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The scientific journal News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences has been indexed in the international abstract and citation database Scopus since 2016 and demonstrates stable bibliometric performance.

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«Қазақстан Республикасы Ұлттық ғылым академиясының Хабарлары. Геология және техникалық ғылымдар сериясы» ғылыми журналы 2016 жылдан бастап халықаралық реферативтік және ғылымиметриялық Scopus дерекқорында индекстеледі және тұрақты библиометриялық көрсеткіштерді көрсетіп келеді.

Сонымен қатар журнал Web of Science платформасының (Clarivate Analytics, 2018) халықаралық реферативтік және наукометриялық дерекқоры Emerging Sources Citation Index (ESCI) тізіміне енгізілген.

ESCI дерекқорында индекстелуі журналдың халықаралық ғылыми рецензиялау талаптары мен редакциялық этика стандарттарына сәйкестігін растайды, сондай-ақ Clarivate Analytics компаниясы тарапынан басылымды Science Citation Index Expanded (SCIE), Social Sciences Citation Index (SSCI) және Arts & Humanities Citation Index (AHCI) дерекқорларына енгізу қарастырылуда.

Scopus және Web of Science дерекқорларында индекстелуі жарияланымдардың халықаралық деңгейде жоғары сұранысқа ие болуын қамтамасыз етеді, олардың дәйексөз алу көрсеткіштерінің артуына ықпал етеді және редакциялық алқаның геология мен техникалық ғылымдар саласындағы өзекті, бірегей және ғылыми тұрғыдан маңызды зерттеулерді жариялауға ұмтылысын айқындайды.

Научный журнал «News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences» с 2016 года индексируется в международной реферативной и наукометрической базе данных Scopus и демонстрирует стабильные библиометрические показатели.

Журнал также включён в международную реферативную и наукометрическую базу данных Emerging Sources Citation Index (ESCI) платформы Web of Science (Clarivate Analytics, 2018).

Индексирование в ESCI подтверждает соответствие журнала международным стандартам научного рецензирования и редакционной этики, а также рассматривается компанией Clarivate Analytics в рамках дальнейшего включения издания в Science Citation Index Expanded (SCIE), Social Sciences Citation Index (SSCI) и Arts & Humanities Citation Index (AHCI).

Индексирование в Scopus и Web of Science обеспечивает высокую международную востребованность публикаций, способствует росту цитируемости и подтверждает стремление редакционной коллегии публиковать актуальные, оригинальные и научно значимые исследования в области геологии и технических наук.

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ZONING OF GROUNDWATER FLOW IN WATER MANAGEMENT BASING OF WESTERN AND NORTHERN KAZAKHSTAN

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Abstract. *Relevance.* Groundwater flow is a key component of the hydrological cycle, particularly in arid and semi-arid regions, where it represents one of the most reliable sources of freshwater and plays a critical role in maintaining river baseflow, ecosystems, agricultural production, and water supply. In Kazakhstan, increasing climate variability, rising air temperatures, changing precipitation patterns, and intensifying anthropogenic pressures, including groundwater abstraction and land-use transformation, have significantly affected groundwater recharge, storage and distribution. These changes create growing uncertainty regarding the availability of renewable groundwater resources and highlight the need for improved approaches to their regional assessment and sustainable management. *Objective.* The study is to regionalize groundwater flow in the watersheds of Western and Northern Kazakhstan and to identify the natural and anthropogenic factors controlling it is spatial variability. *Methods.* The methodology combines hydrogeological data with analysis and assessment of climate and anthropogenic change trends in groundwater basins. Spatial analysis and assessment of watersheds were used to assess groundwater flow variability and identify controlling factors. *Results*. The studies reveal marked spatial unevenness in groundwater flow within watersheds, driven by climatic gradients, geological conditions, and human activities. Analysis of climate trends indicates moderate variations in groundwater formation conditions with regional characteristics, improves the accuracy of groundwater resource assessments and identifies priority zones for sustainable water use. *Conclusions.* Zoning groundwater resources provides an effective basis for assessing the interactions between surface and groundwater within the water management basins of Western and Northern Kazakhstan. The hydrogeological structure of the study area is characterized by a predominance of endorheic aquifers, which occupy 89.2% of the territory, while platform artesian basins account for 91.5% of the total area. Nationally, 74.4% of Kazakhstan's territory is classified as closed groundwater exchange basins, while only 25.6% drains toward the Kara Sea basin.

Keywords: groundwater flow, GIS, water resources management, Western and Northern Kazakhstan

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БАТЫС ЖӘНЕ СОЛТҮСТІК ҚАЗАҚСТАННЫҢ СУ ШАРУАШЫЛЫҒЫ БАССЕЙНДЕРІНДЕГІ ЖЕРАСТЫ АҒЫНДАРЫН АЙМАҚТАНДЫРУ

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Аннотация. *Өзектілігі.* Жерасты суларының ағыны, әсіресе құрғақ және жартылай құрғақ аймақтарда, гидрологиялық циклдің маңызды құрамдас бөлігі ретінде, тұщы судың негізгі су көздерінің бірі және өзендердің, экожүйелердің, ауыл шаруашылығы өндірісінің, сондай-ақ сумен жабдықтаудың негізгі ағынын сақтауда маңызды рөлін атқарушы болып табылыды. Қазақстанда климаттың өзгергіштігінің артуымен, ауа температурасының көтерілуімен, жауын-шашын режимінің өзгеруімен, жерасты суларын алуымен және жерді пайдаланудың өзгеруін қоса алғанда, және антропогендік әсерлердің артуы жерасты суларының қалыптасуына, сақталуына, таралуына айтарлықтай әсер етеді. Бұл өзгерістер жаңартылатын жерасты суларының қолжетімділігіне қатысты белгісіздік тудырады және оларды аймақтық бағалау мен тұрақты басқаруға жетілдірілген тәсілдер қажеттілігін көрсетеді. *Мақсаты.* Батыс және Солтүстік Қазақстанның су шаруашылығы бассейндеріндегі жерасты суларының ағынын аймақтандыру және оның кеңістіктік өзгергіштігін басқаратын табиғи және антропогендік факторларды анықтау. *Әдістері.* Әдістеме гидрогеологиялық деректерді, жерасты сулары бассейндеріндегі климаттық және антропогендік өзгерістердің үрдістерін талдау мен бағалауды біріктіреді. Жерасты сулары ағынының өзгергіштігін балалаумен және бақылыушы факторларды анықтау үшін кеңістіктік талдау және бассейндік бағалау қолданылды. *Нәтижелері.* Зерттеулер климаттық градиенттерге, геологиялық жағдайларға және адамның іс-әрекетіне байланысты су шаруашылығы бассейндеріндегі жерасты суларының ағынының кеңістіктік біркелкі еместігін көрсетеді. Климаттық үрдістердін талдауы аймақтық ерекшеліктері болып келетін жерасты суларының қалыптасу жағдайларының орташа өзгерістерін көрсетеді, сондай-ақ жерасты сулары ресурстарын бағалаудың дәлдігін жақсартады және тұрақты суды пайдаланудың басым бағыттарын аңықтайды. *Қорытынды.* Жерасты суларының ресурстарын аймақтарға бөлу мақсатында Батыс және Сотлүстік Қазақстанның су шаруашылығы бассейндеріндегі жер үсті және жерасты суларының өзара әрекеттесуін бағалау үшін тиімді негіз болып табылады. Зерттеу аймағының гидрогеологиялық құрылымы аумақтың 89,2%-ын алып жатқан эндорейлік жерасты сулы горизонттарының басым болуымен сипатталады, ал платформалық артезиан бассейндері жалпы аумақтың 91,5%-ын алып жатыр. Жалпыұлттық деңгейде Қазақстан аумағының 74,4% жабық жерасты алмасу бессейндеріне жатады, ал тек 25,6%-ы ғана Карс теніз бассейніне қарай ағып жатқан сулар болып келеді.

Түйін сөздер: жерасты ағыны, ГАЖ, су ресурстарын басқару, Батыс және Солтүстік Қазақстан

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РАЙОНИРОВАНИЕ ПОДЗЕМНОГО СТОКА ПО ВОДОХОЗЯЙСТВЕННЫМ БАССЕЙНАМ ЗАПАДНОГО И СЕВЕРНОГО КАЗАХСТАНА

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Аннотация. *Актуальность.* Подземный сток является ключевым компонентом гидрологического цикла, особенно в засушливых и полузасушливых регионах, где он представляет собой один из наиболее надёжных источников пресной воды и играет важную роль в поддержании базового стока рек, устойчивости экосистем, сельскохозяйственного производства и водоснабжения. В Казахстане усиливающаяся климатическая изменчивость, повышение температуры воздуха, изменение режима осадков и рост антропогенной нагрузки, включая отбор подземных вод и трансформацию землепользования, оказывают существенное влияние на формирование, накопление и пространственное распределение ресурсов подземных вод. Эти изменения повышают неопределённость в оценке доступности возобновляемых ресурсов подземных вод и подчёркивают необходимость совершенствования подходов к их региональной оценке и устойчивому управлению. *Цель.* Провести районирование подземного стока в пределах водохозяйственных бассейнов Западного и Северного Казахстана и выявить природные и антропогенные факторы, определяющие его пространственную изменчивость. *Методы.* Методология исследования объединила гидрогеологические данные, пространственный анализ, а также оценку климатических и антропогенных изменений в пределах бассейнов подземного стока. Для определения пространственной изменчивости подземного стока и выявления контролирующих факторов проведено сопоставление гидрогеологических, климатических и водохозяйственных характеристик исследуемых бассейнов. *Результаты.* Установлена выраженная пространственная неравномерность подземного стока в пределах водохозяйственных бассейнов, обусловленная климатическими градиентами, геологическим строением и антропогенной деятельностью. Анализ климатических тенденций выявил умеренные изменения условий формирования ресурсов подземных вод, характеризующиеся региональными различиями. Проведённое районирование позволило повысить обоснованность оценки ресурсов подземных вод и выделить приоритетные зоны для устойчивого водопользования. *Выводы.* Районирование подземного стока формирует научно обоснованную основу для оценки взаимодействия поверхностных и подземных вод в пределах водохозяйственных бассейнов Западного и Северного Казахстана. Гидрогеологическая структура исследуемой территории характеризуется значительной долей бессточных бассейнов подземных вод, охватывающих 89,2 % территории. При этом платформенные артезианские бассейны занимают 91,5 % общей площади исследуемой территории. В национальном масштабе 74,4 % территории Казахстана относится к замкнутым бассейнам подземного стока, тогда как 25,6 % территории дренируется в направлении бассейна Карского моря

Ключевые слова: подземный сток; гидрогеологическое районирование; водохозяйственные бассейны; ГИС; управление водными ресурсами; Западный Казахстан; Северный Казахстан

Introduction. In the context of the increasing impact of climate change and increasing anthropogenic pressure on water resources, the problem of sustainable groundwater management is becoming particularly relevant, especially for arid and semi-arid regions, which include a significant part of the territory of the Republic of Kazakhstan. Groundwater flow is a vital component of the water balance, providing river nutrition, ecosystem stability, and water supply for the population and economic facilities. At the same time, it is spatial unevenness and sensitivity to external factors require spatial analysis. (Smolyar, 2023; Margat and Gun, 2013; Misstear et al., 2023).

The value of global groundwater flow, according to expert estimates, varies between 12-14 thousand km^3/year, while the share of global water withdrawal is only up to 8.3% (Famiglietti, 2014). Groundwater flow plays an important role in assessing the resource potential of groundwater and characterizes the upper limit of possible groundwater extraction over a long period without it is depletion (Link et al., 2023; Luijendijkv, 2022; Eamus et al., 2016).

In arid and semi-arid regions, which cover about 30% of the Earth’s land surface, the renewal of both surface water and groundwater resources is hampered by low and scanty rainfall. Moreover, the majority of this territory consists of endorheic areas, occupying more than 10% of Earth’s land area. Aquifers here are either drained by streams in endorheic river basins or discharged by evaporation in closed depressions. However, in arid and semi-arid regions, groundwater is usually the only permanent source of water (Sagin et al., 2017; Manghi et al., 2009).

According, the unity of groundwater and surface water is reflected by groundwater flow basins (GFB) or water exchange basins (WEB), which represent the continental hydrogeological structure of the drained part of the earth's crust and it is daylight surface, within the boundaries of which the water balance is formed and the water cycle in nature is carried out (Zektser, 1977; Absametov et al., 2019). Groundwater flow is formed in the drainage zone of the earth's crust as a component of the hydrological cycle of the water cycle in nature, determined by the hydraulic potential of the earth's surface relief and structural and hydrogeological features. The upper hydrodynamic zone, called the zone of active or free (intensive) water exchange, appears to be the most important (Vsevolozhsky, 1983; Carletti et al., 2019; Jasechko et al., 2024).

Western and Northern Kazakhstan are characterized by complex hydrogeological conditions, significant variability of climatic parameters and the increasing influence of economic activity, including water extraction, agriculture and industrial development of the territories. Under these conditions, traditional approaches to assessing and zoning groundwater flow, based primarily on stationary observations, prove insufficient to adequately take into account the spatiotemporal variability of groundwater formation processes (Absametov et al., 2016; Smolyar et al., 2012).

Modern geographic information systems (GIS) and spatial analysis methods open up new opportunities for integrating heterogeneous data, including hydrogeological, climatic and anthropogenic factors, which allows for increasing the accuracy and informativeness of assessments. Despite this, issues of comprehensive zoning of groundwater flow taking into account climate trends and anthropogenic impacts for the territory of Kazakhstan remain insufficiently developed, especially at the level of water management basins (Smolyar, 2023; Botter et al., 2007).

In this regard, the purpose of this study is to apply the approach of integrated zoning of groundwater flow and analysis of climatic trends for the conditions of Western and Northern Kazakhstan. The study addresses the following objectives: (1) substantiation of the methodology for zoning groundwater flow taking into account natural and anthropogenic factors; (2) analysis and assessment of climate change and it is impact on the formation of groundwater flow; (3) spatial assessment and mapping of groundwater flow in water management basins.

The scientific novelty of the work lies in the analysis and assessment of trends in climatic and anthropogenic changes in groundwater basins, as well as in the choice of a methodology for zoning the territory by flow basins, which makes it possible to clarify the patterns of it is formation and spatial distribution, as well as to increase the reliability of the assessment of renewable groundwater resources. The practical significance of the study lies in the possibility of using the obtained results to improve the water resources management system and justify water management decisions at the regional level.

Materials and methods. This article presents methodological approaches to zoning Kazakhstan's territory by groundwater basins, including the justification and selection of zoning criteria, analysis and assessment of climate and anthropogenic change trends within groundwater basins, justification and selection of methods for regional assessment and mapping of groundwater, and the development of a geoinformation and analytical subsystem for presenting groundwater assessment results. The results obtained are used to refine the values of renewable resources and regional forecast resources of fresh and low-mineralized groundwater.

Results and discussion. The unity of groundwater and surface water is reflected in groundwater flow basins, or “water exchange basins”, which the continental hydrogeological structure of the drained portion of the earth’s crust and it is surface, within whose boundaries the water balance is formed and the natural water cycle occurs. Hydrogeological zoning by groundwater flow basins involves identifying groundwater flow basin types and establishing the taxonomic rank of these basins (Zektser, 1977). The water exchange basin zoning map is combined with structural-hydrogeological and geomorphological zoning maps, which provides a reflection of the relationships between groundwater flow basins and hydrogeological and geomorphological structures (Vsevolozhsky, 1983).

Hydrogeological zoning by groundwater flow basins (GFB) involves identifying types and establishing the taxonomic rank of basins. The boundaries and structure of groundwater catchments are determined by the relief, which was formed under the influence of the structural and geological development of the region. This development was determined by tectonic geodynamics, as well as the formational composition and lithofacies changes of the rocks composing the corresponding catchments. Types of water exchange basins (WEB) include continental, regional (simple and complex), subregional (components of complex regional basins), local, and elementary, reflecting differences in the drainage patterns of the hydrogeological section of the corresponding drainage hydrographic network and the determinacy of groundwater flow by various hydrodynamic zones (Smolyar et al., 2002; Absametov et al., 2019).

In accordance with the accepted classification as shown in Table 1, there are five main types of water exchange basins: continental, regional, subregional, local and elementary. Their distinction is based on the scale of hydrogeological systems, the composition of hydrogeodynamic zones involved in water exchange, as well as the peculiarities of the formation and direction of groundwater flow.

Continental water exchange basins are the largest hydrogeological systems and encompass all hydrodynamic zones of artesian basins, including zones of free, impeded, and slow water exchange. They are characterized by complete hydrodynamic zonation and groundwater discharge into seas and oceans. Groundwater flow is represented by both descending and descending-ascending flows in the free water exchange zone, and ascending pressure flows in deep hydrodynamic zones (Smolyar et al., 2012; Zektser, 1977).

Regional water exchange basins form within the free-flow zones of large artesian basins and foothill depressions. Their boundaries are determined by the location of regional aquicludes and the characteristics of hydrogeochemical zonation. The structure of groundwater flow is dominated by descending and descending-ascending flows, with limited connection to deeper water exchange zones through tectonic faults.

Subregional basins represent a lower taxonomic level and are formed within a zone of free water exchange drained by a regional hydrographic network. They are characterized by a layered structure due to the alternation of aquifers and confining horizons. Groundwater flow is primarily localized within the basin, and groundwater transit is weak (Vsevolozhsky, 1983; Absametov et al., 2016).

Local water exchange basins correspond to the catchments of small rivers and encompass primarily unconfined and, to some extent, subconfined waters of the free water exchange zone. Within these basins, downward groundwater flow predominates, and the volume of drained water is comparable to or greater than the volume of transit flow.

Elementary basins are the smallest structural units of zoning and are formed within the boundaries of marginal-order watersheds. They are characterized by the development of downward groundwater flow in a zone of free water exchange, with the amount of drained flow usually less than the transit flow.

Due to the fast that within the elementary and local water exchange basins a significant amount is transit flow, which is discharged into regional or subregional water exchange basins, the total volume of groundwater flow of the elementary flow basins is not equal to the amount of groundwater flow of the local flow basins, and the sum of the flow of the latter is not equal to the total groundwater flow of the regional flow basin (Smolyar et al., 2012).

The presented classification reflects the hierarchical structure of water exchange basins and allows for territorial zoning with varying levels of detail. Balance areas of subsequent orders can be the distribution areas of individual aquifers, including areas of recharge, transit, and discharge of groundwater. Detailed studies identify smaller structural units, such as river valleys and their individual sections, as well as areas of development of various types of groundwater, including karst massifs, alluvial, alluvial-proluvial, and fluvioglacial deposits. This approach ensures, a consistent transition from regional analysis to a local assessment of the conditions of groundwater formation and movement.

The hydrogeological zoning map for water exchange basins is combined with structural-hydrogeological and geomorphological zoning maps, which provides, a representation of the relationships between water exchange basins and hydrogeological structures, as well as between water exchange basins and geomorphological regions. This approach allows us to establish spatial patterns of groundwater formation, movement, and discharge, as well as determine the influence of geological structure and topography on water exchange conditions. This creates a unified basis for identifying hierarchically subordinate water exchange basins and assessing groundwater flow characteristics at various territorial levels.

The territory of Kazakhstan, according to the conditions of formation and distribution of surface river runoff, is divided into two large basins: the open basin of the Arctic Ocean (Kara Sea) and the endorheic basin of internal runoff (Absametov, 2016).

The internal flow basin is divided into 4 endorheic basins: the Caspian Sea basin, the Aral Sea basin, the Balkhash-Alakol basin and the basin of lakes Teniz and Karasor (Smolyar et al., 2012).

According to the water management and administrative zoning of surface water resources on the territory of Kazakhstan, eight water management basins have been identified: Zhaiyk-Caspian, Tobyl-Torgai, Yesil, Shu-Talas, Aral-Syrdarya, Balkhash-Alakol, Ertis and Nura-Sarysu (Sagin et al., 2017; Smolyar, 2023).

The zoning scheme of water exchange basins taking into account water management zoning is presented in Figure 1. Three continental water exchange basins are distinguished: the open Kara Sea, the clothed endorheic Caspian and Aral; two regional water exchange basins: the closed endorheic Balkhash-Alakol and Nura-Teniz.

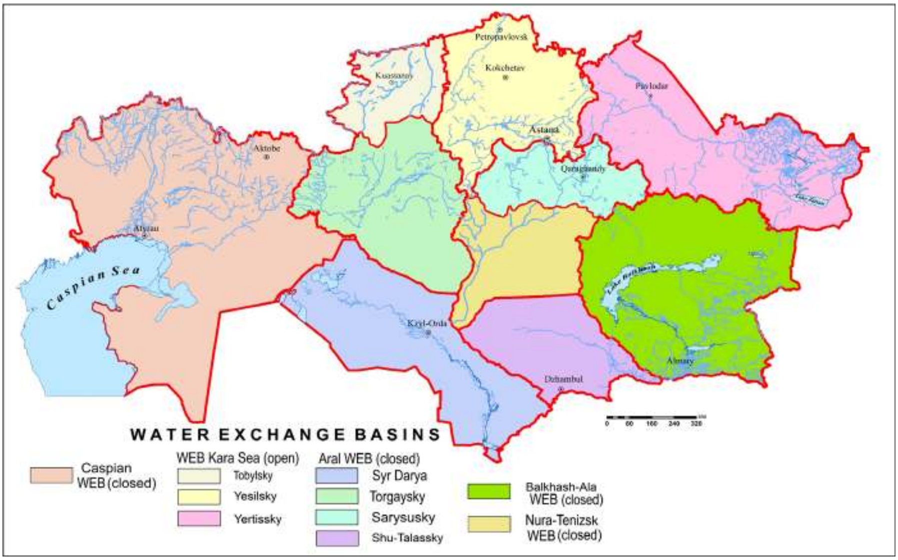

Figure 1. Map of water exchange basins in Kazakhstan.

The largest is the continental Aral water exchange basin (30.7% of the country's territory), while the share of the regional Nura-Teniz water exchange basin is 5.6% (Table 1).

Table 1. Zoning of water exchange basins (WEP) in Kazakhstan.

Type of water exchange basin (WEB)	Square	
	thousand km^2	%
Continental of the Kara Sea (open)	696.24	25.6
Continental Caspian Sea (closed)	640.88	23.5
Continental Aral Sea (closed)	836.69	30.7
Regional Balkhash-Alakol (closed)	397.66	14.6
Regional Nura-Teniz (closed)	151.48	5.6
Total for the Republic Kazakhstan	2722.95	100.0

Table 1 show the distribution of Kazakhstan's territory by type of water exchange basin, which characterizes the directions of surface and groundwater flow, as well as the degree of hydrological connection between the territory and the World Ocean. There are five main water exchange basins within the Republic of Kazakhstan, covering a total area of 2722,95 thousand km^2 (Absametov, 2016).

The Kara Sea continental water exchange basin (open) occupies 696.24 thousand km^2, or 25.6% of the country's territory. It includes the Irtysh, Ishim and Tobyl river basins, whose waters are connected to the Arctic Ocean via the Ob-Kara Sea River system. This type of basin is considered open because it provides external flow beyond Kazakhstan's borders and a connection to the World Ocean.

The continental Caspian water exchange basin (closed) covers 640.88 thousand km^2, or 23.5% of the country's territory. It includes the basins of the Ural and Emba rivers and other watercourses flow into the Caspian Sea. Despite it is considerable size, the basin is considered closed because the Caspian Sea has no natural outlet to the ocean and is the largest endorheic body of water in the world.

The continental Aral Sea basin (closed) is the largest in Kazakhstan, covering 836.69 thousand km^2, or 30.7% of the country's territory. It includes the Syrdarya, Shu and Talas River basins, as well as other watercourses. The final recipient of the Aral Sea's flow is an internal endorheic body of water. A significant portion of the basin is characterized by an arid climate and a high dependence of water resources on transboundary inflows (Smolyar et al., 2002).

The Balkhash-Alakol regional water exchange basin (closed) occupies 397.66 thousand km^2, or 14.6% of the country's territory. The main water bodies are Lake Balkhash, the Alakol lake system and the Ili River. The basin has no ocean outflow and is characterized by internal water exchange, determined by the interaction of surface and groundwater within the lake system.

The regional Nura-Tengiz water exchange basin (closed) is the smallest in area, occupying 151.48 thousand km^2, or 5.6% of the country's territory. It includes the Nura and Sarysu river basins, within flow into endorheic lakes, primarily the Lake Tengiz system. Water exchange here occurs exclusively within the internal hydrographic system (Sagin et al., 2017).

The continental Caspian water exchange basin (Zhaiyk-Caspian water management basin) covers almost the entire territory of Western Kazakhstan within the West Kazakhstan, Atyrau, Mangistau and western half of Aktobe regional and occupies 23.5% of the country's area. The hydrographic network of the basin is represented by the Zhaiyk River and it is tributaries; small endorheic rivers flowing to the Zhaiyk River; the basins of the Zhem, Sagiz and Oyil rivers, as well as other rivers of the Volga and Zhaiyk interfluve, and the northern and eastern coasts of the Caspian Sea. The average long-term surface water resources of the Zhaiyk-Caspian water management basin are estimated at 11.23 km^3/year; and in low-water year – up to 3.0 km^3/year (Smolyar, 2023; Absametov et al., 2019).

The Caspian water exchange basin has been regionalized according to the described methodology. The water exchange basin zoning map is combined with structural-hydrogeological and geomorphological zoning maps, which provides a reflection of the relationships between groundwater flow basins and hydrogeological and geomorphological structures. Within the endorheic Caspian continental groundwater basin, the following have been identified: 1 regional (Zhaiyk), 4 subregional (Kigash, Oiyl, Zhemsk and Sagiz), and the Aral-Caspian endorheic zone (Figures 2).

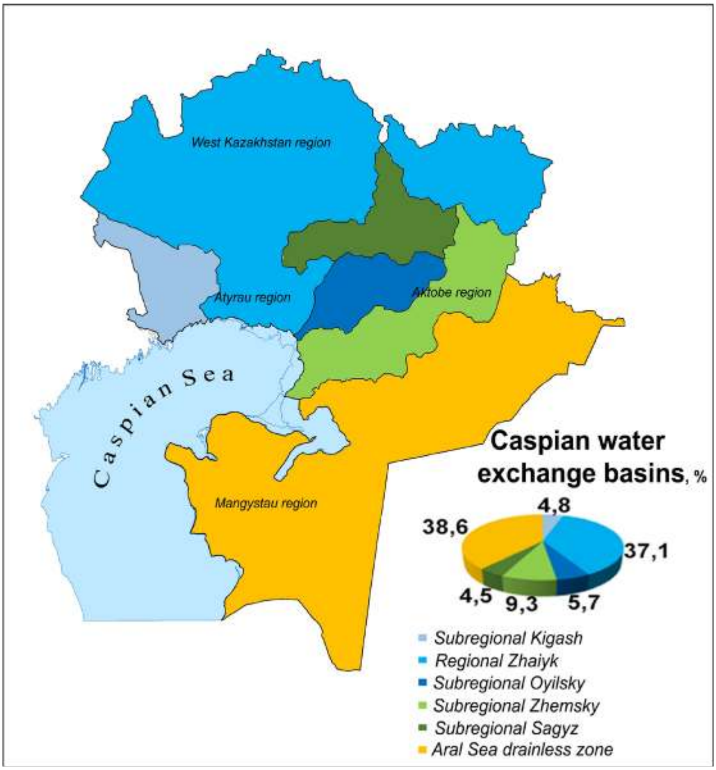

Figure 2. Caspian continental basin groundwater flow.

The continental endorheic Caspian water exchange basin is located at the junction of three major geological structures: the Russian Platform, the Turan Plate, and Ural Mountain-folded region. Hydrogeologically, the territory encompasses three regions: the East Russian, Scythian-Turanian, and Taimyr-Ural (Table 2), and in accordance with the geomorphological zoning of the territory of Kazakhstan, the continental Caspian water exchange basin covers 3 geomorphological regions: the Caspian syneclise, the Turan plate and the folded region of the Southern Ural and Mugalzhar, within which 11 geomorphological regions are distinguished. The names of the geomorphological region within the geomorphological regions are presented in Table 2 (Smolyar et al., 2002; Absametov, 2016).

Table 2. Hydrogeological and geomorphological zoning of the continental endorheic Caspian WEB (Zhaiyk-Caspian WMB).

Hydrogeological zoning		
Regions. Unconfined and confined water basin systems	Provinces. Groundwater basins of the first order (complex basins of unconfined and confined waters)	Subprovinces. Second-order groundwater basins (confined and subconfined water basins)
Eastern European basin system	Russian complex basin	Syrtov basin
	The Caspian complex basin	North-Caspian basin
		Zhem basin
		Donguztau-Predmugalzhar basin
	Preural complex basin	South-Preural basin
Taimyr-Ural basin system	Bolsheural complex basin	Ural basin
Scythian-Turanian basin system	Ustyrt complex basin	Shalkar pool
		North Ustyrt formation water basin
		Bozashin formation water basin
	Amudarya complex basin	South Mangistau basin
		Assakeaudan basin
	Mangystau complex basin	Central Mangistau basin
	Prearal-Turgai-Shu-Sarysu basin	North-Prearal basin
Geomorphological zoning		
Geomorphological region	Geomorphological district	
Caspian syneclise	South of the denudation plateau General Syrt	
	Accumulative plains of the Caspian lowland	
	Zhaiyk-Zhem denudation plateau	
Folded region of the Southern Ural and Mugalzhar	Lowlands and small hills	
	Layered denudation plains of the western rim	
Turanian plate	Accumulative and stratified denudation plains of the Northern Aral Sea	
	Structural-denudational plateau Ustirt	
	Accumulative plains of the Bozashi Peninsula	
	Structural-denudational plateau of Mangistau	
	Structural-denudational plateau Ustirt	
	Lowlands of Mangistau	
	Accumulative and stratified denudation plains of the Northern Aral Sea	
	Accumulative plains of the Torgay-Obagan depression	

Within the boundaries of the identified hydrogeological regions are located eight first-order groundwater basin and 13 second-order groundwater basins. The largest area is occupied by the Caspian (56.5%) and Ustyrt (19.1%) basins, while the smallest are the Predural (1.5%) and Aral-Torgai-Shu-Sarysu (2.1%) basins.

Thus, the zoning of the Caspian continental water exchange basin has revealed it is complex hierarchical structure, reflecting the geological structure, hydrogeological conditions, and topography of Western Kazakhstan. The identification of regional and subregional groundwater basins and their comparison with structural, hydrogeological, and geomorphological units have revealed spatial patterns in the formation, transit, and discharge of groundwater. It has been established that the major hydrogeological structures of the Caspian syneclise, the Turan plate, and the Ural folded region, as well as the characteristics of the modern hydrographic network, have a decisive influence on the organization of groundwater flow (Smolyar et al., 2012).

The Tobyl-Torgay water management basin extends in a meridional direction within the Kostanay region of Northern Kazakhstan, in the Western half of Central Kazakhstan, and occupies 12.2% of the country's area. The basin's hydrographic network is represented by the Tobyl river with it is tributary, the Ubagan river, the Torgay river with it is tributary, the Yrgyz river, and other small streams. The average long-term surface water resources of the Tobyl-Torgay water management basin are estimated at 2.12 km^3/year; in low-water year, at 0.29 km^3/year (Smolyar, 2023).

The Tobyl-Torgay water management basin was zoned according to the described methodology. 2 water exchange basins were identified: the regional Tobyl basin, part of the open continental Kara Sea basin in the northern half of the basin, and the regional Torgay basin, part of the endorheic continental Aral Sea basin in the southern half of the basin (Figure 3).

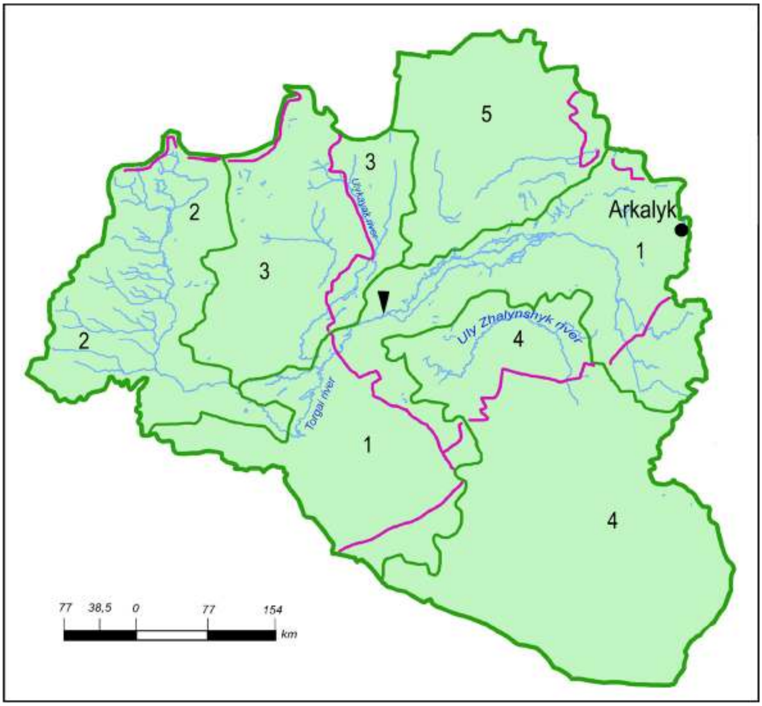

Figure 3. Zoning scheme of the flow basins of the Tobyl water exchange basin.

The regional open Tobyl water exchange basin is located within the southern marginal part of the West Siberian plate and includes the regional Tobyl water exchange basin itself and 2 subregional basins: the Ubagan and Toguzak (Table 3). The regional Tobyl and subregional Ubagan basins occupy mare than 94% of the area.

Table 3. Zoning of open and endorheic flow basins of the Tobyl water exchange basin.

Type of water exchange basin	Square	
	thousand km^2	%
Flow of the open		
Regional Tobyl	53.02	50.4
Subregional Ubagan	46.06	43.8
Subregional Toguzak	6.07	5.8
Flow of the endorheic		
Regional Torgay	69.61	30.5
Subregional Kyrgyz	37.08	16.3
Subregional Ulkayak	35.83	15.7
Uly-Zhilanshyk	55.74	24.4
Subregional basin of Narzum and Sarykopa	29.8	13.1

The regional endorheic Torgay water exchange basin accupies the southern part of the Scythian-Turanian plate, which extends in the northern direction, and includes the regional Torgay water exchange basin itself and 4 subregional basins: Yrgyz, Ulkayak, Ulyzhilanshyk and Naurzum-Sarykopin (Figure 3, Table 3).

The zoning maps of the Tobyl-Torgay water management basin by flow basins are combined with the maps of structural-hydrogeological and geomorphological zoning (Absametov, 2016; Sagin et al., 2017), which ensured the reflection of the relationship between the groundwater flow basins, hydrogeological and geomorphological structures.

In hydrogeological terms, 2 hydrogeological regions are distinguished within the boundaries of the Tobyl water exchange basin: the West Siberian and Taimyr-Ural regions, each containing one basin of the I and II order (Smolyar et al., 2002). The majority of the Tobyl water exchange basin is occupied by the Nizhnevartovsk-Petropavlosk basin of the West Siberian basin system (78%).

Table 4. Hydrogeological zoning of the open Tobyl water exchange basin.

Regions. Unconfined and confined Water basin systems	Provinces. Groundwater basins of the I-st order (complex basins of unconfined and confined waters)	Subprovinces. II-nd order groundwater basins (confined and subconfined water basins)
West Siberian basin system	West Siberian complex basin	Nizhnevartov-Petropavlov formation water basin
Taimyr-Ural basin system	Bolsheural complex basin	Ural basin
Scythian-Turanian basin system	Ustyrt complex basin	Shalkar pool
	Aral-Turgai-Shu-Sarysu basin	North-Aral Sea basin
		Torgai basin
Central Kazakhstan basin system	Ulytau-Zhezkazgan complex basin	Ulytau basin
		Zhezkazgan basin

Within the Torgai water exchange basin, there are three hydrogeological regions: the Scythian-Turanian, Taimyr-Ural, and Central Kazakhstan (Table 4) (Absametov, 2016). Within the boundaries of the identified hydrogeological regions there are 4 I-st order groundwater basins and 6 II-nd order groundwater basins. The largest area is occupied by the Torgai (54%) and the North Aral basins of the II-nd order of thi Aral-Torgai-Shu-Sarysu basin of the I-st order of the Scythian-Turan hydrogeological region (Absametov, 2016; Smolyar et al., 2020).

The open Tobyl water exchange basin, in accordance with the geomorphological zoning of Kazakhstan, covers 2 geomorphological regions: the south of the West Siberian plate and the folded region of the Southern Ural and Mugalzhar, within 3 geomorphological regions are distinguished.

Within the territory of the endorheic Torgai water exchange basin, 3 geomorphological regions are developed: the Turan plate, the folded region of the Southern Ural and Mugalzhar, and the Kazakh Shield, within which five geomorphological regions are distinguished (Smolyar, 2023; Smolyar, 2017).

Therefore, the zoning of the Tobyl-Torgay water management basin based on groundwater flow basins revealed significant differences in the spatial organization of groundwater systems between it is Northern and Southern parts. The Tobyl basin is associated with the open continental basin of the Kara Sea and is dominated by the hydrogeological structures of the West Siberian plate, whereas the Torgay basin belongs to the endorheic Aral basin system and is characterized by a more complex hydrogeological and geomorphological structure. The integration of groundwater flow basin zoning with structural-hydrogeological and geomorphological frameworks made it possible to identify the hierarchical organization of groundwater flow systems and the main factors controlling groundwater recharge, flow and discharge. The obtained results provide a scientific basis for regional groundwater flow assessment, groundwater resource evaluation and the development of sustainable water-resource management strategies in Northern and Central Kazakhstan.

Conclusion. The research results demonstrate that zoning by groundwater basins is an effective basis for studying the relationship between surface and groundwater resources within the water management basins of Western and Northern Kazakhstan. A methodology for hydrogeological zoning by groundwater basins was substantiated and selected for the Zhaiyk-Caspian and Tobyl-Torgay water management basins. Water exchange basins, reflecting the unified processes of surface and groundwater flow formation within hydrogeological systems, were adopted as the basic territorial unit.

The identification and taxonomic classification of water exchange basins were conducted, as well as their correlation with the structural, hydrogeological, and geomorphological zoning of the territory. It was established that the Zhaiyk-Caspian water exchange basin belongs to the Caspian continental groundwater basin and includes one regional and four subregional basins. Within the Tobyl-Torgay water exchange basin, two regional water exchange basins – the Tobyl and Torgay – were identified, comprising six subregional groundwater basins.

Within the Zhaiyk-Caspian and Tobyl-Torgay water management basins, endorheic groundwater basins predominate (89.2% of the area). In terms of hydrogeology, the platform artesian basins of the Caspian Depression, Scythian-Turanian and West Siberian plates predominate (91.5% of the total area of the water management basin). The common regional recharge area for the three identified water exchange basins in Kazakhstan is the lowlands of the Southern Ural and Mugalzhar.

The analysis revealed that the majority of Kazakhstan's territory (74.4%) lies in closed water exchange basins (the Caspian, Aral, Balkhash-Alarol and Nura-Teniz basins), where runoff does not groundwater flow into the ocean. Only 25.6% of the country's territory lies in the open Kara Sea basin, which receives external flow through the Ob river system. This water exchange structure determines the high dependence of Kazakhstan's water resources on domestic climatic conditions, evaporation and transboundary water inflows from neighboring countries.

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