



Hydrogeological and Hydrochemical Characteristics of Groundwater in Western Kazakhstan Used for Pasture Watering

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ABSTRACT

The aim of this study is to investigate groundwater sources potentially suitable for pasture watering. This paper presents the results of studies of groundwater sources used for pasture watering. An analysis of the hydrochemical parameters of groundwater in the western region used for watering pasturelands was carried out. The article examines the state of pasture watering with groundwater in the West Kazakhstan, Atyrau, and Mangystau regions of the Republic of Kazakhstan. The hydrochemical analysis of water was carried out using chemical and physicochemical methods. The scientific and practical significance of the study lies in the fact that, under current conditions, fundamentally sound solutions are needed for the fullest possible use of aquifers for pasture watering, based on the study of the hydrodynamic characteristics of aquifer strata and advances in well drilling. The significance of the hydrogeological studies conducted on the water supply of pasture areas lies in the fact that restoration of the destroyed pasture water infrastructure and the wide use of explored groundwater reserves will make it possible to significantly increase the economic efficiency of transhumant livestock husbandry.

Keywords: Western Kazakhstan, Transhumant livestock husbandry, Pasture, Pasture watering, Groundwater sources

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INTRODUCTION

Agriculture is the world's largest water-consuming sector, and more than one-third of agricultural water is used for livestock production (Heinke *et al.*, 2020; Rafiei *et al.*, 2022). In many climatic zones, the water requirements of cattle are met by precipitation, associated water available on pastures, and surface runoff (Zeydlinejad *et al.*, 2023; Karimi *et al.*, 2024; Thamaga *et al.*, 2024). However, in arid areas, such as the semi-arid parts of the United States of America, South America, and Australia, groundwater is an important source of water for livestock grazing because it is virtually unaffected by changes in surface hydrology. Although cattle drinking water consumption may seem insignificant on a global scale, it can represent a substantial share of extraction at the regional level (Gleeson *et al.*, 2020; Zwarteveen *et al.*, 2021; Sarami-Foroushani *et al.*, 2024). For example, in the Great Artesian Basin (GAB) in Queensland, Australia, livestock grazing is the main type of land use, and groundwater extraction to support it, including

drinking water for cattle and domestic use, is estimated at 50% of total water extraction. Pressure on global freshwater resources is projected to increase due to rising meat consumption as population grows, economic prosperity increases, and awareness of the impacts of climate change expands (Wu *et al.*, 2020; Rochford *et al.*, 2023). Groundwater constitutes approximately 30% of global freshwater reserves and is a crucial source for domestic, agricultural, and industrial needs; in many regions, especially semi-arid ones, groundwater is often the last available source of fresh water (Frappart & Merwade, 2022; Costa *et al.*, 2025). Groundwater is one of the most important resources that can be brought into use rapidly; it does not require treatment and has been used from past to present to meet drinking, municipal, irrigation, and industrial water demands (Aslan & Sepetcioglu, 2025). Vast areas of deserts and semi-deserts in Kazakhstan, occupying about 60% of the total territory of the republic and used mainly as natural autumn-winter pastures for transhumant livestock husbandry, can in most cases be transformed into valuable highly productive agricultural land with developed pasture management on the basis of the enormous groundwater reserves available there (Dar *et al.*, 2021; Ongayev *et al.*, 2021;

Ongayev et al., 2022; Di Fiore et al., 2024; Elerian et al., 2024; Haddad et al., 2024; Petrova et al., 2024; Todayama et al., 2024; Zakaev et al., 2024; Zar et al., 2024; Huang, 2025; Rivas & Munoz, 2025; Welie & Liesbeth, 2025). The huge resources of artesian basins and groundwater flows make it possible, by means of boreholes and wells, to bring groundwater to the surface almost anywhere within pasture territories and to use it locally without major water transfers, with minimal expenditure of funds and time (Nasiyev et al., 2021; Sepahvand et al., 2025).

This article examines the distribution of groundwater within the western region of the country. Its similarity to the above-mentioned articles lies in the research objects. However, this article focuses on the provision of pasture areas in the western regions with groundwater. The presence of groundwater is confirmed by survey data from the territories of these regions. The Republic of Kazakhstan possesses vast pasture areas, the modern and proper development and water supply (pasture watering) of which constitutes a crucial element in the problem of developing modern livestock husbandry and meeting the needs of the country's growing population and its export potential for high-quality and environmentally safe meat products (Nasiyev et al., 2023; Ongayev et al., 2023; Yadav et al., 2023; Ongayev et al., 2024). Thus, the purpose of the article was to investigate the distribution of groundwater sources used for pasture watering in Western Kazakhstan.

MATERIALS AND METHODS

Study area and survey design

The objects of the study were underground sources used for pasture watering at the locations of transhumant livestock husbandry in the West Kazakhstan, Atyrau, and Mangystau regions. A hydrogeological survey of pasturelands was conducted to determine the actual state of water resources by examining groundwater intake facilities. In the West Kazakhstan Region, data from 503 dug wells and 372 boreholes surveyed during the reporting period were analyzed together with materials from our own studies and data obtained through design and survey organizations and executive bodies. In the Atyrau Region, data from 148 dug wells and 18 boreholes were analyzed. In the Mangystau Region, data from 28 dug wells and 45 boreholes were analyzed.

Water sampling and hydrochemical analysis

Water samples from underground water sources were collected in accordance with the regulatory document "Nature Protection. Hydrosphere. Devices and Equipment for Sampling, Primary Processing, and Storage of Natural Water Samples," which is regulated in the Republic of Kazakhstan for collecting water samples from sources. The location of the sampling site was recorded using GPS. Water samples were collected in plastic bottles thoroughly rinsed with water. If the delivery of samples to the laboratory was delayed for more than 24 hours, the water samples were preserved. Samples intended for cation analysis

were preserved with 1 mL of concentrated nitric acid (HNO₃) to maintain the ions in solution.

Chemical analysis of the water samples was carried out at the accredited testing center of the Science Department of Zhangir Khan West Kazakhstan Agrarian Technical University and at the laboratory of Zhaiykhhydrogeology LLP. Hydrochemical water analysis was performed using chemical and physicochemical methods in accordance with standard testing methods. Sulfates were determined by the spectrophotometric method; pH, by the potentiometric method; nitrogen-containing substances, sodium, and potassium, by the photometric method; and calcium, magnesium, carbonates, bicarbonates, and chlorides, by the titrimetric method.

Hydrogeological characteristics of the study regions

West Kazakhstan Region. The region is predominantly flat, with spurs of the General Syrt and the Cis-Ural Plateau in the north and northeast, while most of the territory is occupied by the Caspian Lowland. Groundwater is mainly associated with marine deposits of Caspian transgressions, where strong salinization and poor leaching result in high mineralization. Additional aquifers occur in Pliocene sandy deposits, Upper Cretaceous Maastrichtian strata, aeolian sands of the Naryn massif, and river alluvium.

Atyrau Region. Groundwater resources include pore waters in Quaternary deposits and confined artesian waters in pre-Quaternary, mainly Upper Albian, strata. The region lies within the Caspian Lowland, a marine accumulative plain composed of Neogene and Quaternary sediments. Important aquifers are developed in aeolian sands, alluvial valleys, and lacustrine and marine deposits. In the Ural-Emba plain, discontinuity of the regional aquiclude improves groundwater circulation and recharge from adjacent artesian basins (Al-Jassim et al., 2024; Guillen & Pereira, 2024; Kyaw et al., 2024; Murphy et al., 2024; Park, 2024; Clark & Foster, 2025; Coleman et al., 2025; King et al., 2025; Tan et al., 2025; Toktogonov et al., 2025).

Mangystau Region. Located on the Mangystau Plateau, the region combines northern salt marshes with southern uplands, including the Ustyurt Plateau and the Mangystau Mountains. Its hydrogeology is represented by several artesian basins, with the main aquifers associated with Quaternary aeolian sands and marine formations.

RESULTS AND DISCUSSION

Aquifers of marine deposits related to the Caspian transgressions (Post-Khvalynian, Khvalynian, Khazarian, and Baku) are widely distributed in the West Kazakhstan Region. The waters occur at depths from 3–5 m in depressions (hollows, sandy plains, etc.) to 15–20 m in elevated areas. In the pre-Syrt plains, the waters are encountered at depths of 7–25 m (**Table 1**).

Table 1. Hydrogeological characteristics of the surveyed underground water sources from aquifers in the West Kazakhstan Region

Aquifers	Well type	Number	Depth, m	Static level, m	Yield, dm ³ /s	Mineralization, g/dm ³
1	2	3	4	5	6	7
Modern aeolian	dug well	89	1,8-6,8	0,5-6	0,02-1,46	0,2-9,6
Middle–Upper Quaternary alluvial	dug well	7	4,3-8	1,9-5,4	0,28-0,52	0,4-10,1

	borehole	14	14-38	3,1-6	0,13-1,4	0,6-3,1
Lower-Upper Quaternary alluvial-deltaic	dug well	4	4,8-9,5	3-8	1,49-2,09	0,3-0,6
	borehole	13	28-50	3-4,8	1,1-4	0,18-4,2
Upper Quaternary marine Khvalynian, Lower-Middle Quaternary marine Baku-Khazarian	dug well	374	2-26	1-18	0,01-1,98	0,1-18,5
	borehole	138	8-41	2,3-14	0,02-2,6	0,16-19,9
Locally water-bearing Lower-Middle Quaternary deluvial	dug well	1	19	10,5	2,2	0,5
	borehole	7	12-25,5	3-10,5	0,05-2,5	0,8-3,6
Locally water-bearing Lower-Upper Quaternary horizon of the upper part of the Syrt sequence (Q1-III _{sr} 3)	borehole	6	33-43	7-16	0,5-1,24	2,8-8,5
Upper Pliocene sub-Syrt	dug well	28	4-21,58	3-15,5	0,02-1,38	0,4-10,5
	borehole	80	21-93	2-42	0,3-3	0,2-13,9
Upper Pliocene Akchagyl	borehole	36	22,2-120	2,8-28	0,3-5,1	0,3-10
Upper Pliocene Apsheron	borehole	68	30-80	2-44	0,06-3,5	0,5-41,3
Upper Cretaceous Maastrichtian	borehole	10	38-60	3-43	0,02-3	0,47-9,1

Fresh and slightly brackish waters, with salinity of 1–3 g/L, formed by infiltration of atmospheric precipitation, occur mainly along the outer margin of the Caspian Lowland at depths of 2–10 m over an area of approximately 40–50 thousand km². Here, borehole yields do not exceed 0.01–0.5 L/s but in some places reach 1–2 L/s with a drawdown of 1–3 m. In the central part of the lowland, slightly mineralized waters occur as lenses 0.2–1.5 m thick and 0.1–2 km long.

Within the General Syrt and Trans-Ural Syrt, the mineralization of waters in Pliocene deposits ranges from 0.5 to 5 g/L, in some places reaching 8–10 g/L. Their chemical composition varies from bicarbonate and sulfate-chloride calcium-sodium to sodium chloride. The yields of boreholes penetrating water-bearing sands range from tenths of a unit to 1–2 and, more rarely, 3–5 m/s with water-level drawdowns of 1–35 m. In the remaining areas of the pre-Syrt plains, where polymictic sands with interbeds of gravel and pebbles are widespread, borehole yields reach 8–10 L/s with a drawdown of 6–10 m. In the Caspian Lowland, saline waters are widespread throughout the Pliocene deposits. From the margin toward the central part of the lowland, a regular increase in groundwater mineralization is observed, from 5–15 to 20–80 g/L. In terms of chemical composition, these waters are mainly sodium chloride, and only locally chloride magnesium- or calcium-sodium.

On the watershed plains of the Ural-Emba Plateau, waters of the marl-chalk horizon are penetrated by boreholes at depths of 10–60 m; borehole productivity varies from 0.3 to 4.5 L/s with drawdowns of 3–7 m. In the pre-Syrt areas, groundwater is encountered by boreholes at depths of 30–100 m and more, with productivity from 1–3 to 10–15 L/s. Water mineralization is highly variable. In the Syrt zones, it does not exceed 1–3 g/L. In terms of chemical composition, these are mixed bicarbonate-chloride calcium and sodium waters. From north to south and from east to west, the total dissolved solids increase, and already in the western part of the chalk plateau and in the south of the General Syrt, they reach 7–10 g/L or more.

Unconfined groundwater in sands occurs at depths of 1–3 m in deflation hollows, on interdune and interrillage plains, and in *sor* depressions and at 5–15 m beneath ridges and dunes. In all sandy massifs, with slight deepening of the water-receiving part of wells into the aquifer, yields of 0.05–0.5 L/s were obtained.

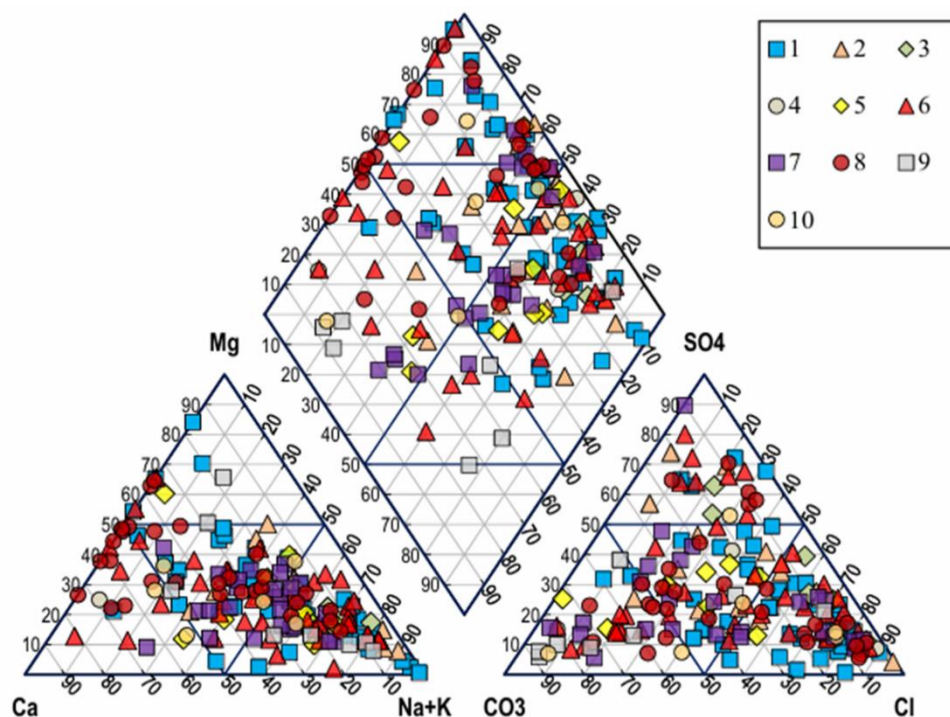
The presence of loose, highly permeable sands promotes the rapid infiltration, especially in non-stabilized areas, of a significant portion of winter-spring atmospheric precipitation and the formation of fresh and slightly brackish groundwater. The least mineralized waters, with total dissolved solids mainly up to 1 and more often 0.5 g/L, are developed in the northern half of the Naryn massif and in the Buldurty-Kaldygayty sands. Here, fresh waters are almost continuously distributed and have significant thickness (3–10 m). In other areas, however, waters with mineralization from 2 to 10 g/L are predominant in sandy massifs. Fresh waters occur here as lenses floating on the surface of saline and brackish water. Under *sors* and salt marshes, water mineralization varies from 10 to 50 g/L and more. Fresh waters with mineralization up to 1 g/L are mainly bicarbonate or sulfate-bicarbonate calcium and sodium in chemical composition. Among waters of elevated mineralization (2–10 g/L), chloride-sulfate and chloride-sodium varieties predominate, often of mixed composition. Chloride sodium waters are developed on interdune-interridge plains.

The discharges of watering points in valleys and ravines vary from 1 to 8 L/s with drawdowns of 5–9 m. Especially low yields of 0.5–0.2 L/s are observed in the lower reaches of river valleys in the Caspian Lowland. The mineralization and chemical composition of groundwater are rather varied. In river valleys, groundwater in alluvial deposits is almost everywhere fresh, with total dissolved solids of 0.2–1 g/L, while in the lower reaches it ranges from 1 to 5 g/L or more. Water mineralization also increases downstream. Elevated and high groundwater mineralization (5–15 g/L) is also observed in the valleys of some river tributaries, where saline waters from underlying deposits are discharged along tectonic faults. In terms of chemical composition, the waters are mainly bicarbonate and bicarbonate-sulfate calcium or sodium; brackish waters are sulfate-chloride and chloride sodium, while slightly saline waters are chloride sodium.

A special position is occupied by groundwater horizons in the so-called flood-spread areas, which are alluvial-deltaic depressions with numerous river channels and lakes. Groundwater in them is confined to clayey fine-grained sands and sandy loams 3–8 m thick, and its level occurs at depths up to 3–5 m. The salt composition of groundwater is varied.

Chloride sodium waters with mineralization of 10–50 g/L predominate. Only in the most drained and desalinated areas are fresh and slightly brackish waters formed, with total dissolved solids up to 3 g/L. Water reserves are limited. Freshwater lenses 0.5–0.7 m thick float on denser saline waters. The waters of the Upper Pliocene sub-Syrt aquifer, the Middle–Upper Quaternary alluvial aquifer, the water-permeable

modern aeolian horizon, the Lower–Upper Quaternary alluvial-deltaic aquifer, the locally water-bearing Lower–Middle Quaternary deluvial horizon, and the locally water-bearing Lower–Upper Quaternary horizon of the upper part of the Syrt sequence (QI–III_sr3) are most often bicarbonate calcium or sulfate waters (**Figure 1**).



1 – Upper Quaternary marine Khvalynian aquifer and Lower–Middle Quaternary marine Baku-Khazarian aquifer; 2 – Upper Pliocene Apsheronian aquifer; 3 – locally water-bearing Lower–Upper Quaternary horizon of the upper part of the Syrt sequence (QI–III_sr3); 4 – Upper Cretaceous Maastrichtian aquifer; 5 – Middle–Upper Quaternary alluvial aquifer; 6 – Upper Pliocene sub-Syrt aquifer; 7 – Upper Pliocene Akchagyl aquifer; 8 – water-permeable modern aeolian horizon; 9 – Lower–Upper Quaternary alluvial-deltaic aquifer; 10 – locally water-bearing Lower–Middle Quaternary deluvial horizon.

Figure 1. Hydrochemical characteristics of water from the surveyed boreholes and wells in the West Kazakhstan Region

The water chemistry of the Upper Cretaceous Maastrichtian aquifer depends on the degree of protection of the horizon and may vary from fresh bicarbonate waters to brackish sulfate waters. The diagram data show significant variability in aquifer composition, ranging from relatively fresh bicarbonate waters to brines dominated by chlorides and sodium. Most samples from all horizons show high concentrations of sodium and potassium. For example, in the Upper Quaternary marine Khvalynian horizon, the values reach 31,164 mg/L, indicating extremely high marine-type mineralization. Chloride waters are dominant in marine horizons (Khvalynian, Baku-Khazarian), where chloride concentrations reach 4,180–5,431 mg/L. Most samples show high concentrations of chlorides (often more than 1,000–3,000 mg/L) and sulfates (up to 3,000 mg/L and above), which is characteristic of deep or marine aquifers (Khvalynian,

Baku-Khazarian). High sulfate contents (above 1,000–2,000 mg/L) were recorded in the sub-Syrt horizon and the upper part of the Syrt sequence, which may be associated with gypsum dissolution processes.

Bicarbonate waters are relatively stable in many horizons, varying within 200–600 mg/L, which is typical of waters from the active water-exchange zone. There are horizons with extremely low mineralization, where all indicators do not exceed several tens of mg/L, which may correspond to zones of active water exchange. Even within a single horizon, a sharp transition from fresh waters to brines is observed, especially in marine and sub-Syrt deposits. At the same time, the aeolian and alluvial-deltaic horizons contain fresher lenses with low salt concentrations. Carbonate ions occur sporadically and in small amounts (up to 138 mg/L), which indicates a predominantly

slightly acidic or neutral environment (Bandi et al., 2024; Dorji & Wangchuk, 2024; Pardo-Zamora & Castellano-Rioja, 2024; Caverro & Ferraz, 2025; Hamaideh et al., 2025; Pop & Stan, 2025; Sagredo-Olivares & Bravo, 2025; Tutticci & Marian, 2025). The waters of the horizons are characterized by a wide range of chemical composition, from bicarbonate-calcium (fresh) to chloride-sodium (brackish and saline). High concentrations of chlorides and sulfates in a number of samples indicate a significant degree of mineralization and a possible relationship with marine deposits. The upper marine horizons (Khvalynian, Baku-Khazarian) tend toward sulfate-chloride contamination and elevated mineralization, while some areas retain a bicarbonate-calcium composition with low mineralization. Waters of the alluvial deposit complex (modern and Quaternary) mostly belong to the bicarbonate-calcium type. The hydrochemical pattern is characterized by a transition from fresh bicarbonate waters in alluvial deposits to chloride-sodium brines in deep or marine Quaternary horizons. The presence of high carbonate concentrations (up to 138 mg/L) in individual zones indicates special physicochemical conditions of groundwater composition formation. Unlike deep horizons, the aeolian horizon is generally less mineralized, which is explained

by its near-surface occurrence and its relation to atmospheric precipitation; however, it demonstrates considerable variability in composition depending on the specific sampling point. Water from the Middle Quaternary aeolian-deluvial horizon is fresh and fully suitable for all types of farm animals (cattle, horses, and sheep) without any salinity restrictions. Indicators in the Middle–Upper Quaternary alluvial horizon are also in most cases within the normal range for livestock watering. The water is characterized as good and is suitable for permanent use in animal husbandry. The Apsheron aquifer (Lower Quaternary deposits) is extremely heterogeneous. There are sources with chloride contents of only 9.45–11.52 mg/L and sulfate contents of 49.5–766.6 mg/L. Such water is suitable for livestock. Due to the presence of highly saline lenses, the use of water from this horizon for livestock watering requires mandatory chemical analysis of each particular borehole. Water with chlorides above 3,000–4,000 mg/L is not permitted for livestock consumption. Groundwater in aeolian formations in the Atyrau Region occurs at depths from 0.5–3 m (deflation hollows, interdune depressions, *sor* and lake depressions, river floodplains) to 15–20 m (elevated watershed plains) (Table 2).

Table 2. Hydrogeological characteristics of the surveyed underground water sources from aquifers in the Atyrau Region

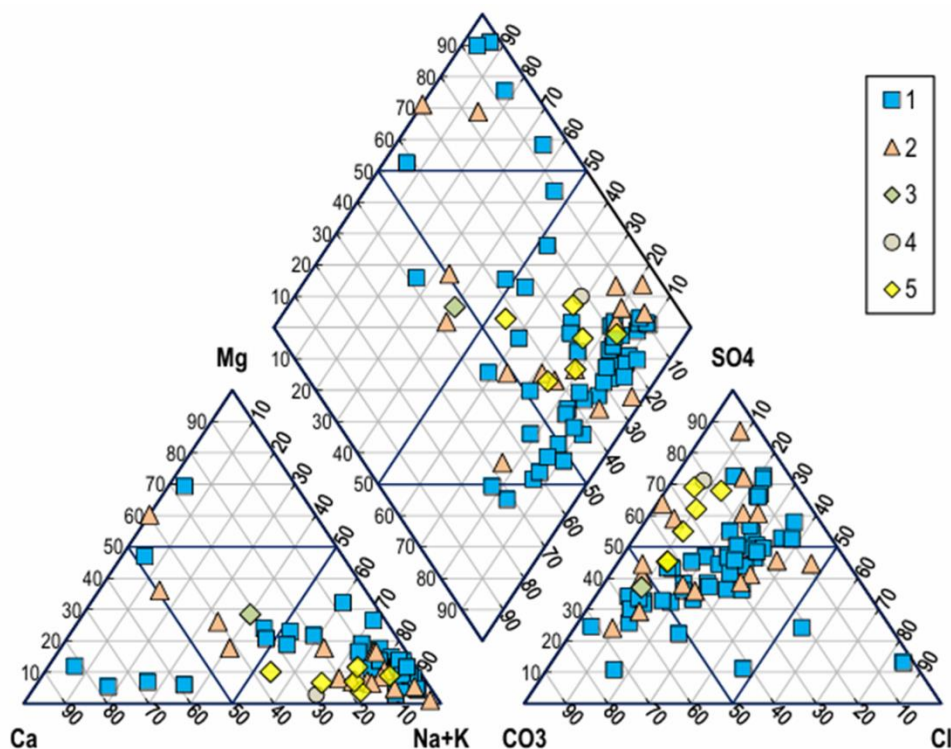
Aquifers	Well type	Number	Depth, m	Static level, m	Yield, dm ³ /s	Mineralization, g/dm ³
Modern aeolian	dug well	109	2-9	1,5-8	0,08-0,52	0,7-20,6
	borehole	2	18-100	10-80	0,3-2,4	4-6,6
Quaternary alluvial deposits	dug well	1	3	2,5	0,2	2,7
	borehole	2	6-12	4-9	1,5	4
Upper Quaternary marine Khvalynian, Lower–Middle Quaternary marine Baku-Khazarian	dug well	29	1,5-13	1-12	0,1-0,3	0,6-14,3
	borehole	12	6-195	5-162	1,4-2,1	0,6-17,3
Cenomanian-Albian deposits	dug well	7	3-6	2-4,5	0,12-0,2	1-5,5
	borehole	2	18	12	1,4	2,5
Upper Cretaceous deposits	dug well	2	5-6	3	0,15-0,18	0,6

The presence of loose, highly permeable sands promotes the rapid infiltration, especially in non-stabilized areas, of a significant portion of winter-spring atmospheric precipitation and the formation of fresh and slightly brackish groundwater. The least mineralized waters, with total dissolved solids mainly up to 1 and more often 0.5 g/L, are developed in Taisoygan and within the valleys of the Emba and Uil rivers. Here, fresh waters have almost continuous distribution and considerable thickness (3–10 m). In other areas of the sandy massifs, waters with mineralization from 2 to 10 g/L predominate. Fresh waters occur here as lenses floating on the surface of saline and brackish water. Under *sors* and salt marshes, water mineralization varies from 10 to 50 g/L and more. Fresh waters with mineralization up to 1 g/L are mainly bicarbonate or sulfate-bicarbonate calcium and sodium in chemical composition (Figure 2).

Among waters of elevated mineralization (2–10 g/L), chloride-sulfate and chloride-sodium varieties predominate, often of mixed composition. Chloride sodium waters are developed on interdune-interridge plains. Groundwater in all these

formations occurs at depths from 0.5–3 m (deflation hollows, interdune depressions, *sor* and lake depressions, river floodplains, etc.) to 15–20 m (elevated watershed plains). The mineralization and chemical composition of pore groundwater are extremely diverse. The least mineralized waters (with rare lenses of saline waters), with total dissolved solids up to 1 g/L, are developed in the Naryn massif, Biryuk-Taisoygan, and also in the valley of the Ural River.

Confined waters are widespread in the region. However, slightly mineralized waters (total dissolved solids 1.5–5 g/L) are developed only within the thickness of Upper Albian deposits in the marginal part of the South Emba salt-dome district, east of the Kulsary, Tyulyus–Karachungul belt. They are confined to horizons of fine- and medium-grained quartz-glaucinite sands with a total thickness of 25–70 m (on average about 35 m) and occur near salt domes at depths of 250–350 m and between domes at depths of 500–700 m. Groundwater mineralization varies from 2–8.3 g/L in the eastern part of the South Emba district to 15–160 g/L and more in the west of the district and in the central part of the Caspian Depression. The water composition is sodium chloride.



1 – water-permeable modern aeolian horizon; 2 – Upper Quaternary marine Khvalynian aquifer and Lower–Middle Quaternary marine Baku-Khazarian aquifer; 3 – Upper Cretaceous aquifer complex; 4 – Quaternary alluvial aquifer; 5 – Cenomanian-Albian aquifer complex.

Figure 2. Hydrochemical characteristics of water from the surveyed boreholes and wells in the Atyrau Region

Alluvial waters often have a more pronounced bicarbonate component compared with marine horizons, which tend toward the sulfate-chloride type. Deep aquifer complexes (Cretaceous deposits — Cenomanian-Albian and Upper Cretaceous) are usually characterized by a more stable chemical composition. In the diagram, they are grouped in the zone reflecting the gradual metamorphization of composition from bicarbonate to sulfate or chloride with increasing depth. In all horizons, a significant predominance of sodium and potassium over divalent cations (calcium and magnesium) is observed. This is typical of zones with intense evaporative concentration or marine genesis of the deposits. In the Khvalynian and Baku-Khazarian deposits, the highest average sulfate-ion values were recorded (776.5 mg/L). This may indicate the presence of gypsum in the water-bearing rocks. The total ion content in the Upper Cretaceous horizon is

less than 1,000 mg/L, which complies with standards for all types of livestock. Most water sources from the Cenomanian-Albian deposits are within the mineralization range of 1,000–3,000 mg/L. Such water is suitable for cattle, sheep, and horses without restriction. Sources in the marine Khvalynian and Baku-Khazarian horizons with sodium contents above 4,000–8,000 mg/L are unsuitable for cattle but may be used to a limited extent for adult sheep (the most salt-tolerant animals) with gradual adaptation.

The most powerful source of pasture watering is fresh and slightly brackish groundwater from the Cenomanian-Albian deposits, widely known in Mangyshlak. These waters are of great importance in the territory located east of the Caspian Karakums, where the Cenomanian-Albian aquifer complex occurs at depths of 300–500 m (Table 3, Figure 3).

Table 3. Hydrogeological characteristics of the surveyed underground water sources from aquifers in the Mangystau Region

Aquifers	Well type	Number	Depth, m	Static level, m	Yield, dm ³ /s	Mineralization, g/dm ³
Modern aeolian	dug well	16	5,4-11	4,7-10	0,1-0,2	0,7-49,2
	borehole	6	20-80	12-64	0,5-1,2	0,9-16,1
Upper Quaternary marine Khvalynian, Lower–Middle Quaternary marine Baku-Khazarian	dug well	2	3-5	2-4	0,3	14,1
	borehole	9	15-500	9-70	0,09-1,2	0,6-9
Eocene-Paleocene deposits	borehole	3	90-300	70	1,2	3,2-9,5
Cenomanian-Albian deposits	borehole	4	70-500	50-54	0,8-1,2	0,98-8
Sarmatian deposits	dug well	10	5-20	1,2-12	0,09-0,32	1,28-10,7

	borehole	18	18-1200	12,5-120	0,6-1,4	3,8-22,5
Modern lacustrine-sor deposits	borehole	1	1000	120	1,4	16,8
Upper Cretaceous deposits	borehole	4	100-500	70-80	0,9-1,2	5,6-10,1

Groundwater reserves with mineralization of 1–3 g/L here are preliminarily estimated at more than 5 m³/s, of which 1.5–2 m³/s of water can be obtained under free artesian flow.

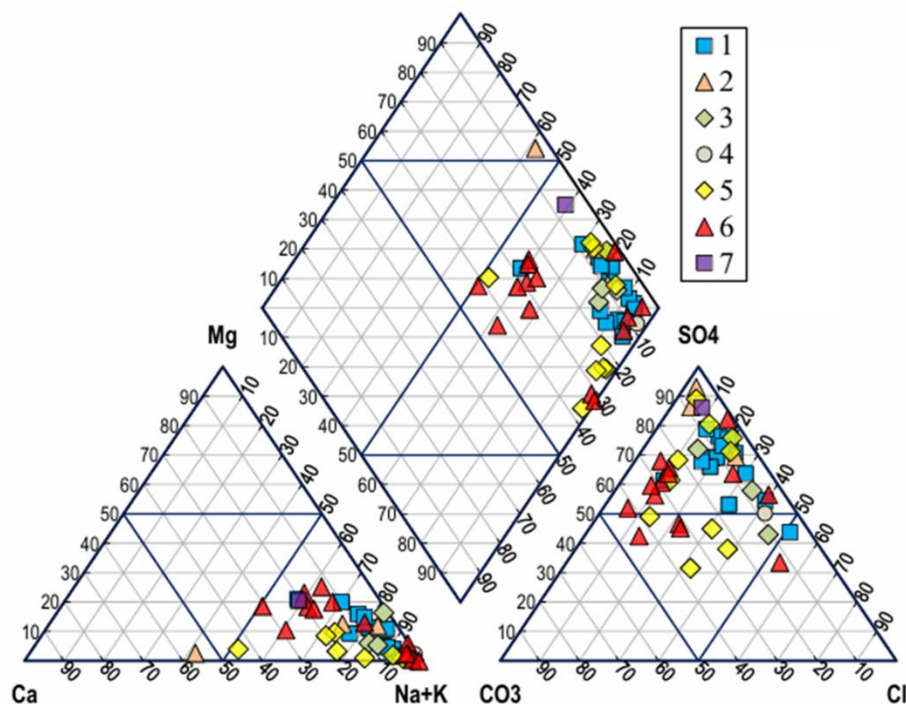
At present, there are more than 100 flowing boreholes in this area, yielding slightly brackish waters with mineralization from 1 to 4–6 g/L and a total discharge of 0.6 m³/s. However, only a small portion of this water is used for livestock watering. On the Mangyshlak Peninsula, waters of the Cenomanian-Albian aquifer complex are used for livestock watering in the areas of mountainous and southern Mangyshlak.

Marine Quaternary deposits are widespread everywhere, but groundwater occurs in them locally in lenses and interbeds of sand. In the central elevated part of the North Mangyshlak, or Buzachi, artesian basin, fresh and slightly brackish waters predominate, while along its margins saline waters and brines occur. The depth of groundwater occurrence, depending on

landform morphology, varies from 5 to 10 m and sometimes reaches 15 m.

From a hydrogeological point of view, the Central Mangyshlak district is a local recharge area for many aquifers. Groundwater suitable for pasture watering is developed mainly in Permian-Triassic and Cenomanian-Albian deposits. Within the Permian-Triassic sequence, these waters are confined to the uppermost, most fractured part of the zone, up to 40–50 m thick, and have mineralization of 0.3–0.8 g/L, more rarely higher. Groundwater in polymictic sands and sandstones of the Upper Albian and Cenomanian occurs at depths of 10–70 m and has mineralization of 0.6–2 g/L.

Analysis of the data indicates significant hydrochemical heterogeneity. Deep horizons (Cenomanian-Albian, Cretaceous) have a stable, mature composition, whereas Quaternary and modern horizons strongly depend on evaporative concentration processes and interaction with salt-bearing sediments.



1 – Sarmatian aquifer; 2 – Eocene–Paleocene aquifer complex; 3 – Upper Cretaceous aquifer complex; 4 – aquifer of modern lacustrine-sor deposits; 5 – Upper Quaternary marine Khvalynian aquifer and Lower–Middle Quaternary marine Baku-Khazarian aquifer; 6 – water-permeable modern aeolian horizon; 7 – Cenomanian-Albian aquifer complex.

Figure 3. Hydrochemical characteristics of water from the surveyed boreholes and wells in the Mangystau Region

The upper part of the platform cover of the South Mangyshlak artesian basin is of the greatest practical importance, where groundwater suitable for pasture watering is contained in Cenomanian-Albian and Sarmatian deposits, as well as in Quaternary aeolian sands. The depth of groundwater

occurrence in the aquifers of the Cenomanian-Albian complex within the area is highly variable. Borehole productivity varies from 5 to 48 L/s. Fresh and slightly brackish waters (0.7–8 g/L) in Sarmatian deposits occur in the northern and central parts of the plateau at depths of 15–40 m. The yields of watering points

are 0.1–8 L/s, more rarely up to 8 L/s. Fresh waters (0.3–1 g/L) are also developed in sandy aeolian massifs. When penetrated by boreholes, these waters yield 1–8 L/s. Fresh waters (0.3–1 g/L) of shallow occurrence (1–25 m) are also developed in sandy aeolian massifs. When penetrated by boreholes, these waters yield 1–8 L/s.

One of the important sources of pasture watering is groundwater from Sarmatian limestones, which is widespread in Mangyshlak and on the Ustyurt Plateau and is relatively easily accessible because of its shallow occurrence. The thickness of the zone of fresh and brackish waters in different parts of this territory varies from 1–3 to 5–10 m and only rarely reaches 20 m. Waters from the Sarmatian limestones are widely used for livestock watering. These waters are encountered by wells 5–15 to 30–40 m deep and, more rarely, 60 m. Groundwater from the Sarmatian limestones is encountered by wells and boreholes at depths from 5–10 to 50–60 m, with yields from hundredths of a unit to 0.5 L/s.

Within the Quaternary aeolian sands and Neogene limestones, which are widespread within Ustyurt, slightly mineralized groundwater suitable for pasture watering is contained. These waters occur at depths from 5–6 to 20–30 m and more. The thickness of the water-bearing rocks varies from 10 to 25 m, and the mineralization of the waters often exceeds 1–3 g/L. The water abundance of the deposits varies: the yields of watering points range from 0.1–0.3 to 6 L/s. Specific capacities are 0.1–0.5 m/s. Groundwater is encountered in sands at depths from 1 to 12 m. The thickness of the aquifer in the center of the massif reaches 17–20 m, decreasing toward its margins to 1.5–0.5 m. Water mineralization varies within 0.7–12 g/L, and in depressions between bakhans it reaches 50 g/L and more.

CONCLUSION

The organization of pasture watering directly depends on the availability of water resources in the area.

For the effective use of groundwater, it is necessary to describe the hydrogeological conditions and the distribution of groundwater within pasture areas. Various parameters of artesian and groundwater, the conditions of their formation, their regime, and the patterns of occurrence of high-yield aquifers should be studied and mapped in greater depth and detail. For this purpose, research should be directed toward groundwater exploration and testing, as well as detailed hydrogeological surveying of pasture territories, especially in areas where groundwater occurs sporadically and has highly variable mineralization. The republic has vast pasture areas that are not used in the economy, with a total area amounting to tens of millions of hectares. At the same time, the forage from only the pastures currently in use replaces no less than several million hectares of arable land. This clearly demonstrates the importance of pasture-watering measures.

Within the framework of this project, research work is being carried out to develop methods for the effective watering of pastures using groundwater.

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