Features of implementation of measures to improve the hydrological regime of the Pshish River in the Kuban water basin

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Abstract. The article discusses ways to improve the hydrological regime of the Pshish River in the Kuban water basin. In the context of the progressive shortage of fresh water, especially in the south of Russia, the study of the water resources of the Kuban River basin is of particular relevance. Medium and small rivers are still poorly studied in hydrological terms. At high water levels, the Pshish River and the Krasnodar reservoir are the feeding boundaries for ground water in the protected area, and they are drains at low water levels. When the water levels in the reservoir are less than 29 m (this is the low-water level in the Pshish River in the area of the transverse dam), its influence on the protected area practically ceases, since the coastline of the Krasnodar reservoir recedes from the transverse dam far to the northwest, exposing the previously flooded riverbed. Clearing of flooded riverbeds is proposed to be carried out by the method of roiling. This method is used in reservoirs with the flow, because the essence of it is that muddy sediments are roiled using a floating dredger with water jets and the slurry is not sucked into the dredger and suspended sediments are transported by the flow of water in the bowl of the "dead" area of the reservoir. The use of this method is recommended for economic reasons, since it is 2.4 times cheaper than clearing with the removal of pulp.

1. Introduction

The longest and abundant river of the Great Caucasus of Russia is the Kuban River. It is the main water artery of the western and north-western part of the northern slope of the Great Caucasus range and the southern part of the Western Ciscaucasia, carrying its waters through the territories of: Krasnodar and Stavropol Territories, Karachaevo-Cherkessia and Republic of Adygea. The Kuban River basin occupies the north-western part of the Caucasus and is 57.9 thousand m². The length of the Kuban River to the dam of the Krasnodar Reservoir is 630 km, and the catchment area is 45.9 thousand km². Feeding of the Kuban River is mixed: glacial, snow, rain and ground. According to the flow regime, the Kuban River is the mountain river. The runoff is characterized by a significant seasonal unevenness and a large amplitude of changes in the flow rates [1].

In the area of the Krasnodar reservoir, the average river slopes are about 0.1 %, the flow rate in high water is 1.0...1.5 m/s and the flow rate in low water is 0.4...0.6 m/s. The spring-summer high
The filtration properties of soils were determined at the previous stages of research using single and cluster pumping from wells. In [4, 5, 6], the results of previous studies were generalized and the following values were taken as the calculated values of the soil filtration coefficient (K): clays and loams IGE-2.3 – 0.05 m/day; sandy loams IGE-4–0.5 m/day; small sands IGE-5 – 12 m/day; medium-sized sands IGE-6 – 22 m/day; large sands IGE-7 – 27 m/day; gravel and pebble soils – 35 m/day.

The coefficient of total water supply capacity (Km) of ground water varies from 50 to 250 m³/day (the average value is 150 m³/day), and the coefficient of level conductivity (a) under the active water output of cover clays and loams of n = 5 % is a = 3000 m³/day (average value).

As noted above, the protected area of the high floodplain of the Pshish River was periodically flooded by flood waters in natural conditions and was mostly swampy. Currently, the reclamation condition of this territory occupied by rice fields and fish hatchery ponds depends primarily on the technical condition of discharge (drainage) channels and the operation of the pumping station, the pumping drainage and the surface water from the protected area in the Pshish River.

The Pshish River and the Krasnodar reservoir at high water levels are feeding boundaries of groundwater in the protected area, and they are drains at low water levels. When the water levels in the reservoir are less than 29 m (this is the low water level in the Pshish River in the area of the transverse dam), its influence on the protected area practically ceases, since the shoreline of the reservoir recedes from the transverse dam far to the northwest, exposing the previously flooded riverbed [7].

The area of high floodplain terraces adjacent to the protected area from the north-east is a permanent feeding boundary of the groundwater of the high floodplain. It should be noted that surface runoff also flows off their surface along the beams to the protected area. The territory of the high floodplain is almost barren, so most of the sediments goes to the water saturation of rocks of the aeration zone and the supply of groundwater. The amount of infiltration supply of groundwater in the cold period of the year (November-March) can reach 1.5 mm/day. In the warm period of the year (April-October), the partial discharge of groundwater occurs due to evaporation and transpiration from the surface of groundwater [8].

Water supply decrease in the protected area is carried out by drainage of groundwater into on-farm channels of rice irrigation systems and fish hatcheries with a depth of up to 3 m and a distance of about 350 m between them on rice irrigation systems [9] and 600-800 m – on fish hatchery ponds.

It should be noted that in recent years, rice sowing [10] has not been carried out in the protected area. Fish hatchery ponds are abandoned; their feeding and water discharge pumping stations are destroyed. Ponds with the lowest ground level of 31-32.5 m and the area along the transverse dam were flooded due to the wedging of groundwater and surface runoff, including from the territory of above-floodplain terraces [11].

During the survey period, the water level in the reservoir was at the level of 29.38 m and the water edge shifted far to the north-west from the transverse dam. In the Pshish River, water levels were close to low water levels and it was the main drain for the protected area [12]. The general direction of
The greatest depth of groundwater grade of 2-3 m was observed in the area of the operating pumping station and along the Pshish River; higher ground levels are also observed here. The lowest depths of groundwater (0.1-1.0 m) were observed along the ledges of above-floodplain terraces and in the area of fish hatcheries [13].

The level regime of groundwater is almost everywhere hydrological, artificial, depending on the water levels in the Pshish River, the Krasnodar reservoir, water discharge channels, ponds of fish nurseries. Due to the shallow depth of water in the channels, the zone of their influence on ground water is small and about 100 m according to works [14, 15]. In this regard, away from the Pshish River (more than 500-900 m) in rice fields near irrigation channels the groundwater regime will be mixed, but close to climatic; the maximum groundwater levels will be observed in the period from February to April, and the minimum from August to October. The amplitude of the level fluctuation varies from 0.6 to 1.0 m [16].

Due to the chemical composition the groundwaters are hydrocarbonate, rarely hydrocarbonate-sulphate, of different cationic composition; their mineralization varies from 0.6-1.0 g/dm³ along the riverbed of the Pshish River and ledges of above floodplain terraces of up to 1-2 g/dm³ (more rarely) in the central part of the protected area. Groundwater with mineralization of up to 1 g/dm³ is non-aggressive to W₄ concretes in terms of water resistance, and with a mineralization of more than 1 g/dm³ – weakly medium aggressive.

2. Results

Monitoring of water resources in the Kuban River basin is relevant and necessary for the purpose of regular monitoring of the state of water bodies, their quantitative and qualitative indicators, timely identification and forecasting of negative processes affecting the quality of water and the state of various water management structures.

The length of the Pshish River is 248 km (before the flooding of its lower reaches by the Krasnodar reservoir, the river was 10 km longer, and its basin was 1.850 km²). The maximum width is 1.5 km in the Ganzhinsky reservoir. The depth there reaches up to 8 m. At the same time, this indicator in the rest of the Pshish river basin is up to 2 m. The reservoir passes through several parts of the Kuban River. A small lowland part of Adygea is at the end of the way. The general direction is north. But the course of the current is zigzag – the “artery” flows around the high massifs of the western tip of the Main Caucasus. The average water consumption is 25 m³ per second. Its feeding consists of several types. It is associated with unstable snowmelt. So everything is different every year. Icing does not last every year, there are 22 tributaries (without streams) and the largest ones are the Gunayka and the Tsetse, the Srednie Elizavetka, the Ganzha.

On the Pshish river, the flood is completely absent. The maximum flow is formed by rain floods. The flood season here usually lasts from October to April. Especially high floods are observed when an ice crust forms on the earth's surface. An example of such floods on the rivers of this region is the floods of February 26, 1965, December 5, 6, 1973, a series of floods in the third decade of December 2001 – January 2002, and a number of others.

As a rule, the maximum annual water consumption on the Kuban River is observed during the spring-summer flood. The rise of levels began in late February-early March, the highest costs and levels were observed in June, during the period of intense snowmelt and melting of glaciers in mountains as well as precipitation during this period. The average duration of the spring-summer flood is 215 days. Up to 60...70 % of the annual runoff of the Kuban river occurs in the spring-summer flood [17].

The greatest winter snow and rain floods are observed most often in February-March. The average duration of flooding is 22 days. Often, the decline of one flood is superimposed on the rise of the next. The maximum average daily recovered water consumption for the previous period reached 2010...2300 m³/s. The maximum water consumption in the unregulated mode in Krasnodar exceeded 2000 m³/s once every 15-20 years; 1500 m³/s – once every 5 years; 1000 m³/s – almost annually, and
Sometimes several times.

The minimum inflow to the Krasnodar reservoir is observed in the autumn-winter period. The minimum monthly average water consumption is observed mainly in January-February. However, over the past 20 years, due to warm winters, the minimum monthly average water consumption in the Kuban River is increasingly observed in November. The minimum monthly average consumption of 95% of water supply in the shot of the dam is 80.3 m³/s [18].

The maximum calculated wave height at the reservoir with an acceleration length of 29 km and an estimated eastern wind speed of 2% is 3.02 m, which is equal to 38.2 m/s. During the observation period (1976-1990), the highest wave height in the reservoir was observed with winds from the eastern and southern-western directions and is 1.95 m and 1.8 m, respectively. But accelerations during the period of observations of the wind speeds of 20 m/s and more were not observed.

The maximum calculated ice thickness in the reservoir adopted in the project is 70 cm, the maximum observed is 39 cm (avanport, January 1980). The average number of days with ice formation during the winter varies from 50 in the upper section of the reservoir to 40 in the avanport.

The greatest number of days with ice formation was observed in the winter of 1984-1985 and amounted to 95-108 days. The average number of days with ice formations in the reservoir is 55-70 days, the maximum is 107-118 days. The deposited sediments in the estuaries of the tributary rivers are now fixed by woody vegetation and are quite resistant to planned and deep deformations. The erosion of sediments is more slow than their deposition. Thus, the living cross-section of the riverbed is gradually reduced due to the loss of floodplain space and partially channel space. In 2018, the geomorphological work was carried out to determine the capacity of the Kuban, Pshish and Psekdups Rivers. The results of these works showed that the estuaries of these rivers, despite of heavily silted, are able to pass floods with an efficiency of 0.5% at the water mark up to 33.45 m in the reservoir. Everywhere under these conditions, the rivers will leave the channel, but the embankment dam of the native banks have a margin of height in about 1 m [19].

The Krasnodar reservoir causes a water level backwater on the tributary rivers, which, when passing the maximum water flow, can spread to the Pshish river for 10-12 km. The length of the coastline exposed to wave processing is 74 km. In recent years, the intensity of processing of the banks as a result of the operation of the reservoir with a reduced normal retaining level has decreased.

The engineering protection structures of site No. 11 in the Pshish river protect an area of 1.350 hectares from submergence and flooding, including 390 hectares at a normal retaining level = 32.75 m.

The protected area is located in Belorechensky district of Krasnodar Territory.

The structures are classified as the III class efficiency.

The structure of engineering protection structures includes:
- transverse barrier dam;
- subdam drainage channel;
- longitudinal (right bank) of the dam embankment;
- drainage and water discharge pumping station No.11 (previously called “Fokino-II”) [20].

A transverse barrier dam protects the site from the reservoir side. Its length is 3.25 km, the maximum height is 5.0 m; the width of the crest is 6.0 m, the elevation of the crest is 36.00 m, upper slope at a length of 300 m is fixed by the stone cover in width of 40 cm on a layer of gravel-sand mixture; by the reinforced concrete slabs in the length of 200 m, by the gravel in width of 20 cm along 1230 m, 5 cm laid on gravel rammed into the ground.

The longitudinal (right-bank) embankment dam is located along the Pshish river on its right bank. The length of the dam is 7.36 km, the maximum height is 6.5 m; the width of the ridge is 3.0 m, 4.5 m, 6.0 m, the upper slope at a length of 510 m is fixed with a stone sketch 30 cm thick on a layer of the gravel-sand mixture.

The longitudinal dam is mated with the protective shaft of the Pshish River in the area of the village Bratskiy. The drainage function is performed by the subdam canal with a length of 1.8 km.

Drainage and discharge pumping station No. 11, located on PC 40 of the longitudinal dam, receives filtration, surface and discharge water from the rice system. In recent years, the pumping station has
been reconstructed.

After reconstruction, drainage and discharge pumping station No. 11 has a capacity of 5.0 m³/s, equipped with 4 AD 6300-27b-3 pumps and the 1 AD 2000-21-2-06 pump. The installed capacity of the pumping station is 875 kW. The volume of the regulating pool is 350000 m³ (the old channel of the Pshish river). The discharge of pumped water is carried out in the Pshish river through pressure pipelines with a diameter of 820 and 630 mm. In accordance with the study of feasibility of the reconstruction, the longitudinal dam was reinforced on the section of PK 58-63, where the riverbed of the Pshish River was close to the dam and threatened it with erosion. Parameters of the reinforcing of the dam are as follows: length - 360 m, average height - 2.3 m, top width - 4.5 m, top slope - 1:2.5, bottom slope - 1:2 (Figure 1).

![Figure 1](image1.png)  
**Figure 1.** Engineering protection of the Pshish River valley: a – drainage and discharge pumping station No. 11; b – transverse dam.

### 3. Conclusion

About 6.5 million/m³ of sediments annually fall to the Krasnodar reservoir, which amounted to more than 160 million/m³ of sediments during the reservoir’s existence. The distribution of sediments in the Krasnodar reservoir is extremely uneven. About 50 % of the total volume of sediments is concentrated in the upper part of the reservoir and along the estuaries of tributary rivers. The section of the reservoir from the village Voronezhskaya to the mouth of the Belaya River, where the average thickness of sediments exceeds 2 m, is silted up to a large extent.

Clearing of flooded riverbeds is proposed to perform by the method of roiling. This method is used in reservoirs with the flow, because the essence of it is that muddy sediments are roiled using a floating dredger with water jets and the slurry is not sucked into the dredger and suspended sediments are transported by the water flow into the bowl of the “dead” volume of the reservoir. The use of this method is recommended for economic reasons, since it is 2.4 times cheaper than clearing with the pulp removal. The main volume of entrained and suspended sediments enters the reservoir through the flooded riverbeds that flow into the Krasnodar reservoir.

For the sediments to reach to the bowl of the “dead” volume, it is proposed to clear the flooded riverbeds in the Krasnodar reservoir, the siltation of which is about 1.0 m, including at a length of 33.5 km, a depth of 1.0 m and a width of 50 m in the Pshish River.

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