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USE OF ARTIFICIAL GROUNDWATER RECHARGE TECHNOLOGIES FOR CENTRAL KAZAKHSTAN PASTURES WATERING

Abstract. The most acute problem of pasture watering is bound to one of the arid regions of the Republic that is Central Kazakhstan. Under the current conditions, groundwater plays a significant role in providing high-quality drinking water resources. Conservation of surface flow in underground aquifers in arid and semi-arid areas of Central Kazakhstan is of great importance. For the first time in the practice of watering pastures in the foothills and hilly areas of Kazakhstan, the process of creating underground reservoirs based on low-power flows of underground fissure-groundwater is studied. The result of this study is a substantiated and developed concept scheme for creating watering structures on pastures based on artificial groundwater recharge (creation of mainly small underground reservoirs) in the hilly areas of Central Kazakhstan (Sary-Arka pasture).

Keywords: water resources, Sustainable Development Goals 2, groundwater, artificial groundwater recharge, pastures watering.

Introduction. One of the conditions for sustainable development of the nation state is a water supply to economic sectors, the largest water consumer of which is agriculture, an industry designed to provide the population with food. This problem has priority attention in the 17 sustainable development goals (SDGs) developed in 2015 with the main goal being SDG-2: Zero Hunger, which aims to end hunger, ensure food security, improve nutrition, and promote sustainable agricultural development. Current estimates suggest that nearly 690 million people, or 8.9 % of the world's population, are hungry. Food security is also one of the main directions of national security of the Republic of Kazakhstan. At the same time, the development of traditional cattle breeding requires solving the issues of watering livestock.

Research developments on the effective use of groundwater for the sustainable development of farm livestock are very relevant and prompt. Pasture watering plays a major role in the use of groundwater resources in Kazakhstan [1, 2, 4].

Within the bounds of Central Kazakhstan, predominantly structure of free-flow fractured waters of shallow circulation is distinctive for the region. It is confined to the zone of open fractures of effusive, intrusive, terrigenous-sedimentary and metamorphic pre-Paleozoic and Paleozoic formations. Good exposure of the rocks promotes active water exchange and the development of fresh, slightly brackish and brackish waters [7, 5].

Slightly inclined accumulative plains, situated in wide ancient and modern river valleys, play a crucial role in the surface structure for artificial groundwater replenishment [3]. Karaganda region, in general, has an underdeveloped river network. In this region, alluvial-proluvial deposits of buried valleys, which underlie both permanent and temporary surface watercourses, serve as natural collectors for storing surface water emissions [13].

Materials and research methods. Among the main natural factors that determine the possibility of using the method of artificial groundwater replenishment in the region, as well as influencing the effectiveness and the choice of rational technological schemes, the physical and geographical conditions of the region have prime importance and include geomorphological, geological, hydrogeological, climatic (mainly precipitation) and hydrological (development of the hydrographic network) factors [8]. These factors determine natural collectors and the possibility of artificial collectors creation which are suitable for surface water storage, allow to assess and collect unused water runoff, are cost-effective foe replenishment [12].

For practical application, the following schemes and methods of artificial groundwater recharge are used:

a) Direct non-pressure circuits:
- Flooding of the area;
- Use of infiltration basins or reservoirs;
- Increasing the planned size of surface water flow;
- Use of infiltration channels or trenches;

b) Direct pressure circuits:
- Use of discharge wells;
- Use of absorption pits and mines;
- Use of absorption wells;
- Pouring water into boreholes;
- Filling natural (karst) cavities and caverns with water;

c) Combined methods:
- Infiltration pools in combination with pits or wells;

d) Indirect methods
- Recharge from a surface water source caused by a decline in groundwater levels;
- Artificial modification of the aquifer (hydraulic fracturing, crushing of water-bearing rocks using explosions, etc.).

The method of artificial recharge consists of increasing the incoming component of the general balance of the exploited aquifer during the year or certain seasons by filtering surface stream water from special structures (pools, canals, trenches, etc.), or through occasional flooding of natural depressions [6].

Results and its discussion. Central Kazakhstan has many pasture areas confined to various natural-geographical zones. Predominantly, these are dry steppes, where the amount of precipitation does not exceed 100-300 mm/year. Under these conditions, water is the main factor limiting the use of pastures due to its low water supply. Pasture lands, occupying a significant area (more than 160 million hectares), are located in arid climatic conditions and are generally deprived of surface water sources [4]. Nevertheless, they have a large feed capacity potential, sufficient to support, for example, more than 80 million sheeps. The pastures harbor large areas of fertile land, which, if irrigated, could produce high and stable yields of high-calorie feed. However, modern effective pasture areas development systems in the region are hampered by the lack of surface watercourses. A significant part of the Central Kazakhstan pasture lands is located far from the rivers; in addition, surface waterflow of the region is defined mainly as small rivers and temporary watercourses with a pronounced spring flood, which occurs within 0.5-1.5 months and makes up to 90% of the annual flow. Therefore, areas watered by rivers (about 2150 thousand hectares) are areas with low reliability to water sources, which are periodically inactive. Jointly with unwatered areas, this amounts to more than 50% of all pastures in the territory.

Additionally, vast areas of pastures cannot be flooded with groundwater due to either: the low productivity of the aquifer, the absence of fracture zones, or the reduction of groundwater reserves during seasonal droughts (July-September) [2]. The water of wells existing on pastures is often highly mineralized, whereas filling trenches quickly dry out in the climatic conditions of Central Kazakhstan (high temperatures and strong winds) [1]. The scientific developments of Kazakh scientists carried out in recent years make it possible to solve this complex problem by artificially recharging groundwater reserves of the upper aquifers and extraction it to the surface [8]. The use of specific technologies makes it possible to create watering points in artificial ground reservoirs on the thinnest groundwater aquifers and stage-by-stage restoration of productive pasture lands.

Despite the fact that certain problems of storing groundwater for water management facilities are reflected in a number of fundamental works by scientists from the CIS and Kazakhstan [14, 16, 17], listed research has not covered the issues of artificial regulation of groundwater flow of small temporary watercourses by underground dams with the creation of groundwater reservoirs and, thus, increasing groundwater reserves specifically in pastures. The unique scientific developments available in Kazakhstan for the creation of watering points at ground reservoirs can significantly increase the possibilities of grazing livestock in Central Kazakhstan and contribute to the solution of this major national economic problem [4]. The issue of creating watering points in Central Kazakhstan allows to practically approach the solution to the complex problem of watering the Sary-Arka pastures. Watering points can be created by dint of the water accumulated in artificially created underground reservoirs, within underground drainage basins, in narrowed areas in places of "exit" and "crimps" of the underground flow cross-section [15].

These watering points are provided with water all year round, are environmentally friendly, have the necessary pressure and volume for watering large (up to 500 heads of livestock or more) flocks of sheep, cattle and camels, do not damage pasture lands as all structures are hidden underground, and are simple in service. One such watering point is capable of watering about 3 thousand hectares of pastures.

The artificial recharge of groundwater reserves considered in this work, and the construction of irrigation structures on this basis ensure a sufficient amount of water of drinking quality in pastures, simplicity and accessibility of maintenance, low cost and quick payback of construction costs [10, 11]. The research carried out will make it possible to stop the threat of further spread of land degradation and desertification of pastures. For the first time in the practice of watering pastures, the process of creating underground reservoirs and regulating low-power flows of underground fissure-groundwater on this basis is being studied. The prospects of research are determined by the ability to create highly efficient watering structures in a short time, with low construction costs, that will solve the problem of creating productive pasture lands in Kazakhstan.

As a water collector for underground reservoirs, a large area with a leveled surface, surrounded by small hills (a cirque in an inter-hill saddle with the dimensions of 2×3 km) is selected. The selected territory turns out to be in a saddle-like terrain where solid precipitation accumulates and where melt water flows. Well-divided relief and intense fracturing of rocks create favorable conditions for the infiltration of precipitation. The zone of exogenous fracturing, which has a relatively small thickness, forms in the selected area a kind of relatively small underground runoff basin, the boundaries of which are determined by the terrain. In this case, the boundaries of underground and temporary surface flow usually coincide. There are practically no permanent surface watercourses here. Groundwater drainage basins in Central Kazakhstan are usually interconnected, so underground overflow occurs from one basin to another, located lower hypsometrically. It was this circumstance that was used in the theoretical substantiation of the idea of building artificial underground reservoirs for watering pastures - in the closing section of the basin, in narrowed areas in the places of "exit" and "pinching" of the underground flow section [9]. The amount of underground flow that is planned to be used for a watering point is determined by the drainage area of the basin.

A typical technological scheme of a watering point based on artificial replenishment of groundwater reserves using ground reservoirs is shown in figure 1. A water retaining dam with an inspection well is built at the closing section of the underground drainage basin. At a depth of 2.5-3.0 m, a drainage trench located in the dam site and filled with water-bearing soil (stone clastic material, coarse crushed stone) reveals the aquiferous zone of bedrock. In addition, the complex includes: a tubular water conduit, a storage tank and a water trough.

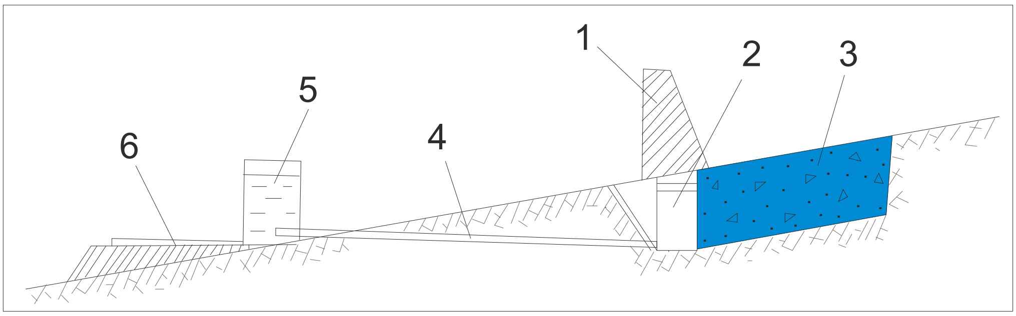

Figure 1 – Typical technological scheme of a watering point based on artificial replenishment using groundwater reservoirs: *1* – earth dam; *2* – inspection well; *3* – drainage trench; *4* – tubular water conduit; *5* – storage tank; *6* – watering trough

Figure 2 shows a system of artificial replenishment of groundwater with the placement of the entire complex of structures on one site with a) linear single-row and b) double-row arrangement of infiltration structures (pools). It is advisable to use such schemes to: increase the productivity of existing water intake; increasing groundwater reserves in the area of the newly designed water intake; reducing the length of capture structures in conditions where permeable rocks are characterized by sand or gravel-pebble deposits of sufficient thickness with a total thickness of cover low-permeable layers of no more than four meters. This scheme is acceptable for water supply to rural settlements located in pastoral areas of the region.

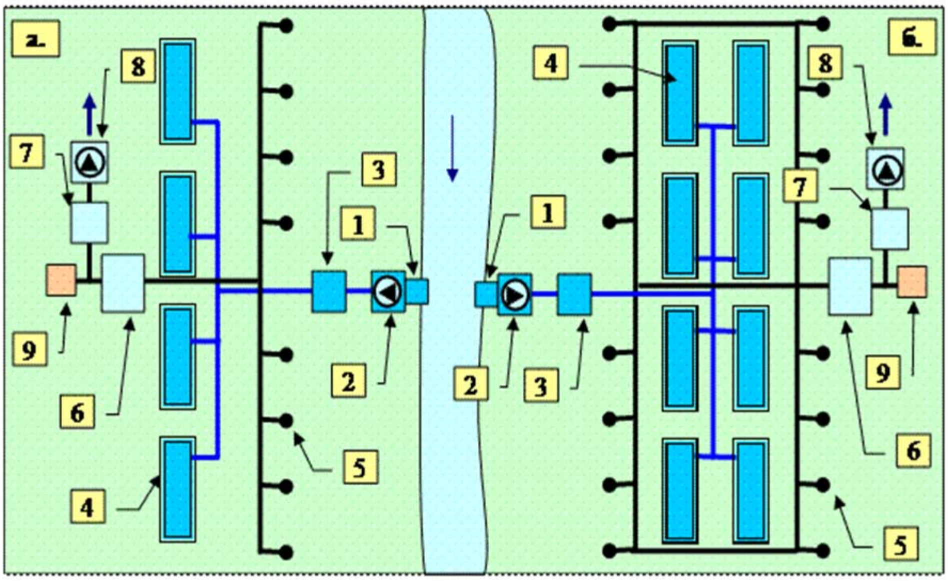

Figure 2 – Open scheme of artificial groundwater replenishment (type I) using infiltration basins:
1 – water intake from a surface source; *2* – first lift pumping station; *3* – water preliminary treatment facilities (if necessary);
4 – infiltration basins; *5* – wells; *6* – facilities for groundwater purification; *7* – clean water tank;
8 – pumping station of the second lift; *9* – installation for water disinfection

When designing systems for artificial replenishment of groundwater, the following steps should be carried out: selection of the technological scheme of the system; choosing the type, design, operating mode and method of regeneration of infiltration structures, determining their performance; calculation of the flow rate of capture structures and changes in water levels in the zone of their influence, taking into account the flow of water from infiltration structures; determination of the required degree of water preparation from the replenishment source, the design and composition of treatment facilities, taking into account predicted quality of water in groundwater intakes.

The design of devices for collecting water from a replenishment source and its transportation, pre- and post-treatment facilities for water, clean water reservoirs, pumping stations and water pipelines is carried out in the same way as the design of corresponding structures in conventional (without replenishment) domestic and drinking water supply systems using surface water and groundwater.

The examination and analysis of proposed schemes of artificial replenishment of groundwater have facilitated their systematization and justified the organization and creation of underground reservoirs for collecting and storing flood runoff and meltwater, the result of which is shown in the table.

Zoning of Central Kazakhstan was carried out according to the terms of the artificial replenishment of groundwater. The map (Figure 3) highlights the schemes for artificial groundwater recharge and identifies areas where large underground reservoirs could potentially be created:

1. Valleys of densely populated and industrially developed main rivers of the region – Nura, Sherubai-Nura, Taldy, Zharly, Tunduk, Kengir, Sarysu, etc. For these areas, an open replenishment system (type I) with infiltration basins is proposed. A typical technological replenishment scheme involves using gravity to convey surface water, including settling basins, infiltration basins, and horizontal water intakes.

Types of technological schemes of artificial replenishment of groundwater

Recommended standard technological schemes of artificial replenishment	Scheme No.	Description of a standard technological scheme	Operating principle of a standard technological scheme
Open technological schemes			
Type I	1	An open system of artificial groundwater replenishment structures with infiltration basins	Water from the replenishment source is directed to a water intake structure, where it is pumped through a distribution pipeline into infiltration structures, such as pools. From these structures, the water percolates into the aquifer, replenishing the groundwater reserves. Groundwater can be extracted using various structures designed for this purpose, such as wells or horizontal catchments, with wells being the most commonly used. The extracted water is then collected in a storage tank. If the groundwater meets GOST standards for drinking water, the storage tank serves as a clean water reservoir. However, if the groundwater contains substances in concentrations exceeding permissible limits for drinking water, treatment facilities are incorporated into the system to remove these contaminants. The treated water, compliant with SanPIN standards, is then supplied to consumers. In all cases, the water undergoes disinfection using chlorine at the treatment facility.
Type I	2	An open system of artificial groundwater replenishment structures with infiltration basins with a preliminary reduction in water turbidity (used when using flood waters)	
Type I	3	A system for artificial groundwater replenishment in sandy areas	
Type I	4	A system of karst carbonate structure with places of point and area infiltration of recharged fissure-karst waters and groundwater	
Type I	5	Cascade of water retention dams	
Type I	6	A system using reservoirs on rivers within alluvial fans in areas of intensive water intake	
Closed technological schemes			
Type II	7	Groundwater replenishment system through absorption wells	An important feature of closed-type systems is the preliminary improvement of water quality, the turbidity of which should not exceed 1-3 mg/l. These systems consist of rows of wells, which can be both infiltration and water intake wells. This arrangement helps combat clogging (calmatization) and restore the injectivity of the wells. Additionally, preliminary water treatment is included to meet the required standards.

2. Areas of development of carbonate structures. In these regions, an open replenishment system No. 4 (type I) is recommended. This is particularly relevant for areas where carbonate structures are prevalent.

Areas of possible creation of underground reservoirs associated with the largest buried valleys. Many modern rivers on the platform plains of Central Kazakhstan have ancient buried valleys formed during the Lower Quaternary and Pliocene periods. These regions are suitable for the accumulation of underground runoff and spring floodwaters to replenish groundwater reserves. An open replenishment system No. 6 (type I) is suggested for these areas.

3. In certain areas, a closed replenishment scheme No. 7 (type II) is recommended, utilizing absorption wells to enhance groundwater reserves.

Conclusion. Reservoirs constructed in the bowels of the earth under appropriate hydrogeological conditions do not disturb the environment and are economically beneficial.

Detailed knowledge of the geological and hydrological features of the area is necessary in order to select a site and structure for artificial groundwater recharge. In this case, it is necessary to take into account and consider the following factors: geological boundaries; hydraulic boundaries; groundwater inflow and outflow; volume of aeration zone; porosity; hydraulic conductivity; surface water resources available for groundwater recharge; water balance of the territory; lithology and depth of the aquifer.

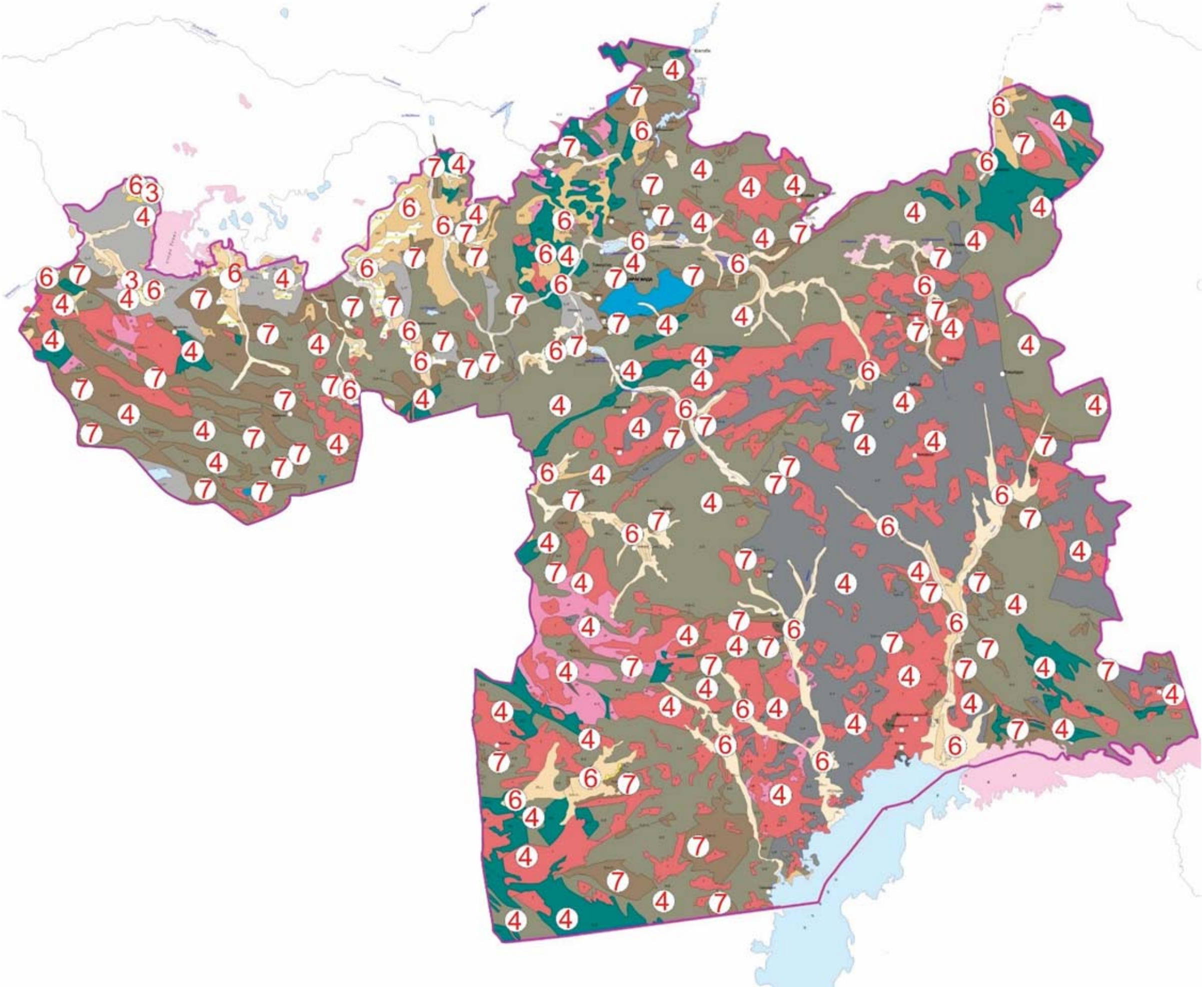

Figure 3 – Location of typical schemes of artificial replenishment of groundwater in the Karaganda region.

Note: the color and geological index correspond to the age of the water-bearing rocks. Digits indicate the number of the recommended standard technological scheme of artificial replenishment from table.

Aquifers with high vertical and moderate horizontal water conductivity and a significant thickness of the aeration zone are best applied to organize artificial groundwater recharge. In any case, when carrying out artificial groundwater recharge, the thickness of the aeration zone should not be less than 3 m to prevent flooding of the area.

For the first time in the practice of watering pastures in the foothills and hilly areas of Kazakhstan, the process of creating underground reservoirs based on low-power flows of underground fissure-groundwater is being studied.

The results of the conducted research within the framework of this work showed that in Central Kazakhstan there are favorable conditions for the widespread use of methods for artificial replenishment of groundwater reserves, depending on hydrogeological conditions and the availability of surface water sources.

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ОРТАЛЫҚ ҚАЗАҚСТАНДАҒЫ ЖАЙЫЛЫМДАРДЫ СУАРУ ҮШІН ЖЕР АСТЫ СУЛАРЫН ЖАСАНДЫ ТОЛТЫРУ ТЕХНОЛОГИЯЛАРЫН ҚОЛДАНУ

Аннотация. Жайылымды суарудың ең өткір мәселесі республиканың құрғақ аймақтарының бірі – Орталық Қазақстанда болып отыр. Мұндай жағдайларда жер асты сулары сапалы ауыз су ресурстарымен қамтамасыз етуде маңызды рөл атқарады. Орталық Қазақстанның құрғақ және жартылай құрғақ аймақтарындағы жер асты сулы горизонттарында жер үсті ағынын сақтаудың маңызы зор. Қазақстанның тау бөктеріндегі және таулы аймақтарындағы жайылымдарды суару тәжірибесінде алғаш рет жер асты жарықтары-жер асты суларының қуаттылығы аз ағындары негізінде жерасты су қоймаларын құру процесі зерттелуде. Орталық Қазақстанның таулы аймақтарында (Сарыарқа жайлауында) жер асты суларын жасанды түрде толықтыру (негізінен шағын жерасты су қоймаларын құру) негізінде жайылымдарда суару құрылыстарын құрудың негізгі схемасы негізделді және әзірленді.

Түйін сөздер: су ресурстары, Тұрақты Даму Мақсаттары-2, жер асты сулары, жасанды толықтыру, жайылымдарды суару.

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ИСПОЛЬЗОВАНИЕ ТЕХНОЛОГИЙ ИСКУССТВЕННОГО ВОСПОЛНЕНИЯ ПОДЗЕМНЫХ ВОД ДЛЯ ОБВОДНЕНИЯ ПАСТБИЩ ЦЕНТРАЛЬНОГО КАЗАХСТАНА

Аннотация. Наиболее остро проблема обводнения пастбищ стоит в одном из аридных регионов республики – Центральном Казахстане. В этих условиях значительную роль в обеспечении доброкачественными ресурсами питьевых вод играют подземные воды. Сохранение поверхностного стока в подземных водоносных горизонтах в засушливых и полузасушливых районах Центрального Казахстана имеет большое значение. Впервые в практике обводнения пастбищ в предгорных и мелкосопочных районах Казахстана исследуется процесс создания подземных водохранилищ на основе маломощных потоков подземных трещинно-грунтовых вод. Обоснована и разработана принципиальная схема создания обводнительных сооружений на пастбищах на базе искусственного восполнения подземных вод (создание преимущественно небольших подземных водохранилищ) на территории мелкосопочных районов Центрального Казахстана (пастбища «Сары-Арка»).

Ключевые слова: водные ресурсы, Цели Устойчивого Развития-2, подземные воды, искусственное восполнение, обводнение пастбищ.