analysis of recent studies and publications, the issue of well development is an important and relevant area in modern science. The choice of method and technical means for well development is an important and complex scientific and practical task. To achieve maximum technical and economic indicators, this problem must be solved for the specific geological and technical conditions of a particular field.

Thus, the **purpose of the article** is to scientifically substantiate the use of technology for the development of water wells in the conditions of the Tonirekshin field on the Mangystau Peninsula.

Objectives of the work are:

1. Assessment of geological and hydrogeological conditions of the Tonirekshin field.
2. Critical analysis of the exploration work carried out.
3. Analysis of known well development methods.
4. Choosing the optimal method of development.

**Methodology.** The assigned tasks were solved by a comprehensive research method, which includes a review and synthesis of literary and patent sources, conducting analytical studies of existing methods for developing water intake wells and their interpretation in relation to the geological and technical conditions of the Tonirekshin field.

**Results.** ***Assessment of geological and hydrogeological conditions.*** The Tonirekshin groundwater field is located in the Beineu district of the Mangystau region and has an area of about 10 km$^2$. Its waters belong to the Alb-Cenomanian deposits complex. They are located in layers of different-grained sands interbedded with clay layers [13]. From above, the aquifer complex is limited by marl-chalk strata. Below, the role of waterproof material is played by clays. In the direction to the southeast, the layers go down, the depth of the roof reaches 470 m, and the static pressure reaches 400 m. The piezometric water level is located above the daytime surface. In the northern part of the site, water has low mineralization from 2 to 4 g/l, which increases to 6.3–8.6 g/l in the southern direction.

Geological and hydrogeological conditions of the work area are given in Table 1.

***Critical analysis of the exploration work carried out.*** For the first time, work on drilling water wells on the territory of the Tonirekshin field was carried out in 1979–1980.

The Guryev hydrogeological party received an order from the Mangyshlak branch of the Kazgiprovodkhoz Institute to conduct preliminary exploration of groundwater at the Tonirekshin field for oasis irrigation of lands in the Beineu district of the Mangystau region.

The customer put forward the following requirements:

1. Total water demand – 1,000 l/s.
2. Irrigation area – 1,000 ha.
3. Mineralization – no more than 5 g/l.
4. Continuous groundwater intake regime – 6 months.
5. The flow rate of individual wells is not lower than 5 l/s.
6. Service life – 4,500 days.
7. Lowering the water level from the surface – no more than 100 m.

The purpose of the drilling work was to delineate the area of distribution of brackish waters with a salinity of up to 5 g/l. Drilling was carried out applying URB-3AM and 1BA15V units using clay drilling fluid and core sampling. 9 wells were drilled with a total footage of 4,830 m. The greatest depth of the wells was 600 m. To a depth of 200–300 m, bits with a diameter of 132 mm with a core pipe with a diameter of 127 mm were used. After that, the well was expanded to 243 mm and a casing string with a diameter of 168 mm was lowered. After cementing this column to the design depth, drilling continued with a diameter of 132 mm and a filter column with a diameter of 127 mm was lowered. The filter was a 127 mm perforated pipe with a wire wrap and a mesh covering. The length of the filter was equal to the thickness of the formation. The wells were developed with an airlift using a DK-9 compressor.

Changes in flow rate and a number of other parameters were measured for 5 wells within 1.5 years after the completion of drilling. For three wells, the flow rate increased: from 30 to 45 l/s, from 25 to 36 l/s and from 2.5 to 6 l/s. For one well, the flow rate did not change, for another one it dropped from 30 to 6 l/s.

The designs of water intake wells and hydrogeological results of exploration work are presented in Table 2.

Analysis of the results given in Table 2 shows significant differences in flow rate, specific flow rate and static groundwater level for wells drilled in a small area of 10 km$^2$. At the same time, aquifers everywhere are represented mainly by fine-grained sands with an admixture of fine- and medium-grained sands. The depth of their roof, as well as the base, varies within 4 % of the average value. Considering that the geological and technical conditions for all wells are similar, such a wide variation in well flow rates is due to ineffective well development technologies.

*Table 1*

Geological and hydrogeological structure of the Tonirekshin groundwater field

| Parameter | Unit | Meaning | | |
|---|---|---|---|---|
| | | from | before | average |
| Aquifer sands, fine-grained | % | 27 | 39 | 33 |
| The same fine-grained | % | 40 | 80 | 60 |
| Same medium grain | % | 10 | 15 | 13 |
| Filtration coefficient | m/day | 2.1 | 7.8 | 4.2 |
| Depth of the top of the aquifer | m | 412 | 447 | 430 |
| Sole depth | m | 453 | 495 | 474 |
| Aquifer thickness | m | 23 | 65 | 40 |
| Capacity of aquicludes | m | 2 | 40 | 21 |

*Table 2*

Exploration results

| Parameter | Unit | Meaning | | |
|---|---|---|---|---|
| | | from | before | average |
| Production string depth | m | 200 | 300 | 450 |
| Its outer/inner diameters | mm | – | – | 168/154 |
| The well diameter | mm | – | – | 243* |
| Filter column depth | m | 380 | 600 | 490 |
| Filter column diameters (external/internal) | mm | – | – | 127/117 |
| The diameter of the hole for it (diameter of the crown) | mm | – | – | 132 |
| Core pipe diameter | mm | – | – | 108/98 |
| Well production | l/s | 5 | 45 | 27 |
| Specific flow rate | l/s/m | 0.3 | 1 | 0.65 |
| Static water level | m | 5 | 48 | 27 |
| Mineralization | g/l | 2 | 4 | 3 |

* *After enlarging a well drilled with a diameter of 132 mm*

There are three options for the behavior of observation wells:

1. At one of the five wells, during well development, a high flow rate was obtained, which remained constant throughout the entire period of regime observations.
2. For three wells during the same time, an increase in flow rate was noted.
3. At one well, the initially high production rate dropped catastrophically within a year and a half.

In our opinion, the main reason for such different results in changes in well flow rates was the behavior of the largest sand granules contained in aquifers, which acted as proppant. In the first case, during development, all the bridging agent, as well as fine and fine-grained sand, was washed away and the enlarged channels that remained after this were supported by large granules, which did not allow these channels to close. In the second option, the content of large granules was less than in the first, and the content of fine and fine-grained sand, as well as bridging agent, turned out to be higher. The filtration rates achieved during development turned out to be insufficient to create stable inflow channels of the final size. The water inflow channels continued to expand with a corresponding increase in flow rate. The well continued to produce water containing sand and clogging agent, requiring additional treatment. There is a risk that after a certain time, the ever-increasing dimensions of the channels will exceed the permissible value and, under the influence of rock pressure, they will close with a sharp drop in flow rate. The third option represents a possible final outcome of the second option. The reason for the sharp drop in flow rate could also be a scuffed mesh. A mesh-wire filter about 40 m long with a frame of 127 mm (the total diameter of which could not be less than 132 mm) was lowered into a well, which was drilled with a bit with a diameter of 132 mm. When the mesh was scuffed, the formation material freely passing into the filter column, after a certain time, depending on the length of the settling tank and filter pipe, could almost completely block the flow of water into the well.

Obviously, the first of the three options is optimal, when already during development the well flow rate was brought to the maximum possible value.

After achieving the maximum possible flow rates, it is necessary to determine the maximum permissible filtration rate using the known filtration coefficient, and calculate whether the actual filtration rate exceeds the permissible value.

If the answer to this question is positive, a fountain fitting [14] should be installed at the well outlet and adjusted so that the resulting reduced flow rate corresponds to the permissible filtration rate. This will ensure stable operation of the well for a long time. A similar device is widely used when drilling for oil and gas in order to extend the flowing stage of wells.

***Requirements for the development of water wells in the conditions of the Tonirekshin field.*** Based on the analysis of the geological and technical conditions of the field and previously carried out exploration work, we formulated requirements for the process of developing water intake wells:

1. Higher depressions than previously used.
2. Dynamic nature of the impact (high acceleration).
3. Possibility of repeated exposure in one descent.
4. Compliance with available depths.
5. No risk of spontaneous negative impact on the formation.
6. Possibility of use by the drilling crew.
7. Low costs for equipment and work with it.

The use of a well development method that meets the listed requirements will ensure a significantly more complete removal of bridging agent and fine-grained sand from the formation. The channels formed at the site of the removed material will have increased openings, length and number, as well as increased stability due to the influx of the largest sand granules being pulled up. As a result, the total flow rate of the wells available on the site will increase sharply.

***Analysis of known advanced well development methods in relation to the conditions of the Tonirekshin field.*** The drilling of water wells at the Tonirekshin site was carried out applying a rotary method using drilling fluids, because Due to the significant (up to 600 m) depth of the wells, the use of other drilling methods, such as percussion-rope, is difficult. Drilling fluids dramatically increase the stability of wells in loose (as in the area under consideration) rocks. Typically, drilling fluid is created by mixing clay in water. By dissolving to tenths of a millimeter, clay particles impart colloidal properties. When moving, the drilling fluid is a liquid, but at rest it turns into a gelatinous solid – a gel.

The most important requirement for the drilling fluid is described by the formula [15]

$$\rho_M g H_A = \alpha \rho_W g H_S, \quad (1)$$

where $\rho_M$ and $\rho_W$ are density of drilling fluid and formation water, kg/m$^3$; $H_A$ and $H_S$ are depth of the roof of the formation and its static head, m; $g$ is acceleration of gravity, m/s$^2$; $\alpha$ is safety factor.

In formula (1) on the left there is the hydrostatic pressure of the drilling fluid at the level of the reservoir roof, on the right – the reservoir pressure. When $\alpha < 1$, a depression is created in the reservoir. Water from it flows into the well. When drilling in unstable rocks, the walls of the well may collapse. When $\alpha > 1$, repression occurs. The drilling fluid enters the formation. Particles of the solid phase of the drilling fluid clog the pores of the rock – the process of clogging occurs. Since option $\alpha < 1$ threatens accidents, the minimum acceptable value is set, for example, $\alpha_{min} = 1.1$.

***Flushing a well using a hydraulic brush*** always performed after completion of drilling and lowering of the filter. Water displaces drilling fluid from the well. Since its density is lower than that of the drilling fluid, repression in the productive zone decreases, and since the viscosity of water is much lower than the viscosity of the drilling fluid, the mud cake formed on the well wall is washed away and the filter holes are cleaned. This effect increases with the speed of the jet, so it is advisable to install nozzles (hydraulic brush) at the bottom of the water supply drill string.

In general, flushing, including flushing using a hydraulic brush, affects mainly the filter cake and does not have a significant impact on deeper clogging zones.

Using this method, it is not possible to create higher depressions than previously used. There is also no dynamic nature of the impact (high acceleration).

***Airlift pumping*** usually follows a washing step. Water drops from a static level characteristic of a given formation to a certain dynamic level. A decrease in $S$ characterizes the depression in the reservoir, which is equal to

$$P_D = \rho_W g S. \quad (2)$$

The greater the pumping capacity, the greater the reduction. The advantage of an airlift is that there are no moving parts subject to wear by solid particles carried out of the well. Typically, concentrically located water-lifting and air pipes are lowered into a cased well. The latter are connected to the compressor, and have a mixer at the bottom. Above the mixer, a mixture of air and water rises through water-lifting pipes. At the mouth, the air evaporates and water is supplied to the storage tank. The mixture is lifted due to the difference in hydrostatic pressure between the water in the space behind the water-lifting pipes and the mixture of water and air in the water-lifting pipes. The depression on the formation $P_D$ is calculated using formula (2), and the depression $S$ is determined by a level gauge lowered into the space between the production and water-lifting strings

During pumping, decolmatation affects not only the filter cake (as during flushing), but also the near-well zone of the formation blocked by the drilling fluid gel.

This method also makes it possible to create only low depressions and fails to achieve a dynamic nature of the impact on the productive formation. In addition, it requires relatively high operating costs for the equipment used.

***Bailing***, is also a means of pumping. It is usually carried out when there is no compressor available. The bailer is lowered below the water level. When descending, the bailer valve is open due to water resistance, and the bailer is filled with water. As the weight of the water rises, the valve closes and the water is held in the bailer. On the surface, the water is removed and then scooping out the water is repeated many times. When the bailer is removed from the water, its level decreases by the following amount

$$S = h\frac{f}{F},$$

where $h$ is the length of the bailer, m; $f$ and $F$ are the internal cross-sectional areas of the bailer and production string, m$^2$.

The created depression in the time before the repeated descent causes an influx of water from the formation into the well and, depending on the ratio of the filtration coefficient of the rock, with the cycle period and the volume of the bailer, a complete or partial restoration of the level will occur.

After removing the bailer, during its emptying and repeated lowering, the resulting depression will cause an influx of water from the formation into the well and the dynamic level approaching the static level. The magnitude of this approximation depends on the formation filtration coefficient (the rate of water inflow from the formation into the well) on the one hand, and the capacity of the bailer and the speed of its ascent and descent, on the other. During partial return, with each descent of the bailer the dynamic level will increase. This in turn will cause an increase in inflow. After a certain number of descents of the bailer, equilibrium will occur and the bailer process will begin to be characterized by a certain dynamic level. A sign of maximum decolmatation achieved under the given conditions and a signal to stop bailing will be complete lightening of the contents of the bailer.

Like the previous two methods, gelling does not allow creating high depressions and a dynamic nature of the impact on the near-well zone of the formation.

***Swabbing*** has a more intense effect on the formation compared to gelling. A drill pipe with a valve at the end is lowered into the casing on a rope. It looks like a rubber cup-shaped cuff, the bottom of which rests on a steel disk from below. The diameter of the collar and disk is less than the diameter of the casing. When descending, the resistance of the water bends the cuff upward, narrowing it, and thereby ensures unhindered movement. When rising, the resistance of the water bends the cuff down, increasing its diameter until it touches the casing wall, and the steel disk does not allow the cuff to turn out. The swab lifts the entire column of water above it and creates a significant depression. The induced influx depends on the rate of rise and the permeability of the formation. If it is large, then the level of formation water follows the rising cuff in contact with it.

With a rapid rise, intense abrasion of the cuff occurs. In addition, they encounter ledges formed due to the difference in the internal diameters of pipes and couplings. Therefore, it is recommended to carry out swabbing at low speeds and within one casing pipe [16]. In this case, the swabbing effect is significantly reduced.

Since during swabbing the influx of water into the well occurs under the influence of reservoir pressure, then, in conditions where this pressure is absent (free-flowing formations), swabbing cannot be used for well development.

Unlike previous methods, swabbing allows you to create fairly high depressions. However, it cannot have a significant dynamic impact on the productive formation.

In addition to the simplest and most accessible methods for developing hydrogeological wells given, a number of special methods have been developed, the use of which usually significantly increases the efficiency of decolmatation and the increase in flow rate, but at the same time requires the use of special installations and specially trained personnel.

***Explosion of a detonating cord.*** The detonating cord (DC) [17] has a diameter of 6–8 mm. Each meter contains from 13 to 33 g of hexogen. Torpedo (TDC) includes from 1 to 5 cords. The length of the TDC reaches 100 m. There is a detonator in the upper part and a load with centralizers in the lower part. At the moment of explosion, a gas bubble with high pressure is formed in the productive zone of the well. It expands at a speed of about 1,000 m/s, and the pressure drops. By inertia, the bubble continues to expand even when the pressure in it drops below the pressure in the aquifer. Depression is created. Under the pressure of the inflow, the expansion of the bubble turns into compression. The size of the bubble is rapidly decreasing. By inertia, the bubble creates an increasingly higher pressure inside itself, which again exceeds the reservoir pressure and forms a second maximum, which is lower than the first. The bubble begins to expand again and the overall process is a picture of damped oscillations. After completion, the well is cleared of the bridging agent using an airlift. Torpedoes can be used in conditions where the pressure in the well does not exceed 50 MPa. Cases have been recorded where, as a result of the explosion of a DC, the well flow rate increased fivefold [18].

Along with the positive qualities, this method of development has a number of significant disadvantages that essentially reduce the effectiveness of its use. As a result of detonation, great pressure is exerted on the walls of the filter column. The smaller the diameter of the filter column, the greater it is. Thus, to use this method, it is necessary to use large pipes with maximum wall thickness, which significantly narrows the scope of application of detonating cords.

In addition, there is a risk of damage to the filter column from the blast wave. The smaller the distance between the DC and the filter column, the greater the risk of damage to the column. This indicates the importance of installing centralizers. If they are present, the impact of the blast wave may be far from destructive, while in the absence of centralizers the cord will lie on one of the walls of the pipe and the filter will be destroyed.

Widespread mesh coverings practically do not withstand explosive effects.

Another important disadvantage is the reduction in the flow rate of water intake wells treated by this method after a certain period of operation. This is especially true for loose rocks. The fact is that since the compression wave from the explosion of the DC is stronger than the rarefaction wave, this method does not so much remove the bridging material from the pores of the aquifer, but rather creates new channels in it, pressing the bridging material into their walls. Over time, the created channels close under rock pressure and the flow rate drops.

In addition, having analyzed the compliance of the method of well development using the explosion of a detonating cord with the specific requirements put forward for the development process in the conditions of the Tonirekshin field, we will highlight such inconsistencies. With this method it is impossible to repeatedly influence the productive formation in one run. There is a significant risk of spontaneous negative impact on the formation. In addition, the organization must have the right to use explosive materials, and an explosives expert must be on staff.

***Electro-hydraulic vibrations.*** A projectile is lowered into the hole on the cable, at the end of which discharge electrodes are located. They are supplied with current coming from a step-up transformer [19] through a bank of capacitors. When the charge of the capacitors, rising, reaches a critical value (about 50,000 V), a breakdown of the special liquid located between the electrodes and poured into the well occurs. The resulting plasma, due to its enormous temperature, forms a vapor-gas bubble, expanding at a speed of the same order as a gas bubble during the explosive method. A similar process of damped oscillations occurs, with the same advantages and disadvantages. The main advantage over the explosive method is the possibility of automatically occurring repeated breakdowns, when, after a fall, the charge of the capacitors accumulates again and the next discharge occurs [20].

When cleaning the filter from bridging agents, the shock wave during the electro-hydraulic method of development can have a destructive effect on the filter frame and coating.

The electrohydraulic method requires high energy consumption. When transmitting a discharge pulse from the surface to the bottom, about 30 % of its total costs are lost for every 100 m of cable. This sharply limits the depth of use of this method. Devices have been proposed in which pulse generators are located in a downhole submersible tool, but it is difficult to place all the necessary elements in it: a transformer, a capacitor bank, etc. and their isolation under conditions of high hydrostatic pressure have led to the predominant spread of installations with a pulse generator located on the surface.

The method of electro-hydraulic impulses is fundamentally similar to the method of detonating cord explosions. In both methods, the factor directly affecting the aquifer is a gas bubble that performs damped oscillations. The result is also common – the expansion and increase in the number of channels for the supply of water from the formation to the receiving part of the well. Both methods also have a common drawback, which manifests itself especially in loose rocks, when after a certain period of operation the flow rate can decrease due to the closure of the walls of the formed channels under the influence of hydrostatic pressure.

The electro-hydraulic pulse method has a number of advantages over the explosive method.

In contrast to the explosion of a DC, which gives only a single impulse, the electro-hydraulic method makes it possible to give multiple impulses with a given frequency of up to 200 Hz.

The impact factors with this method can be adjusted within a wide range. In particular, the minimum diameter of the receiving part processed with this method can be 50 mm, which is impossible with the explosive method.

At the same time, the explosive method also has its advantages. The length of the receiving part to be processed is practically limited only by the length of the DC threads, which in practice reaches 100 m or more. With the electro-hydraulic method, the length of the downhole tool is about 1–2 m; therefore, if it is necessary to decolmatate a long receiving part (for example, in rocks with low water content), processing of the receiving parts will have to be done in parts, which is associated with various complications and large expenditures of time and energy.

During implosion, a low-pressure area is created in the productive part of the well, which at a given moment instantly connects with the near-well area of the formation, creating high depression and a sharp influx of formation water into the well at a speed of up to 200 m/s. Such a jet tears off the clogging material from the place where it is fixed – from the surface of the filter, from the well wall from deep areas of the near-well zone – and carries it into the well, from where it is subsequently removed by known methods; washing, gelling, airlift. The resulting influx continues until the water level in the low pressure zone rises to the static level of the formation. Therefore, the higher the static pressure, the greater the effectiveness of this method [21].

In foreign countries, the implosion method has found wide application and is implemented by lowering a metal capsule with a glass lid on top into a well [22]. The air is pumped out of the capsule, creating a vacuum in it – a pressure below atmospheric. After the capsule is lowered into the productive zone of the well, the glass cover of the capsule is destroyed by the explosion of the detonator. With this method, the time of implosion action sharply reduces, which is very favorable from the point of view of decolmatation. Following the depression on the formation, a hydraulic blow is also created on it from the fall of a column of water located above the capsule when it fills the space occupied by the capsule. The bubble of air and gas remaining in the capsule is compressed, and later, when the shock action is replaced by hydrostatic pressure,

The main disadvantage of this method is the relatively high cost of equipment and operation.

***Choosing the optimal learning method.*** The results of a comparative analysis of the compliance of development methods with the formulated requirements for the process of development of water wells for the conditions of the Tonirekshin field are given in Table 3.

Analysis of the results given in Table 3 shows that two methods best meet the formulated requirements: swabbing and implosion. We choose the implosion method as the most effective. Like swabbing, it does not meet one of the above requirements – it has an increased cost of equipment. However, its impact on the formation due to the multiple excess speed of depression pulses is much more intense than with swabbing. The effectiveness of this method is especially great in relation to the Tonirekshin field due to very high static heads.

**Conclusions.**

1. The main exploitable aquifers that are part of the Tonirekshin groundwater basin are considered.
2. In order to select the optimal methods for developing water intake wells, a critical analysis of information on the geological and hydrogeological features of the basin was carried out.
3. It is noted that on a relatively small area of this site under similar hydrogeological conditions there is an extremely high variation in the flow rates of drilled wells.
4. Requirements for the process of development of water wells in the conditions of the Tonirekshin field have been formulated.
5. Well-known advanced methods of well development are analyzed in relation to the conditions of the Tonirekshin field. Their advantages, disadvantages and compliance with the requirements are revealed.
6. The implosion method was chosen as the best method for developing water wells in the conditions of the Tonirekshin field. Further research will be aimed at developing implosion well development technology.

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*Table 3*

Comparison of the main well development methods

| No. | Method | Requirements for the development process | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
| 1 | Flushing | 1 | 1 | 1.6 | 1.4 | 1.4 | 1.6 | 1.6 | 8.03* |
| 2 | Airlift pumping | 1 | 1 | 1.4 | 1.4 | 1.4 | 1.4 | 1 | 3.84 |
| 3 | Bailing | 1 | 1 | 1.2 | 1.4 | 1.4 | 1.6 | 1.6 | 6.02 |
| 4 | Swabbing | 1.6 | 1 | 1.2 | 1.4 | 1.4 | 1.6 | 1.6 | 9.63 |
| 5 | TDS explosion | 2 | 2 | 1 | 1.4 | 1 | 1 | 1.2 | 6.72 |
| 6 | Electro-hydraulic impulses | 1.4 | 1.4 | 1.6 | 1 | 1 | 1 | 1 | 3.14 |
| 7 | Implosion effect | 1.8 | 1.8 | 1.6 | 1.4 | 1.4 | 1.4 | 1 | 14.22 |

* *Coefficients were determined by the method of expert assessments in the range from 1 to 2, where 1 is complete non-compliance with the requirements; 2 is maximum compliance with the requirements. The final score was determined as the product of the coefficients*

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## Вибір оптимальних способів освоєння водозабірних свердловин в умовах родовища Тонірекшин (Казахстан)

*М. Т. Білецький*[1], *Б. Т. Ратов*[*1], *В. Л. Хоменко*[2], *А. Р. Бораш*[3], *С. К. Муратова*[4]

1 – НАТ «Казахський національний дослідницький технічний університет імені К. І. Сатпаєва», м. Алмати, Республіка Казахстан
2 – Національний технічний університет «Дніпровська політехніка», м. Дніпро, Україна
3 – Каспійський державний університет технологій та інжинірингу імені Ш. Єсенова, м. Актау, Республіка Казахстан
4 – Каспійський громадський університет, м. Алмати, Республіка Казахстан
[*] Автор-кореспондент e-mail: b.ratov@satbayev.university

**Мета.** Наукове обґрунтування застосування технології освоєння водозабірних свердловин в умовах родовища Тонірекшин півострова Мангістау.

**Методика.** Поставлені завдання вирішувалися комплексним методом дослідження, що включає огляд та узагальнення літературних і патентних джерел, проведення аналітичних досліджень існуючих способів освоєння водозабірних свердловин та їх інтерпретація стосовно геолого-технічних умов Тонірекшинського родовища підземних вод.

**Результати.** Розглянуті основні придатні до експлуатації водоносні горизонти, що входять до складу басейну підземних вод Тонірекшин і проведено критичний аналіз інформації про геолого-гідрогеологічні особливості басейну. Сформульовані вимоги до процесу освоєння водозабірних свердловин для умов родовища. Проаналізовані відомі передові методи освоєння свердловин. Виявлені їх переваги, недоліки й відповідність вимогам, що висуваються. Як найкращий метод освоєння водозабірних свердловин в умовах родовища Тонірекшин обрано імплозійний метод.

**Наукова новизна.** Уперше для геолого-технічних умов Тонірекшинського родовища підземних вод за допомогою методу експертних оцінок науково обґрунтовано вибір оптимального способу освоєння водозабірних свердловин, що забезпечує декольматацію присвердловинної зони й максимальний дебіт якісної води для господарського та питного водопостачання.

**Практична значимість.** Для конкретних геолого-технічних умов родовища підземних вод Тонірекшин обрано найбільш відповідний метод освоєння водозабірних свердловин – метод імплозійного впливу. Застосування цього методу забезпечить значне зростання дебіту свердловин і вирішення проблеми оазисного зрошення земель Бейнеуського району Мангістауської області (Казахстан).

**Ключові слова:** *півострів Мангістау, родовище Тонірекшин, методи декольматації, метод імплозії*

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