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Operation of Reservoirs in Kura River Basin in Azerbaijan

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***Keywords*— mountain rivers, water resources, sediments, hydraulic size, reservoir, spillway dam, flushing gallery, gate.**

***Abstract*— The given article is devoted to the ways of solving the problems connected with the rational use of water resources in high-muddy mountain rivers. The analysis of technical and operational indicators of reservoirs constructed on mountain rivers characterized by high turbidity is carried out and silt control measures are investigated. The silt control issue is now gaining a big actuality and national economic significance. This problem is especially acute in the South Caucasus, Central Asia and other places where many mountain reservoirs have been constructed. The given article analyzes the existing methods of sediment wash out from reservoirs and proposes a new method for silt control during the operational period.*

I. BACKGROUND

Reservoirs are gigantic sediment basins, that trap a significant part of suspended sediment flow. When the reservoir gets filled with dead volume of sediment, further sediment deposition leads to a decrease of useful volume of the reservoir and operating upset. The experience of operating reservoirs constructed in the world over the past 70-80 years shows that reservoirs constructed on many mountain rivers, due to siltation, in a short time lose their useful volume and become unusable without completing their intended operation life.

Most of the reservoirs located on mountain rivers flowing through the territory of the North Caucasus and Central Asia lost their 70-90% volumes within 5-10 years. Pirsaatchay, Bolgarchay, Javanshir and Airichay reservoirs can be taken as an example of the most prone to siltation in the Republic of Azerbaijan. The Ayrichai reservoir, commissioned in 1986 with a useful volume of 80 million m^3, is 80% silted by 2016. Pirsaatchay and Bolgarchay reservoirs, which are constructed in 1964-1965 are totally out of use due to siltation. The main reason for the rapid siltation of all these reservoirs is the increased turbidity of the river and the lack of preventive measures during exploitation.

There are several mountain rivers with increased turbidity on the territory of the Republic of Azerbaijan, the water resources of which are not rationally used for this reason.Examples include the rivers Sumgaitchay, Bolgarchay, Tyuryanchay, Karachay, Girdymanchay, and Pirsaatchay. Girdimanchay is relatively abundant, but also very muddy among these rivers. At present, the water resources of the Girdymanchay River are used only to a small extent. The reason for this is the high degree of turbidity in this river and the passage of frequent destructive mudflows. Attempts to build a reservoir on this river were made several times, but for the above-mentioned reasons, construction works were not started.

II. GENERAL METHOD FOR THE EXPLOITATION OF RESERVOIRS IN AZERBAIJAN

All reservoirs in Azerbaijan, the total volume of which is approximately 22.8 billion cubic meters, are regulated according to the schedule of irrigation consumption. The operation of reservoirs is mainly carried out in the following order

- systematic supervision over the condition of structures;
- ensuring trouble-free flood passage;
- ensuring the safety of hydraulic structures operation;
- ensuring the specified mode of filling and depleting the reservoir;
-timely detection of structures damage;
-regular measurement of water levels in the pools;
- current repair of structures.

Despite the high rates of reservoirs siltation, not a single measure is taken to flush sediments from the basin or to pass high-muddy waters into the downstream. Unfortunately, during the exploitation period, more transparent water is passed from the reservoir to downstream through the surface spillway.

The main method and rules for reservoir operation is, without taking into account the ecological consequences on the environment (ecological pass and fish passing facilities), to maximize the accumulation of river flow in the reservoir.

III. MAIN CHARACTERISTICS OF HIGH-MUDDY RIVER GIRDIMANCHAY

The Girdimanchay River is a left tributary of the Kura River and originates at an altitude of 2900 m on the southern slope of the Big Caucasus Range. After the river flows from the mountains, it forms a wide cone delta in the Garamaryam plateau and splits into many tributaries. According to the water regime, the Girdymanchay River is full-flowing in spring and subject to floods in autumn. The average long-term flow rate of the river is 6.5 m3 / sec. Frequent mudflows are considered hazardous hydrological events on the river. Mudflow springs occupy more than 50% of the catchment area.

According to the observed data, the highest catastrophic water discharge was 201.0 m3 / sec. in July 15, 1988. According to the data on suspended sediment, the amount of annual runoff was equal to 2-3.5 million tons. Since 1960, several options of reservoir design in Girdymanchay River have been studied. To determine the volume of designed reservoir, the calculations were carried out according to the water flow rate of 75%in Girdymanchay River (Q = 4.69 m3 / sec). At the same time, the volume of water flow per year is 149.76 million m3, the volume of sediment is 1.5 million m3 (80% of this sediment occurs in July and October). According to calculations, the required useful volume of the reservoir will be 50.0 million m3. Over a 50-year period of operation, the volume of siltation will amount to 75.0 million m3. The total volume of the reservoir will be 125.0 million m3. Taking these parameters into account, the height of the earth dam will be approximately 140 m.

The construction of earth dam of such a height in a valley of mountain rivers with specific heavy mudflows and flood conditions is not feasible from an economic and operational point of view. Taking into account the current situation, the construction of the reservoir was postponed.

Our research has shown that, considering the solid discharge management and a cost-effective operating regime, it is possible to build a reservoir in such conditions.

New approaches to the operation of medium and small reservoirs in the context of climate change.

Climate change will have significant consequences for water resources. Some of these consequences are already visible today. It is expected that in near future, almost all the countries of the South Caucasus and Central Asia and beyond it will experience negative impacts from the increased frequency and intensity of floods and droughts, and an increase in the shortage of water resources. Moreover, the impacts of climate change on water resources will affect various sectors - agriculture, energy and hydropower, shipping, health, tourism and the environment. Adaptation to climate change is thus a moral, social and economic imperative: action must be taken now, and water resource management must be a central element in any country's adaptation strategy. On the territory of Azerbaijan, it is expected that water reserves will decrease by 15-20% until 2035. In this regard, it is planned to build more than 20 reservoirs on mountain rivers.

IV. METHODS FOR SEDIMENT CONTROL OF RESERVOIRS DURING THE OPERATIONAL PERIOD.

Silting up of reservoirs causes a rapid decrease in the volume of reservoirs, which complicates their operation and shortens the service life of waterworks. Mostly the sediment control measures of reservoirs have passive character. Usually, after siltation of the reservoir, hydraulic flushing or removal of silt by hydromechanical method is carried out. Due to the hardening of silt in the reservoir, the use of these methods is accompanied by the loss of a large amount of water and is considered ineffective from an economic point of view. Measures to reduce siltation of mountain reservoirs can be divided into two groups - **preventive and operational**.

Preventive measures include measures aimed at a general decrease in the flow of sediments into the reservoir by reducing soil erosion in the flow regulating basin. These measures are the most effective means of sediment control and the introduction of mountain reservoirs. Operational measures by execution way can be grouped as follows:

- hydraulic washing of sediments after emptying the reservoir;

- mechanical cleaning of deposits (used for small containers);

- building up the dam to increase the reservoir capacity;

- transit discharge of the total flood discharge into the downstream through spillways with low thresholds. With this option, a lot of clean water will be lost.

- flood water diversion discharge devices (bypass canals, tunnels) into the downstream without lowering the reservoir level. In difficult mountainous areas, the construction of bypass tunnels requires large capital investments.

Thus, the main disadvantage of operational methods of protection against siltation and entry of riverbed mountain reservoirs is that they do not prevent siltation of reservoirs, but are aimed at cleaning up the mass of sediment that has already compacted solidified at the bottom of the reservoir. The concentrated flush flow washes out the soil only along the path of its movement, forming a narrow deep channel at the bottom of the reservoir. The main part of the bowl remains silted up as before / **1,2** /.

As the review of existing works on sediment control of mountain reservoirs shows, none of the above options allows the more turbid parts of the stream to be passed into the downstream without a particular violation of the reservoir filling regime. The layout of the existing water collectors does not allow to solve the assigned tasks, since they are located within the limits of the dam and the discharge of excess flows into the downstream comes from the more clarified part of the reservoir. They do not provide monthly discharge of a certain part of the high-turbidity flow into the downstream and this leads to premature siltation of mountain reservoirs. *To solve the tasks, we have developed two options for dealing with sediment during the operational period of the reservoir.*

First option. To flush bed silt and pass of a part of the high-turbidity flow into the downstream, without disturbing the hydraulic regime of mountain reservoirs (the length of the lake is relatively short, the height of the dam is large), we have developed a new layout of the spillway structure. It is known that in almost all design solutions for regulating the flood discharge in the reservoir, a spillway is constructed near the dam, which passes a more clarified flow into the downstream pool.

In the new layout, the head of the spillway structure on mountain reservoirs is moved to the initial section of the reservoir **/ 5 /.** The head of the spillway structure in the form of a water intake tower is located in the river bed between the horizons of the–dead volume level (DVL) and the – normally supported level (NSL). The location of the head part is assigned depending on pump regime of the rivers. For the passage of high-turbidity wash flows into the downstream pool of the reservoir, a wash gallery is laid inside the bowl. A sediment collector and a spillway are located on this wash pipe. Depending on the hydrological regime of the river and the hydraulic parameters of the dam, the spillway tower can be two-tiered. In this case, the first water intake threshold (hole) is located at the level of the reservoir, which corresponds to the passage of the first spring flood. The second threshold is located at the level of the NSL and operates in an automatic mode - the type of a mine spillway.

The first water inlet is closed by gates when the surface water inlet sills operate. Such arrangement of thresholds allowsdischarging into the downstream more turbid layer of the flow when the reservoir is not filled with the help of the first water intake threshold during the passage of floods and mudflows. When the reservoir is completely filled, the automatic spillway - the second threshold, provides the escape of extra water discharges. At the same time, the more turbid part of the flow is discharged into the downstream.

For partial regulation and direction of bed siltation into the flushing pipe, it is proposed to construction of silt carrying dam at the wedging site, near the bottom water intake openings. With this option, the bed sediments are completely deposited at the beginning of the reservoir and by partial opening of the gates, are washed into the downstream without disrupting the operation of the reservoir. This arrangement allows the entire mud-stone flow to be passed into the downstream during mudflows and at the same time ensure the safety of the reservoir. The layout of the structure makes it possible to flush out the alluvial deposits from the initial section of the reservoir bowl during the spring and autumn floods, without disturbing the hydraulic regime of the reservoir.

The application of the proposed layout of the spillway structure makes it possible to effectively deal with sediments during the operational period, without reducing the water level in upstream pool.As shown by our preliminary calculations, the use of such design of spillway structures on the Girdimanchay River will significantly reduce the dead volume of the reservoir (reduced from 75.0 to 20.0 million cum-meter) and, at the same time, significantly reduce the height of the dam (approximately two times). Lowering the height of the dam dramatically reduces the estimated cost of the reservoir. (Figure 1.)

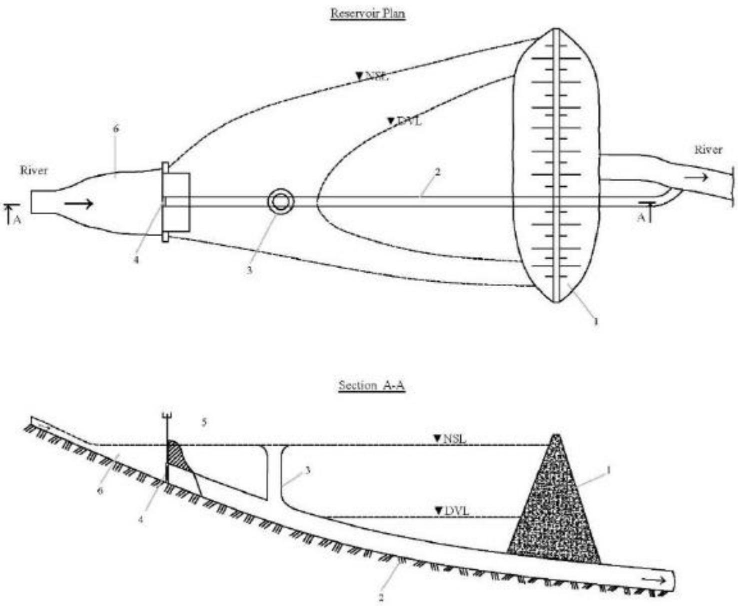

Fig. 1 Schematic plan and section of reservoir structures.

1-dam; 2-bottom pipes; 3-surface spillway; 4-bottom water intake; 5-sediment retention spillway dam; 6- basin of preliminary desilting of bed sediments.

The proposed method of silt control of the reservoir bowl is carried out during the operational period and therefore it is more effective than the methods used for cleaning after siltation.

Second option. One of the effective ways to preserve the useful capacity of the reservoir, and does not exclude other methods, is the passage of turbid river flows that form bottom suspension currents in reservoirs through specially designed holes in the body of the dam. In some cases, this way helps to remove from 50 to 60% of all sediments entering the reservoir annually./ **3,4**/

To discharge bottom suspension flows from the reservoir into the downstream,special sediment-capturing structures can be used, which are located in front of the dam inside the reservoir. Such structures can be constructed on the principle of a continuously flushing sediment basin. In order to save the washing flow, we have developed a fundamentally new design of the sediment-entraining "flooded sediment basin" **/ 6 /**. The design is made in the form of a rectangular chamber with washing galleries -2. The ends of each gallery are secured with special locks -1. The chambers of the "sediment basin” are covered from above with perforated plates. In order to increase the ascending velocities, truncated cones, turned upside down, are located above the slab -3(Fig. 2).

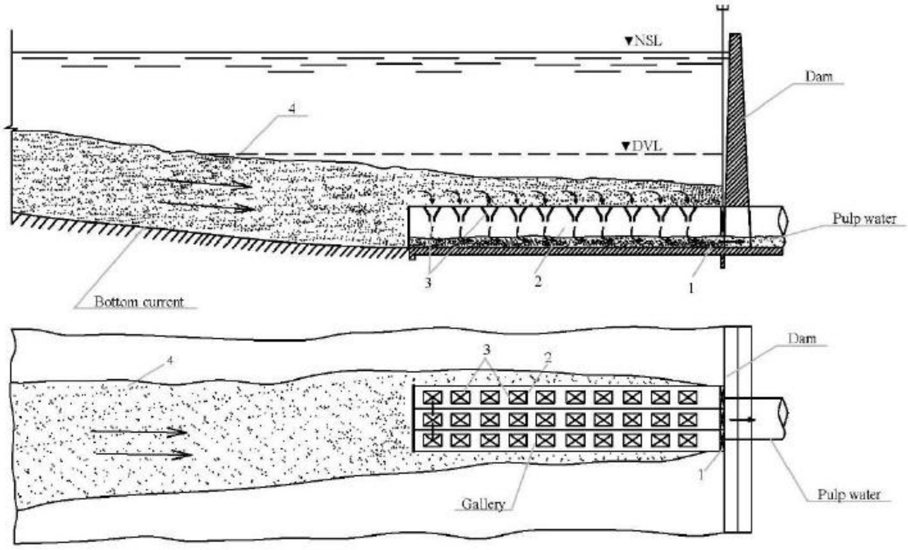

Fig. 2. Construction for the passage of bottom suspension flows from the reservoir.

Bottom flow-4, stepping on the sediment-entraining gallery-2, move towards the dam. By opening the control gate-1 at the end of the wash gallery-2, it is possible to catch a part of the bottom currents with high turbidity and discharge into the downstream of the dam. With such design of the structure, sedimentation and removal of sediments from bottom currents occurs identically to non-periodic sediment basin. The use of such structures makes it possible to increase the concentration of sediments in the washing flow by several times in comparison with the incoming bottom sediments. This allows you to significantly reduce water consumption for flushing the sediment.

Depending on the hydraulic regimes in the wash gallery, the gates can be used to regulate the value of vertical velocities in the bottom layer of bottom currents. These vertical "suction" -currents accelerates desilting in the bottom currents.

An example of the calculation for the proposed design was carried out on the example of the Nurek reservoir (flow rate of bottom currents - 40 m3 / s; depth of bottom currents h = 10 m; depth of reservoir H = 150.0 m; width of bottom currents B = 45.0 m; bottom current velocity V = 0.088 m / s; hydraulic size of sediments W = 0.2 mm / s; turbidity of bottom currentsρ = 15.0 kg / m3, throat d1 = 0.1 m, D = 5.0 m). As shown by the calculation example, letting one fourth of the bottom currents out of the reservoir, it is possible to achieve an increase in the turbidity of the washing flow by about 4 times, in comparison with the initial turbidity. The developed design makes it possible to partially precipitate and wash out the turbidity of the bottom currents. With the help of this design, it is possible to intermittently let the thicker parts of the stream from the "lake of turbidity" into the downstream. In such cases, the concentration of turbidity in the wash stream sometimes reaches 15-20%.

V. MAIN CONCLUSIONS

1. Long-term observations on the reservoirs of Azerbaijan show that a large volume of siltation of the reservoir basin occurs mainly with the passage of spring and autumn torrential floods. In about 4-5 months, more than 80% of the solid annual river flow is deposited in the reservoir.

2. 90% of Agrichai reservoir was siltedover the 30 years of operation, with a decrease in its total volume from 80 million m3 to 10 million m3. For almost 40 years of operation, the Pirsaatreservoir is silted for 95%, and trees have grown inside the bowl.

3. As our research shows due to climate change, the hydrological characteristics of rainfall and, accordingly, the peaks and periods of floods in rivers have changed. Already in our region, the frequency of spring and autumn flash floods has increased.

4. One of the most effective ways to remove sediment from reservoirs is hydraulic flushing. The maximum volumes of sediment washed into the downstream of the hydroelectric complex are achieved only with optimally selected discharge flow rates when the reservoir is completely emptied.

5. The use of hydro mechanization, when cleaning the bottom of reservoirs from sediments, allows them to be

removed from large areas and in almost any volume. However, the cost of such work is extremely high

6.The most optimal way is to pass high-muddy waters during a flood bypassing the collected water in the reservoir. In the operational and water management calculations of the reservoir, it is necessary to take into account the passage of high-turbidity waters during the flood from the reservoirs.

7. Project processing for the construction of a reservoir on the Girdimanchay River in Azerbaijan showed that when applying our proposals (first option), it is possible to significantly reduce the dead volume of the reservoir and, accordingly, the height of the dam.

8. The use of a constructive solution to remove the solid discharge of the river from the basin of the reservoirs during the operational period will significantly lengthen the operating life of the reservoirs and, at the same time, improve the environmental conditions of the river bed in the downstream.

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