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РЕСПУБЛИКИ КАЗАХСТАН

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CALCULATED WATER DEMAND AS THE MAIN FACTOR INFLUENCING THE RELIABILITY OF HYDROGEOLOGICAL FORECASTS AT THE EVALUATION OF GROUNDWATER ELASTIC RESERVES

Abstract. The article covers the problems of low reliability of hydrogeological forecasts concerning the state of groundwater resources due to significant difference between the amount of estimated elastic reserves registered on governmental level with included in prognostic calculations and actual water intake dynamics of its temporal variations. As a result, it leads to overestimation of prognostic levels with actual state.

This problem is most acute within the Almaty urban agglomeration. The choice of this region as a pioneer is obvious for hydrogeologists. Within the limits of the allocated territory as of 2008, the state balance accounts for about 15% of the total value of the drinking water quality of groundwater resources in the Republic of Kazakhstan. The volume of groundwater production within the region is about 45%. This burden on the subsoil is not presented in any other region of the Republic of Kazakhstan.

On the basis of available developments in this issue, given appropriate solutions and ways of changing existing approaches to hydrogeological forecasts in estimating groundwater reserves are proposed to eliminate emerging inconsistencies, i.e. the implementation of forecasting taking into account the real, rather than overestimated in the calculation of the dynamics of water withdrawal.

Keywords: groundwater supply, reliability of hydrodynamic forecasts, actual water intake, management of operation.

The reliability of hydrogeological forecasting has always been of great interest, both for the authors of the forecasts themselves and for users.

With respect to the task of assessing the operational reserves of groundwater, the reliability of forecasts is determined primarily by:

- the possibility of extracting the required amount of water for the entire design life of the water intake facility;
- the correspondence between the magnitude of the predicted and actual depressions or depths of the dynamic levels of groundwater;
- compliance of the quality of the selected water with the forecasted life of the water intake facility.

In this article, the main focus is on the quantitative side of the issue under consideration, stressing that a favourable and reliable forecast is an effective basis for subsoil use management and the basis for resolving the issues of submitting subsoil use rights for the production of groundwater to new subsoil users.

This problem is particularly acute in the areas exploited by many subsoil users: in large cities, urban agglomerations located on the area of artesian basins, intermountain depressions and other areas, where groundwater is exploited in conditions of intensive interaction between existing water intakes. Even more intensive interaction is expected between existing and projected water intakes with a load equal to the approved groundwater reserves [1].

As an example, let us consider the Almaty city agglomeration. The core of the metropolitan area is one of the two cities of republican subordination of Almaty, which population, as of 2016, is 1,716,779 people. The total population of the agglomeration for 2015 amounted to 2 460.4 thousand people.

The question of assessing the correspondence between forecasts and nature is relevant for about half a century.

In the authors' opinion [1], the reliability of the performed predictions depends on two groups of components:

- hydrogeological parameters and boundary conditions adopted in the calculations (hydrogeological models) or calculation schemes;
- design costs of settlement water intakes and their allocation schemes.

The first group of questions always caused the most attention of hydrogeologists. Currently, it is being solved by creating hydro-geological models and selecting parameters and boundary conditions to achieve a match between the model and nature in natural and disturbed conditions. The second group of questions is usually not seriously considered, and the calculations use the specified needs and the designed well pattern developed by the authors [1].

In the mid 60-ies of the XX century, the Ministry of Geology of the USSR, in ARRIHEG it was assigned work on the convergence estimate of exploration data and the operation of existing water intakes. This work was carried out throughout the territory of the USSR, and its results were subsequently summarized in L.S. Yazvin's book "Reliability of hydrogeological forecasts in assessing the operational reserves of groundwater" [2], which became his main doctoral dissertation.

The essence of the convergence estimate of exploration data and the operation of existing water intakes consisted of the following:

- with the parameters obtained during the exploration and calculation of the reserves, and the boundary conditions, the water intake calculation was applied to the actual arrangement of the wells, with their actual capacity;
- the calculated lowering of the level obtained in the calculation was compared with the actual one;
- the analysis of the reasons revealed at comparison of actual and calculated level depressions was carried out.
- analysis of the reasons for the discrepancy between forecasts and operating data and identification of the main sources of the formation of groundwater operational reserves;
- selection of the optimal design scheme was made based on the analysis of operating data for the revaluation of groundwater resources.

As a result of comparison of the calculated and actual depressions of the levels, it turned out that in most cases their calculated values significantly exceed the actual ones.

The authors did not set out to consider all the reasons for these discrepancies, but the main ones are related to the following. Since the piezoconductivity coefficient of the pressure water was close to 106 m^2/day in the case of evacuations during experimental filtration operations, which corresponded essentially to the Thijs scheme (isolated reservoir), the calculations were carried out formally. As a rule, only the geometric outlines of boundaries were taken into account, and such factors as overflow were not considered in. To eliminate this contradiction, the concept of "generalized" parameters was introduced. Most often, the piezoconductivity coefficient value (usually close to 104 m^2/day) was chosen, at which the calculated and actual level reduction at the calculated moment coincided [1].

Thus, we have considered the first part of the question - justification of the initial data for forecasting with the purpose of counting (reassessing) operational reserves. This is the most developed part of forecasting issues. Formally, on the basis of this, the appraisal (reassessment) of the operational reserves is carried out. With sufficiently substantiated input data for forecasting its reliability will correspond to the reliability of the initial data of the calculations, since the methodology itself and the technology of predictive calculations can be considered reasonably justified theoretically, practically and methodically [1, 2].

Why, then, comparing the results of forecast calculations and the actual position of groundwater levels, do we observe significant discrepancies in them?

Analysis of operational experience of a number of deposits of the foothill plume of the Zailiysky Alatau allowed to identify the main reasons for this discrepancy. Let us consider them in more detail:

The first circumstance is connected with the current methodology for calculating the operational reserves of groundwater, placing them on the state balance and then taking into account the stocks that are on state records when calculating new water intakes or revaluing reserves. The existing practice of counting operational reserves developed in the 70-80s of the XX century is reduced to the following:

- a priority need;
- a long-term need;
- the maximum possible water abstraction.

With the regional assessments, the above scheme has been preserved, while also possible water abstraction in perspective areas is also estimated. The calculated reserves of categories A, B, C_1 and C_2 are put on the state balance and are taken into account in subsequent calculations of the interaction of water intakes.

Despite the fact that often water requirements were determined when developing integrated schemes for the use and protection of water resources, and for specific cities and other consumers were calculated by the main design institutes, they were repeatedly overestimated. This has led to a large gap between the claimed water requirements (approved reserves) and actual water abstraction. Accordingly, the level forecast performed in the calculation of reserves has a very significant difference with the actual levels observed in the operation of water intake facilities.

Excessively high demand for water is difficult to explain. It should be noted that the norms of water consumption used in the USSR (500 dm^3/day for 1 person) were almost 2.5 times higher than those in Europe [2]. Also in the 1970s and 1980s, there was an aspiration to build up the maximum possible operational reserves at each individual field.

The second circumstance causes significant differences between the predicted and actual use of groundwater and is associated with the following. Water supply of cities and groups of settlements was planned at the expense of large centralized water intakes outside the urbanized territories with the elimination of single water intakes within urban areas and other ecologically unfavorable places. However, the real development took a different path. Explored sites located at a distance from water users have not been developed, and the system of single water intakes is developing to this day.

An example of this situation is the Alma-Ata deposit of groundwater in the foothill plume of the northern slope of the Trans-Ili Alatau. To prevent pollution of groundwater within Almaty, in 1990, the State Committee of the USSR recommended the liquidation of departmental water intakes with the transfer of enterprises to centralized water supply. The number of departmental water intakes within the Alma-Ata deposit since the previous approval of operational reserves has increased and currently stands at about 200.

The third circumstance. During the Soviet period, in almost all cities, there were significant leaks from main and breeding networks, resulting in unproductive losses, reaching on average about 30% of total water extraction.

As an example, we consider the water supply system in Almaty, which is based on the use of underground and surface water. The operating organization actually implements an average of 65-68% of the supplied water from all sources into a single water supply network of the city. The loss of water during transportation is 32-35%. Because of the old water supply network, about 20% of the water is filtered back into the aquifer throughout the city [5, 6].

With the transition to a new economic system, the operating organizations began to pay much attention to measures to reduce leaks, the industrial enterprises - to the transition to the circulating water supply systems, etc. All this led to a previously not planned increase in water consumption, but, on the contrary, to its significant reduction.

For clarity, let us consider the balance of drinking water consumption in Almaty for 1990-2040. [5,6]. To do this, we will construct a graph of the estimated demand of the megapolis used in reassessing the exploitation reserves of the Talgar underground water deposit with the actual use of groundwater and surface water (fig. 1).

As can be seen from the graph above, the total productivity of the water supply system tends to decrease from 1104.6 thous.m^3/day in 1990 to 794.5 thous.m^3/day in 2010.

The estimated design demand of the city in the water by 2040 is estimated at 1640.5 thous.m^3/day. Comparing the estimated demand for 2010 (1646 thousand m^3/day), we observe that it is twice the actual consumption.

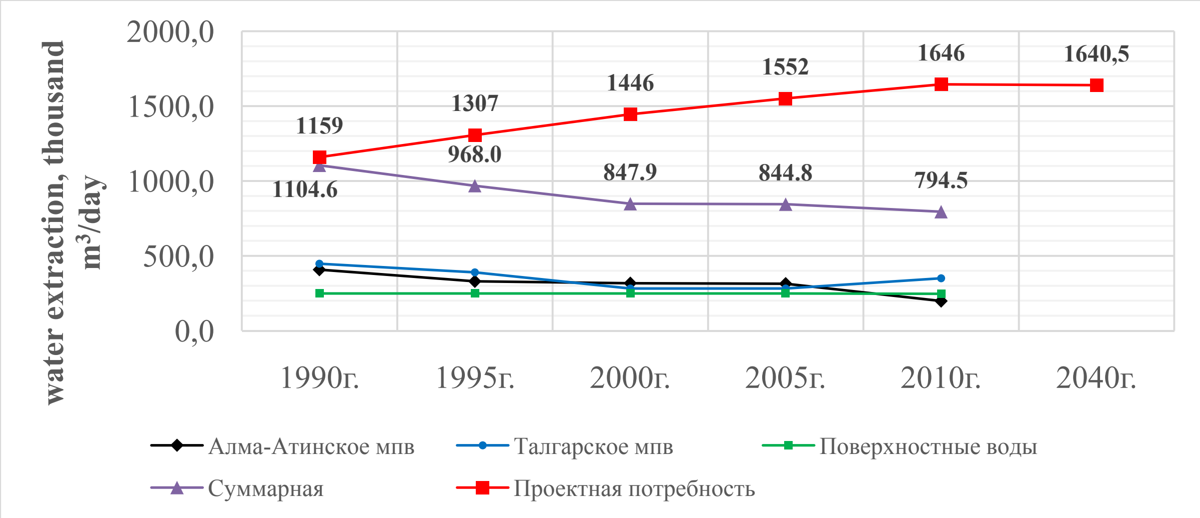

Figure 1 – Graph of correlation of design and actual indicators of groundwater production and use of surface water for water supply in Almaty

Let us consider the results of the analysis of the operational experience of the Alma-Ata, Talgar, Kaskelen, Pokrovsky and Boraldai deposits of groundwater located within the piedmont plume of the northern slopes of the Zailiysky Alatau.

Figure 2 shows a graph of the change in total water abstraction within the Almaty urban agglomeration for the period 1960–2014.

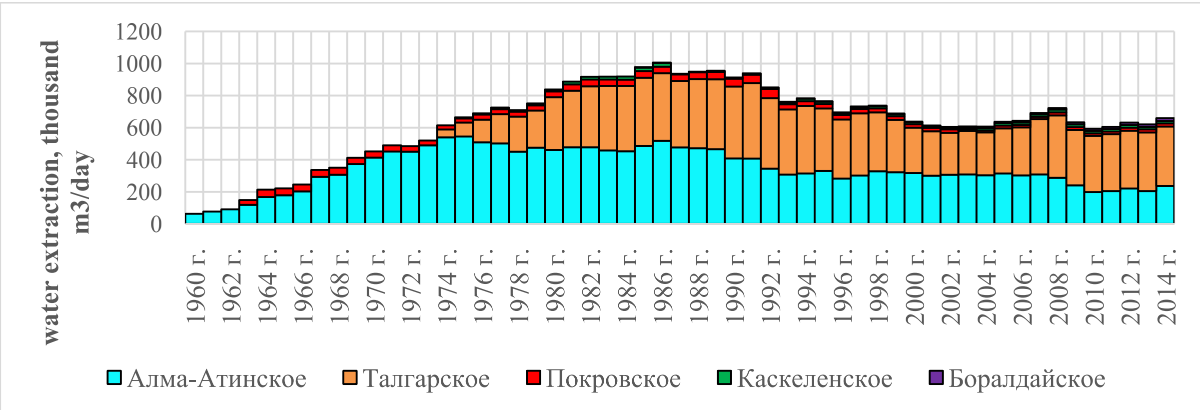

Figure 2 – Graph of total groundwater abstraction within the Almaty metropolitan area

From the presented graph it can be seen that in the period from 1960 to 1986, there was a gradual increase in water abstraction from 62.46 thousand m^3/day to 1005.98 thousand m^3/day (16 times). Subsequently, there is an insignificant stabilization of the total average annual water extraction within 940 thousand m^3/day. The subsequent period is characterized by a decrease in the total productivity from 760 thousand m^3/day in 1993 to 605 thousand m^3/day in 2002 and its subsequent stabilization within 640 thousand m^3/day.

The maximum total annual water extraction for selected deposits falls in 1986 and is 1005.98 thousand m^3/day.

The reduction in the productivity of existing water intakes has undoubtedly affected the level surface of groundwater. Currently, there is a restoration of the groundwater level throughout the territory under consideration. This issue is especially relevant in the northern part of Almaty, where the built-up areas are flooded.

To analyze the use and comparison with the operational reserves of groundwater in the state balance in the Almaty metropolitan area, the following graph is constructed.

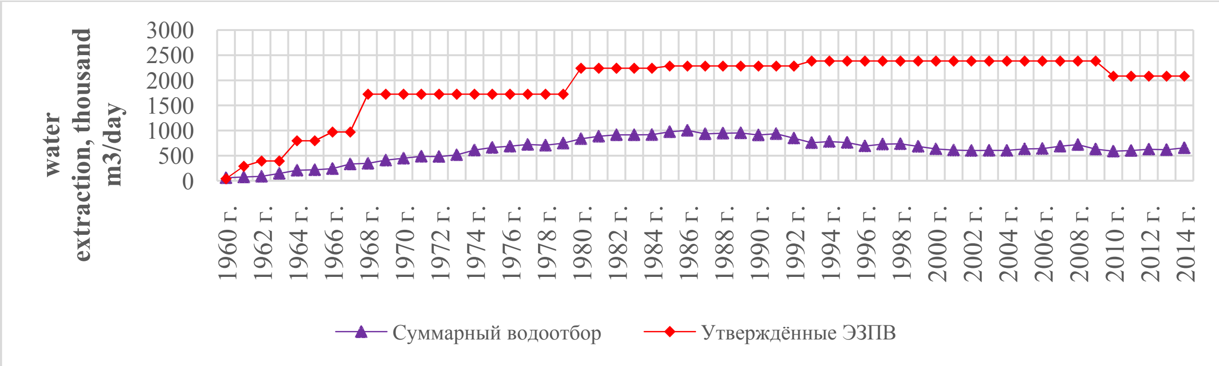

Figure 3

As we see, even during periods of maximum water collection, the actual productivity is 2-3 times lower than the amount of approved operational reserves.

For a visual representation of the share of the use of groundwater operational reserves that are on the state balance within the territory under consideration as of 2014, we give the following diagram.

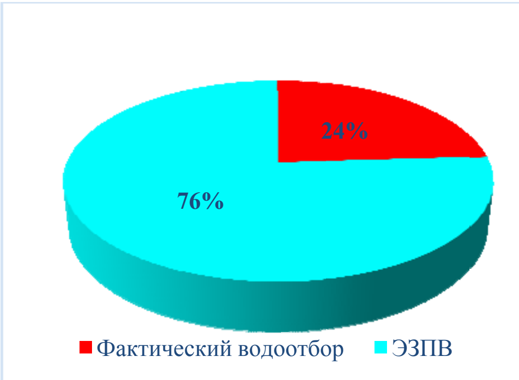

Figure 4 – Diagram of the use of the operational groundwater resources in the state balance in the Almaty metropolitan area

The analysis of the current state of the use of groundwater within the foothill plume of the Zailiysky Alatau shows that the actual volume of production in these deposits does not reach the calculated values. The share of the use of approved operational reserves within the territory under consideration does not exceed 24%.

It should also be added that the estimated water requirements used in the initial exploration of most of Kazakhstan's underground water resources are often taken as initial when reassessed and, at present, without any justification. This again predetermines a low degree of reliability in hydrogeological forecasts, even by methods of mathematical modeling.

Thus, based on the performed analysis, the estimated need for water is the least reliable. Therefore, often even with sufficiently high reliability of the initial hydrogeological data (parameters, boundary conditions, etc.) used in predictive calculations of groundwater operational reserves, their real reliability is extremely unsatisfactory.

As a result, the gap between the total value of the operational reserves calculated and consisted in the state balance and the actual water extraction are constantly growing, which leads to an extremely low reliability of the forecast of groundwater status in comparison with the observed one. This hinders the rational development of subsoil, especially in areas with intensive exploitation and difficult water management environment, because the forecast is more "hard" than, the picture actually observed for many decades.

Let us consider a small example. When re-evaluating the operational reserves of the Alma-Ata underground water deposit, at the site of a local water intake for domestic and drinking water supply in a residential complex in the southwestern part of Almaty, its productivity was limited to 1 thousand m^3/day, while the permissible reduction in the water intake area was 75 m, and the decrease in the level from the operation of the wells themselves was 6.7 m. However, the calculated level cut off from interaction with other undeveloped groundwater resources on the state balance was approximately 10 times greater (64 m), which resulted in a significant limitation of water extraction in the water intake area and approval of a part of the submitted reserves for category C_2. The deep occurrence of the groundwater level necessitated the recommendation to drill two production wells, instead of operating due to dehumidification of the upper filter intervals. In this case, there is a need to increase the depth of the well from 325 m to 400 m.

Let us enumerate the main consequences to which predictive overestimation of water abstraction and depths of groundwater levels leads in comparison with their actual state:

1. Granting the right to extract groundwater to new subsoil users from deeper aquifers with increasing depth and complicating the design of wells, and as a consequence causes an increase in costs for the construction of water intake;
2. Overestimation of the sizes of zones of sanitary protection due to the estimated increase in the slopes of groundwater against the real one.
3. Since the assessment of operational reserves was carried out for the maximum possible lowering of the level, in many cases exploration of new groundwater extractions is practically impossible, since taking into account the mutual influence of water intakes on previously explored and new water intakes, the calculated depressions will exceed the permissible value.
4. Corresponding overestimation of migration rates for forecasts of changes in the quality of groundwater.
5. Overstating the negative impact of exploitation on the environment.

Conclusions:

1. At present, there is a significant gap between the forecasted in the assessment of operational reserves and the actual state of groundwater. Forecast levels have already significantly exceeded the actual levels for many decades. This is due to a sharp discrepancy between the forecast and actual water extraction, since the reserves calculated and registered in the state record are many times higher than the actual water extraction.

2. The least reliable components of the forecast are the size and design of the project water extraction. Therefore, it is necessary to take into account in the forecasts only the operational reserves of groundwater that have been mastered or planned for development.

3. Declared and taken into account in the calculation water requirements are gigantic, because they are in most cases repeatedly overstated, and have never been achieved, and in the foreseeable future, as shown by the trend in the dynamics of water diversion formed in recent decades, they will not be used for practical purposes.

4. To implement the selected proposals, appropriate adjustments should be made to the regulatory framework that regulates the principles of counting and recording groundwater resources. First of all, it is necessary to make adjustments to the classification of operational reserves, expanding the concept of off-balance reserves in their general structure and attributing to them all stocks that will not be used in the future.

5. It is necessary to take an administrative decision at the level of the State Reserves Committee of the Republic of Kazakhstan on the transfer of previously explored, but not exploited, groundwater deposits to a reserve fund (transfer to off-balance reserves). To this end, the analysis should be performed of the reconnoitred groundwater deposits, the reserves of which were approved by the State Reserves Committee of the USSR and the TRC until 1991. Based on this analysis, two groups of deposits will be identified. The first group will include deposits, for which the expiry date of the reserves has expired. The second - the deposits, for which the approval of the reserves has not yet been completed, but the operation is not planned until the end of this period. The operational reserves of groundwater for both groups that are not in demand will be transferred to off-balance reserves and will not be taken into account when exploring new deposits and sites [5].

6. It is necessary to strengthen the role of groundwater monitoring as a real basis for predicting changes in the state of groundwaters, and not just its ascertaining.

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СУҒА ЕСЕПТІК СҰРАНЫС – ЖЕРАСТЫ СУЛАРЫНЫҢ ПАЙДАЛАНУ ҚОРЛАРЫН БАҒАЛАУ КЕЗІНДЕ ГИДРОГЕОЛОГИЯЛЫҚ ПАРАМЕТРЛЕРДІҢ СЕНІМДІЛІГІНЕ ӘСЕР ЕТЕТІН НЕГІЗГІ ФАКТОР

Аннотация. Мақалада мемлекеттік баланстағы және болжамдық есептеулер кезінде ескерілетін жерасты суларының бағаланған пайдалану қорларының айтарлықтай айырмасына байланысты олардың күйін және фактілік суалу мен олардың уақыт бойынша өзгеру динамикасын гидрогеологиялық болжаудың сенімсіздігі мәселесі қарастырылады. Бұл жағдай деңгейлердің болжамдық төмендеулерінің олардың нақты жағдайымен салыстырғанда елеулі артуына әкеледі.

Бұл проблема Алматы қаласы маңындағы агломелиорация шегінде көп кездеседі. Бұл аймақтың алғашқы ретінде таңдалуы гидрогеолог мамандар үшін белгілі. Берілген аймақ территориясында 2008 жылдағы күйі бойынша Республикадағы ауыз су сапасындағы жерасты суларының пайдалану қорларының шамамен 15 % мемелкеттік баланста. Ал осы аймақ шегінде жерасты суларын өндіру 45 % құрайды. Республиканың басқа аймақтарында жер қойнауына бұндай әсер келтірілмейді.

Осы мәселе бойынша қорытынды негізінде жерасты суларының қорларын бағалау кезіндегі гидрогеологиялық болжаулардың қазіргі әдістерін өзгерту ұсынылады, яғни суалу барысын есептеу кезінде болжауды бұрмаламай нақты ретінде орындау ұсынылады.

Түйін сөздер: жерасты суларының пайдалану қорлары, гидродинамикалық болжамдарың сенімділігі, фактілік су алу, пайдалануды басқару.

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Алматы, Казахстан

РАСЧЁТНАЯ ПОТРЕБНОСТЬ В ВОДЕ КАК ОСНОВНОЙ ФАКТОР, ВЛИЯЮЩИЙ НА ДОСТОВЕРНОСТЬ ГИДРОГЕОЛОГИЧЕСКИХ ПРОГНОЗОВ ПРИ ОЦЕНКЕ ЭКСПЛУАТАЦИОННЫХ ЗАПАСОВ ПОДЗЕМНЫХ ВОД

Аннотация. В статье рассмотрены вопросы низкой достоверности гидрогеологических прогнозов состояния подземных вод в связи с существенным расхождение величины оцененных эксплуатационных запасов подземных вод, состоящих на государственном балансе и учитываемых при прогнозных расчётах, и фактического водоотбора и динамики его изменения во времени. Это приводит к существенному завышению прогнозных понижений уровней по сравнению с их фактическим положением.

Наиболее остро эта проблема стоит в пределах Алматинской городской агломерации. Выбор этого региона в качестве пионерного очевиден для специалистов гидрогеологов. В пределах выделенной территории по состоянию на 2008 г. на государственном балансе состоит около 15% от суммарной величины эксплуатационных запасов подземных вод питьевого качества в Республике. А объем добычи подземных вод в пределах региона составляет около 45%. Такой нагрузки на недра нет ни в одном другом регионе Республики Казахстан.

На основе имеющихся разработок в этом вопросе, предложены пути изменения существующих подходов к гидрогеологическим прогнозам при оценке запасов подземных вод для устранения возникающих несоответствий, т.е. выполнение прогнозирования с учётом реальной, а не завышенной при расчетах динамики водоотбора.

Ключевые слова: эксплуатационные запасы подземных вод, достоверность гидродинамических прогнозов, фактический водоотбор, управление эксплуатацией.

CONTENT

Publication Ethics and Publication Malpractice in the journals of the National Academy of Sciences of the Republic of Kazakhstan

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