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# Water resources of the republic of Tuva and their current state

## Abstract

The inland location of the Republic of Tyva and its relatively high altitude, combined with the arid climate, contribute to the formation of a specific hydrological regime of water bodies that are vulnerable to climate change. The features of formation and current state of water resources of Tuva are considered. A brief description of the main water objects is given. Existing estimates of the impact of anthropogenic factors and climate change on individual components of the water balance are discussed.

**Keywords:** water resources, rivers, lakes, republic of Tuva

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## Introduction

The Republic of Tuva is the youngest subject of the Russian Federation, which became part of the country in 1944. It is part of the Siberian Federal district, in the South and South – East it borders with the Mongolian people's Republic, in the North-East-Irkutsk region, in the North – West-the Republic of Khakassia, in the East – the Republic of Buryatia, in the West – the Republic of Altai, in the North – Krasnoyarsk region (Figure 1). The length of the territory from North to South is 420km, from West to East – 630km.


**Figure 1** Republic of Tyva on the map of Russia.

## Methodology and conditions of research

In the course of our work, we used comparative geographical, analytical and geoinformation methods and the method of an integrated approach, which showed that Tuva is attractive and rich in water resources. All rivers and lakes within the Republic of Tyva belong to the upper part of the Yenisei basin and a much smaller part – to the basins of the drainage basins of Central Asia with lakes Ubsa-Nur, Ureg-Nur and Achit-Nur (Figure 2). In the extreme South-East, it includes a small section of the Selenga river basin, which flows into lake Baikal. The largest of the rivers reach the small lake, after leaving the mountains on the foothill plains, disappear in the loose soil, spending their reserves on filtration and evaporation.[1,2]

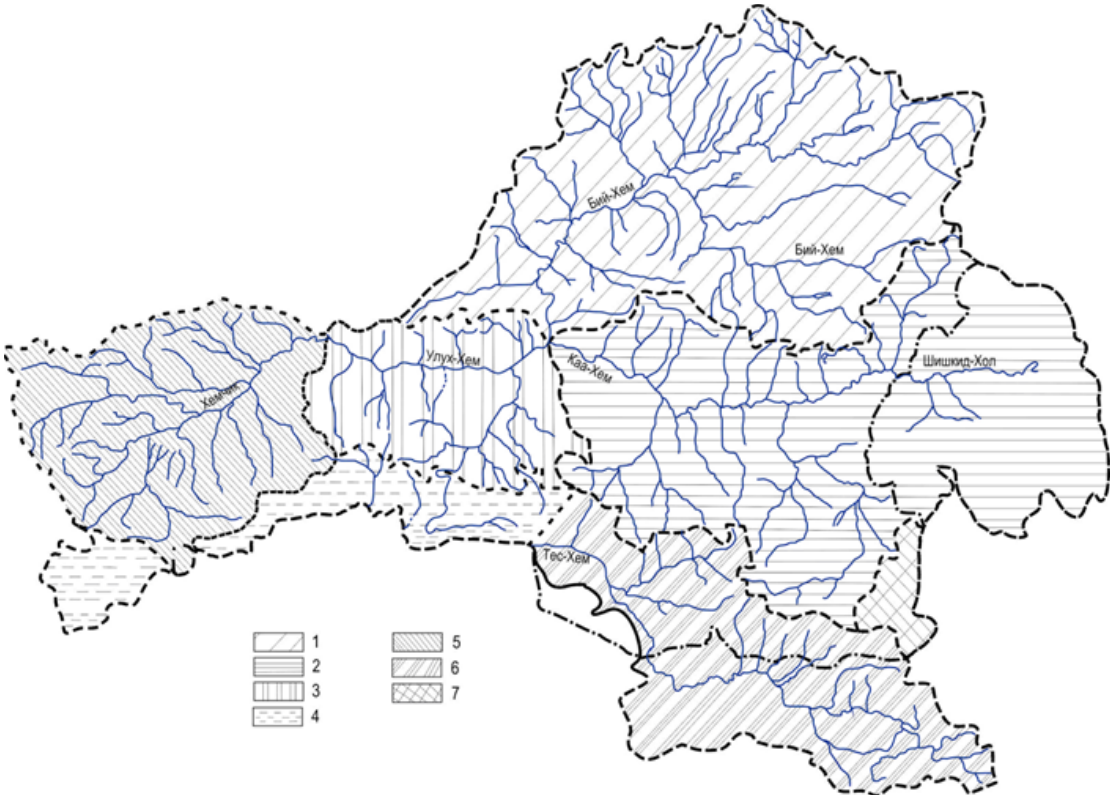


**Figure 2** Schema of Tuva river catchment basins: 1, Biy-Khem catchment basin; 2, the same, Kaa-Khem; 3, the same, Ulug-Khem; 4, the same, rivers of the drainless basin of the Great Lakes of Mongolia; 5, the same, Khemchik; 6, the same, Tes-Khem (Northern part of the basin of the great lakes basin); 7, the same, Muran-Gol (Selenga basin).

The main waterway of Tuva is Ulug-Khem (Upper Yenisei) with two powerful constituent rivers Biy-Khem and Kaa-Khem in the East and a large left tributary Khemchik in the West. In the North-West and North-East, the watershed of the Ulug-Hem basin runs along the ridges of the Western and Eastern Sayan mountains. In the South, the watershed of its basin runs along the Western and Eastern Tannu-Ola Sangilen and ridges; in the West and South-West along the Shapshal and Tsagan-Shibetu ridges. In the East, a small part of the Ulug-Hem catchment area lies within the territory of Mongolia.[2]

There are 15329rivers in the Republic, about 6720lakes with a surface area of more than 1084.4km$^2$ of a seasonally regulated reservoir with a total volume of 10.9m$^3$, and the tail section of the Sayan-Shushensk water reservoir with an area of 262km$^2$. The main river is the Yenisei. The amount of runoff that is formed on the territory of the Republic fluctuates about four billion cubic meters (39596.6millionm$^3$–the average annual value when crossing the administrative section of the river). The volume of runoff entering the territory of the Republic is 3973.5million m$^3$.

In general, the hydrogeological study of the territory is weak. Hydrogeological survey on a scale of 1: 200,000 covered 17.5%, and search operations for underground water – only 20.5% of the area of Tuva.

The river network in the Republic is well developed. The number of watercourses in river basins is:

i. Big Yenisei (Biy-Khem): the total number of watercourses is 4747, with a length of 25823km.

ii. Small Yenisei (Kaa-Khem): the total number of watercourses is 4977, with a length of 20421km.

iii. Upper Yenisei (from the confluence of the Big and Small Yenisei to the administrative border): the total number of watercourses is 2824, with a length of 15293km.

Drainless region of the Ubsunur basin: total number of 2781 with a length of 10710km.

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In total, the Republic of Tyva has 1201rivers with a length of more than 10km, a total length of 30588km, 14128 watercourses or more – 92% of the total number are less than 10km long and are classified as the smallest.

## Power sources, types of water regime

Rivers with mixed nutrition, with the predominance of snow from spring snowmelt and rain in the summer, participate in the formation of river flow. Thus, snow nutrition is 31%, rain 48%, underground –21%. Their role in feeding rivers varies in different areas of Republic. The pronounced continental climate and mountainous nature of the Republic are the main natural factors that determine the regime of rivers in the Ulug-Khem river basin. Their runoff is formed mainly due to spring snowmelt and summer high-mountain food. The snow cover of the mountain belt serves as the main source of food for the river network in the spring and in the first half of summer. Snowmelt begins earlier on the exposed southern slopes of the mountains; on the wooded Northern slopes, snowmelt is delayed and stretches for almost the entire summer.

Glaciers are one of the sources of food for rivers. In the mountainous part of the Republic, the ranges of the Western Tannu-Ola, there are about 20glaciers that feed the Mogen-Buren, Mugur, Barlyk, and Shui rivers; their total area is about 35km$^2$. The highest part of their food supply is located at an altitude of 3980–3300m, the lowest part of the ablation area is at an altitude of 3200–2700m. Most of the glaciers are located in the North-Eastern and North-Western parts of the slopes. The largest of the glaciers has an area of 20.2km$^2$ and a length of 11.5km; it descends from the Mongun Taiga mountain. There are 15glaciers with a total area of 99.7km$^2$ that feed the Khoolash and Togul rivers in the mountain junction of the Shapshal range, at the sources of Khemchik and Alash. The length of the largest glacier is 145km. More than 50% of the glaciers are located on the Northern and North-Eastern slopes, and 30% of them are located in kars, where they are fed by avalanches from steep slopes. Glaciers descend the slopes to 2900–2600m.

There are more than 10glaciers with a total area of about 4,4km$^2$ in the sources of the Great Yenisei and the Khamsara river. According to hydrological zoning the territory is divided into three districts:

*Tuva district* is located in the mountain forest zone of the Republic; these include: the Small and Large Yenisei, Khemchik (without a section of its lower course) and other watercourses.

The water regime is characterized by spring-summer high water with a maximum in late may–the first half of June. In summer and autumn, there are rain floods, and in some years may be 2-5times higher than the high water rises. Summer-autumn and winter temperatures are high. The flood begins in the second half of April–the first decade of May and lasts on average about 70days; during this time, up to 40% of the total annual flow passes through the rivers of the Little Yenisei basin and up to 50–60% along the rivers of the Greater Yenisei system. High water peaks are 10-15times higher than the average annual runoff. The number of floods during the summer and autumn season is 5-10, their duration ranges from 3 to 10–15days or more. In the rivers of the Little Yenisei basin, the average annual flow varies from 2 to 8liter/second km$^2$, and the maximum spring flood from 40t–-200l/s km$^2$, respectively. The intergranular runoff modules are also 1.5-3 and 5–9l/skm$^2$, respectively. Winter runoff is characterized by modules of 0.2–1l/skm$^2$. During the summer and autumn season, about 50% of the total annual flow flows down, and 5-10% in winter. The coefficient of average annual runoff in the arid parts of the Tuva basin is 0.1–0.2, and the highest parts of the mountains that frame it from the North and South, it is exceeded to 0.4-0.6.

*Khemch-Ulug-khem district* is located in the mountainous zone; it mainly includes the rivers of the Tuva basin, the lower course of the Khemchik, Uyuk, and other watercourses. These rivers have a mixed diet, which is dominated by rain. The regime of these rivers is characterized by summer and autumn rain floods, a relatively small spring flood and early autumn. Most of the annual runoff (about 60–65%) is due to rain floods, the number of them for the season reaches 10–15. The longest floods last for 10–12days. The flood flow modulus reaches 20-40l/s km$^2$ or more. The spring flood begins on average in the second half of April, the ice drift lasts 5–7days, the peak of the flood most often occurs in late may–the first half of June. The average height of the flood is 1.5-1.7m. During high water, up to 30% of the annual runoff passes.

The average flow modulus varies between 1–2l/s km$^2$; the flow coefficient is also small (0.1–0.2). In summer, during the inter-flood periods, the runoff decreases slightly, averaging 0.25–0.5l/s km$^2$. In winter, water consumption decreases sharply. On average, this season accounts for 1–2% of the annual flow. *Ubsu-Nur district* covers the rivers of the desert Ubsunur basin, whose catchments are located within the Russian Federation (Tes-Khem, Erzin). Their mode is similar to that of the rivers of the Tuva district. They also feed mainly on rainwater, but are less water-intensive. The average annual flow modulus in the mountainous part of the basin is 2–5l/s km$^2$, while in the lowest desert part it falls to 0.5l/s km$^2$. The average runoff coefficient is one of the lowest for the entire territory –0.05–0.2. In summer, the modulus of inter-soil flow is 1.5–2l/skm$^2$, in winter –0.2–0.4 l/s km$^2$.

Lakes in the Republic are numerous and diverse, they differ in their position, origin, size and composition of water. Most of the lakes are located in the Todzha basin. In total, there are about 6720 of them with a total area of 1084km$^2$. There are especially many lakes in the North-Eastern part of the territory, the number of them is 4890 (73% of the total number), the total area of 720km$^2$.[3]

Lakes differ significantly in terms of hydrological and hydrochemical parameters. At the origin Denia is dominated by glacial-tectonic and moraine-dammed lakes, while other lakes other types (tectonic, glacial, etc.). There are very few floodplain lakes. In particular, in the Great Yenisei basin, the only large floodplain reservoir is the Muyun-Khol lake (an area of 430ha).

The hydrological regime is dominated by low-flow and waste lakes with minor fluctuations in the water level during the year (0.2–0.4m). In strongly flowing lakes basin Khamsyra the oscillation amplitude reaches 1.5–2m in the lake. Azas (Toora-Khem river basin)–1m.

Most lakes have prevailing depths of more than 20m. These deep-water reservoirs have a stable regime of summer temperature stratification. In the main lake district – Todzha (middle mountains) in the second half of July–the first half of August, the water warms up quite well (up to 17–20°). The temperature jump layer in the Albuk lakes is located at a depth of 4–7m. The difference between the temperature of the epilimnion and hypolimnion is 10–12°, and at greater depths the water temperature does not exceed 8°. Water transparency in oligotrophic lakes is 10–18m, oligotrophic-mesotrophic lakes are 5–8m.

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### Modern glaciation

Ancient glaciation covered The Eastern and Western Sayans, the Tannu-Ola range, and the Eastern Tuva highlands. By moraine and fluvioglacial deposits, as well as by well-defined glacial landforms. The long continental history of ancient structures, young tectonic movements and Quaternary glaciation formed the modern relief of the entire territory of the Sayan-Tuva highlands. According to modern estimates, there are about 2,340glaciers in the Altai-Sayan mountain region with a total area of 1,562km$^2$. The main area of modern glaciation in the Northern, North-Western and North-Eastern parts of it. The glaciers of Tuva are divided into three groups:

i. Glaciers of valleys (valley, hollow, kar-valley, hanging valleys).

ii. Glaciers of mountain slopes (kar, kar-hanging, hanging).

iii. Glaciers of denudation surfaces (glaciers of flat peaks).

## Conclusion

The Republic is rich in water resources – rivers, lakes, underground waters, high-mountain glaciers, medicinal springs. In hydrographic terms, the majority of rivers belongs to the reservoirs of the mountain type. The river network belongs to the basin of the river Yenisei and its two major tributaries – Big Yenisei (Biy-Khem) and Small Yenisei (Kaa-Khem), and in minor amounts to the inland lake Ubsunur (the river network of the river Tes-Khem and the number of its small tributaries in the Ubsunur basin).

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## Conflicts of interest

The authors declare that there is no conflict of interest.

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