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EVALUATION OF THE GETAVAN-1 HYDROSCHEME'S SEDIMENTATION REGIME AND THE CREATION OF SEDIMENT ACCUMULATION FLUSHING EFFECTIVE MEASURES

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Abstract

The volume of sediment accumulations in the upstream reach of the dam and the selection of an efficient flushing measurse are determined by the accurate hydrological regime assessment that is made when designing run-of-river structures. In the Tartar River's water intake head sedimentation regime was investigated, the potential accumulation volumes on the dam's upper side were calculated, and a functional design for the deposited sediment flushing unit's operation scheme was developed. Due to the lack of necessary data, the flow rate in the Tartar River water receiving head was measured using three parallel methods that were discovered through research on local watercourses. A comparative analysis of three sediment flow values was done and its calculated value is defined, on the basis of which the annual volume of sediment subject to accumulation in front of the dam of the head and the possible infilling size of the sediment in the upstream reach was determined. The rational placement of

the outlets for flushing deposited sediment is shown while taking into account the volume of deposits, the geometric properties of the head, and its upstream reach.

Key words: water intake unit, reservoir, sediment, flow, dam, deposits, hydrometric observation point

Intriduction

Currently Artsakh's water resources have significantly decreased. evertheless, even under these circumstances, they provide water supply for the population and the irrigation of agricultural lands, and maintenance of production infrastructures. Comprehensive plans for the management of Artsakh's water resources were created prior to the 44-day war. But Artsakh also lost control over the major sources of watercources as a result of the war. New problems emerged with the repair of water supply systems damaged during warfare and the building of new reserves. Work is underway to reconstruct the Haterk's supply gravity irrigation system, which is supplied with the waters of the Trghi tributary of the Tartar River. The best district for gravity irrigation is the Martuni district. The loss of some artesian wells is gradually recovered which is the only solution to the issue at hand.

The Tartar River is the main water artery of the Republic of Artsakh. The river rises from springs located on the eastern slope of the Syunik plateau at an altitude of 3120 m. Flowing in the north-eastern direction, it flows into the Kura River at a distance of 523 km from its mouth. Total dip of the Tatar River is 3117 m, total length 2000 km, slope - 1.56%, river meandering factor - 1.44, catchment area – 2650 km^2, mean catchment height - 1820 m. 72 tributaries that are five km in length or longer flow into the river [1]. The Sarsang reservoir built on it serves only hydropower purposes. River waters are also suitable for water supply and irrigation [2].

The distance the Tartar River runs between Charektar and Getavan communities is about 14 km. The channel drop at this distance is 140 m. It is obvious today that the use of the river flow in this area has become very important both for power generation and irrigation purposes. Based on these considerations, a working project of the hydro-unit §Getavan-1¦ was developed for the use of the Tartar river. The hydro complex is planned to be built on the site between the 950-meter and 808-meter sections of the Tartar River. It includes the head structures (water intake head), the bypass (derivation) pipeline and the hydroelectric station junction. In the present work, the problems related to the water receiving head were studied.

Techniques for removing sediment once it has accumulated in a upstream reach of run-of-river structures include mechanical removal and flushing. The first method is expensive and is only used to remove small-volume accumulations. To remove accumulated sediment, the second approach works better. It has become widespread in reservoirs, and especially when carrying out measures to remove accumulated sediment in front of the head units [3,4].

For the effective implementation of this process, it is important to correctly choose the quantity and placement of the flushing outlets in the construction solutions of the of the dam's unit. This choice determines the width of the river bed where the front of sediment load deposition is formed. Numerous natural observations show that it is rarely possible to carry out a full flushing operation, even in the presence of accumulations with a front width of 12–15 meters and one properly located flushing outlet. A sizable portion of the accumulations remain in place if the opening's location is improperly chosen. We can use the Armavir Canal's head dam on the Araks River as an illustration [5]. Its height is 5 m, and its length is roughly 200 m. Here, 2 of the 4 outlets are located near the right bank, 2 - near the left one. After one day of flushing operation, in their central part remains an unflushed conical pile of sediment with a base size of about 70 x 5 m. More than two dozen concrete dams built on the Hrazdan River are in a similar condition. Their washing outlets were located either on the right or left sides of the dams.. Most of the accumulations in front of these barriers, which are about 20 m wide, remain unflushed.

Conflict Setting

The following measures related to sediment management issues will have to be taken to provide effective operation of "Getavan-1" hydroscheme's head unit:

- Evaluation of the total volume of sediment subject to be deposited in the dam's upstream reach during one year of operation,
- Determination of the possible maximum size of sediment filling in the dam's upstream reach,
- choice of proper placement of outlets for effective flushing of deposited sediment.

Reliable data on the sediment flow are required to solve these issues. The annual volume of stored sediment was 10 thousand m^3, and the flow of water in the river was assumed to be 1.2 kg/s when the project was being developed. The authors' analysis of the solution to this issue, however, reveals that the Tartar River's sediment load regime was not fairly evaluated when making design decisions. It is important to note that in the upstream reach are accumulated both bed sediment carried with the flow and suspended course particles. Below are the results of determining of the river sediment flow and the volume subject to accumulation. The obtained results shown below reveal the flow of sediment carried by river and the volume of the sediment subject to be settled.

Considering the importance of the hydraulic complex, the goal of the work was to estimate the annual volume of sediment entering the head unit and subject to accumulation, to determine the size of possible filling of the sediment in the volume of the upstream reach, and to propose a proper placement of outlets in the dam body for removing deposited sediment by flushing.

Research Results

To achieve the goal of the work, it is important to get reliable data on sedimentation regime of the Tartar River. For this, the sediment flow of the river in the head unit section was estimated in three parallel ways

Obtaining trustworthy information about the Tartar River's water supply system is crucial to achieving the project's objective. Three parallel estimation methods were used to determine the river's main section drainage flow for this:

- on the basis of the available data of suspended sediment flow measured at the "Vaghouhas" hydropost of the Tartar Rive,
- turbidity values of regional rivers,
- using the obtained correlation pattern between the fluid and sediment flows of the Eastern Transcaucasia rivers.

Technique I. On the Tartar River from 1949 to 1980, at certain intervals, six hydrometric observation points operated, three of them on tributaries. Measurement data are given in the table. The "Vaghuhas" hydropost is the closest to the river section of the "Getavan-1" hydroscheme's head unit, the measurement data are used in the below calculations [6].

Table

Average annual distribution of suspended sediment flow rate R and fluid flow rate Q in the Tatar River basin

N	River - Haydropost	Basin surface F, km^2	Dimension	Months												Annual	Average annual turbidity ,g/m^3
				I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII		
1	Tartar- «Karvachar»	483	R, kg/s	0,020	0,022	0,030	0,122	0,371	0,241	0,105	0,079	0,035	0,027	0,021	0,028	0,092	16,9
			Q, m^3/s	3,01	2,91	3,18	5,72	13,13	12,21	6,58	4,47	3,91	3,70	3,39	3,12	5,44	
2	Tartar- «Vaghuhas bridge»	1915	R, kg/s	0,145	0,144	0,89	4,629	15,475	5,391	4,406	2,047	2,561	0,52	0,731	0,066	3,086	223
			Q, m^3/s	6,03	6,28	8,30	15,58	35,08	30,89	17,60	10,99	9,22	8,17	7,60	7,31	13,84	
3	Tartar - «Maghavuz»	2160	R, kg/s	0,213	0,29	1,082	23,95	45,30	24,68	23,427	10,43	4,65	5,85	1,307	0,605	11,814	615,6
			Q, m^3/s	8,31	7,82	10,12	28,58	49,45	42,72	23,45	14,37	13,88	12,43	10,27	8,92	19,19	
4	Tartar - «Mataghis»	2460	R, kg/s	0,34	0,35	1,82	21,42	44,30	53,05	29,69	6,93	5,45	2,01	0,51	0,41	13,86	605,2
			Q, m^3/s	10,0	9,5	13,7	32,1	53,7	52,2	28,3	19,5	15,5	15,8	13,8	11,1	22,9	
5	Levget- «Yegetnut»	363	R, kg/s	0,12	0,15	0,33	6,48	17,14	12,96	6,48	2,49	2,09	1,24	0,48	0,24	4,18	755,9
			Q, m^3/s	2,32	2,50	2,50	7,05	12,72	12,61	7,51	4,72	4,40	3,89	3,40	2,70	5,53	
6	Tutkhun- near the estuary	522	R, kg/s	0,013	0,019	0,053	1,598	4,032	2,655	0,85	0,246	0,097	0,137	0,030	0,020	0,813	191,7
			Q, m^3/s	1,60	1,57	2,16	6,59	9,34	9,94	5,43	3,47	2,99	2,89	3,09	1,80	4,24	

According to the measurements periodically carried out on the Tartar River in the 1960s and 1980s, the average annual flow suspended sediment is 3.1 kg/s.

Technique II. The flow of suspended sediment was determined by the turbidity of the river. The first value of turbidity was taken from the maps developed for rivers of Transcaucasia [7]. According to it, the turbidity values of rivers in the region vary between 250-450 g/m3. The second value is given in the below table of the measurements made at the Vaghuhhas hydropost, where the current turbidity was found to be 223 g/m^3. Taking the average of these data at 300 g/m^3, in case of the 13.8 m^3/s average annual fluid flow of the Tartar River, suspended sediment flow is 4.1 kg/s.

Technique III. The following correlation expression between suspended sediment and fluid flows obtained as a result of the studies carried out for the rivers of Eastern Transcaucasia is used to determine the suspended sediment flow [6]

$$R = 0{,}72\, Q_0^{0{,}95},$$

where Q_O is the fluid flow.

Since the average annual flow of fluid on water intake head unit's river section is 13.8 m^3/s (see Table), then, according to the above formula the flow of suspended sediment will be 8.7 kg/s. This value raises questions about the accuracy of the given formula because it is significantly higher than the earlier values.

To verify this, calculations were made using the same formula and the data obtained in the river hydrostations "Maghavuz" and "Mataghis". In particular, according to the measurements of the "Maghavus" hydrostation, the average annual fluid flow rate is 19.2 m^3/s. According to the same formula, the calculated flow rate of suspended sediment is 11.9 kg/s, which coincides with the value of 11.8 kg/s measured at the same station (see Table). According to the measurements of the "Mataghis" hydropost, the fluid flow rate is 22.9 m^3/s, and that of sediment is 13.9 kg/s. The calculated flow rate is 14.1 kg/s. It is not difficult to see that the results of the calculation and measurement are identical for these two stations. Therefore, there should be no reason to question the value of 8.7 kg/s found above for the "Vaghuhas" hydropost. Thus, in the river section of "Getavan-1" complex, three different values were obtained for the suspended sediment: 3.1 kg/s, 4.1 kg/s and 8.7 kg/s. These values are based on measurements and studies made 3-4 decades ago (no further measurements have been made for various objective reasons). Given these circumstance and the fact that the climate change has also had an effect on river flow, for the further calculations the suspended sediment flow rate is assumed 3 kg/s. Fine particles, smaller than 0.05 mm, are practically do not settle in reservoirs [8]. They make up 60–65% of the suspended sediment on the average. In other words, from sediment of 3 kg/s flow rate only 1kpart g/s is subject to accumulation. The remaining small amount is carried away by the current. As for the bottom sediments, according to the research [9], it is about 40% of suspended sediment flow rate. Thus, the average annual total flow rate of particles subject to accumulation in the unit under study will most likely be 2.2 kg/s.

Therefore, within one year, around 70 million kg or 38.5 thousand m^3 sediment can accumulate in the designed water receiving head (the average density of accumulations is assumed to be 1800 kg/m^3). The results of the aforementioned studies were attained using relatively small quantities. The structure will likely operate under harsher conditions than those predicted by the calculations.

For the head unit to function effectively, it is important to establish the largest sediment filling size that can be accommodated in the dam's upstream reach. The output quantities of the calculation are: in the area adjacent to the head unit, the slope of the Tartar River bed: i_0=0.0093, the frontal width of the dam body: B_d=32 m, the permissible height of the accumulation layer near the dam: h=1 m (from the river bed to the threshold of the water intake entry), the length of the accumulations' spread in the upstream reach: L_s= 120 m.

The accumulation body (Fig. 1) resembles a wedge and has a volume W that is equal to the half volume of a prism with base dimensions B_d*h and height L_s . According to the output data, the volume W of possible accumulations in the upstream reach will be around 2000 m^3. Therefore, even under ideal circumstances, 20 flushing operations will be required to remove the 38,500 m^3 of to remove 38,500 m^3 of deposited sediment in one year.

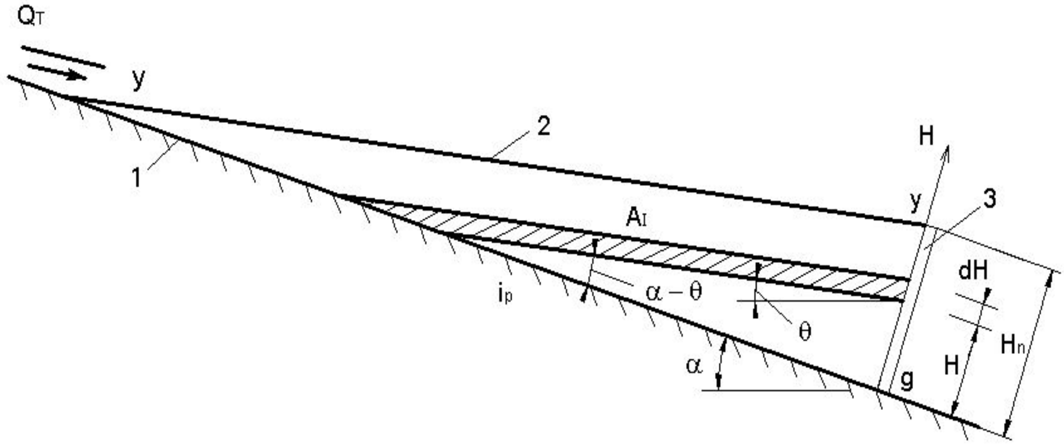

Fig. 1 Wedge-shaped body formation process of deposited sediment in the upstream reach body formation process

It is possible to lower the frequency of flushing operation in the upstream reach during operation, allowing the accumulation layer to rise to h=2 m. As a result, the amount of accumulation W volume will double, and the settler will require more often flushing. On the other hand, a large amount of sediment will enter the water intake and it will be necessary to flush the settler more often. Additionally, it will be very difficult to predict the length of each flush operation based on recent scientific studies [10]. In all cases, only in the run of the structure operation it will be possible to judge how well the aforementioned ideas work.

The operation of the head unit largely depends on the effective organization of the flushing process of accumulated sediment. This can be done with the correct placement of the dam's flushing outlets. If the outlets placement geometry is not designed properly, then the best part of deposited sediment will remains untouched [5]. The three outlets selected in the project development were located next to the water intake located on the right bank of the river (Fig. 2). The three openings chosen for the project were situated next to the water intake on the river's right bank (Fig. 2).

Due to such improper placement of outlets, a large volume of accumulations on the left bank will not be removed. Three wash openings are distributed appropriately to prevent this: two are near the shores, and one is in the middle. With such a setup, it will be possible to remove accumulations in an efficient manner from the entire front of the upstream reach. Additionally, the flushing time will be drastically cut down. In the case of the suggested solution, a valve-service bridge will need to be put in place on the dam.

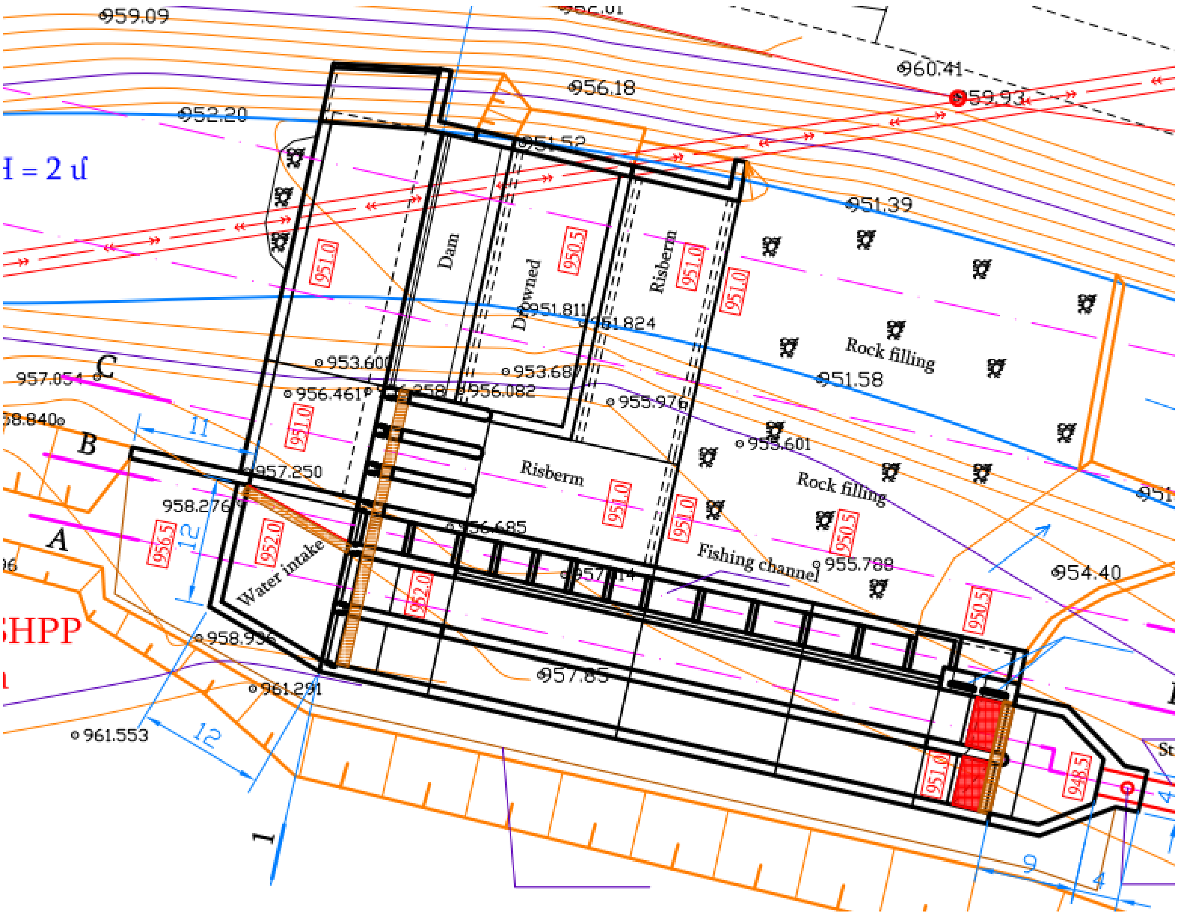

Fig. 2 Project plan of structures' placement in the water intake head unit of the «Getavan-1» hydroscheme

On the one hand, this will make it easier for the neighborhood's residents and the maintenance crew to move around, and on the other, it will make it possible to remove the floating bodies that have gathered in front of the dam during operation, preventing the dam and water intake from quickly becoming clogged.

Conclusions

The Tartar River water intake head unit area's design solutions significantly underestimated the turbidity of the river, which caused a sharp decline in the number of accumulated sediment load.

Applying parallel hydrological methods, determining of the river's sediment reliable regime, it possible to estimate the size of sediment maximum filling in the dam's upstream reach and the volume of accumulated sediment in the course of year. The flushing system's recommended configuration will make it possible to remove effectively the accumulated sediment in the hydraulic unit.

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«ԳԵՏԱՎԱՆ-1» ՀԻԴՐՈՀԱՆԳՈՒՅՑԻ ԳԼԽԱՄԱՍՈՒՄ ՋՐԱԲԵՐՈՒԿԱՅԻՆ ՌԵԺԻՄԻ ԳՆԱՀԱՏՈՒՄ ԵՎ ԿՈՒՏԱԿՈՒՄՆԵՐԻ ԼՎԱՑՄԱՆ ԱՐԴՅՈՒՆԱՎԵՏ ՄԻՋՈՑԱՌՈՒՄՆԵՐԻ ՄՇԱԿՈՒՄ

Բալջյան Պ.Հ.[1,2], Հայրիյան Գ.Լ.[1], Ջավադյան Հ.Ռ.[1], Մեսրոպյան Ս.Ս.[1]
[1] *Շուշիի տեխնոլոգիական համալսարան*
[2] *Հայաստանի ազգային պոլիտեխնիկական համալսարան*

Գետային կառուցվածքների նախագծման գործընթացում ջրաբերուկային ռեժիմի ճիշտ գնահատումը կարևոր դեր ունի պատնեշի վերին բյեֆում կուտակումների ծավալի որոշման և հիդրավլիկ լվացման արդյունավետ միջոցառում ընտրելու համար: Թարթառ գետի ջրընդունիչ գլխամասում ուսումնասիրվել է ջրաբերուկային ռեժիմը, գնահատվել պատնեշի վերին բյեֆում հնարավոր կուտակումների ծավալը և մշակվել հիդրավլիկ լվացման հանգույցի արդյունավետ շահագործման սխեմա: Թարթառ գետի ջրաբերուկային ելքի չափման տվյալների սահմանափակության պայմաններում կիրառվել է այդ ելքի որոշման երեք զուգահեռ եղանակ, որոնք ստացվել են տարածաշրջանային ջրահոսքերի վրա կատարված հետազոտությունների արդյունքում: Կատարվել է ջրաբերուկների ելքի երեք արժեքների համեմատական վերլուծություն և սահմանվել է դրա հաշվարկային մեծությունը, որի հիման վրա որոշվել է գլխամասի պատնեշի դիմաց կուտակման ենթակա ջրաբերուկների տարեկան ծավալը և վերին բյեֆում ջրաբերուկների հնարավոր լցվածության չափը: Հաշվի առնելով կուտակումների ծավալը, գլխամասային պատնեշի և դրա վերին բյեֆի երկրաչափական բնութագրերը տրվել է կուտակումների լվացման համար նախատեսված բացվածքների արդյունավետ դասավորություն:

Բանալի բառեր. ջրընդունիչ, ջրավազան, ջրաբերուկներ, հոսք, պատվար, տղմակալում, հիդրոմետրական դիտակետ:

ОЦЕНКА НАНОСНОГО РЕЖИМА В ГОЛОВНОМ ГИДРОУЗЛЕ «ГЕТАВАН-1» И РАЗРАБОТКА ЭФФЕКТИВНЫХ МЕРОПРИЯТИЙ ПО ПРОМЫВКЕ ОТЛОЖЕНИЙ

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В процессе проектирования речных сооружений правильная оценка наносного режима играет важную роль в определении объемов отложений в верхнем бьефе плотины и выборе эффективной меры гидравлической промывки. В головном водозаборе реки Тартар был изучен наносной режим, оценен предельный объем отложений в верхнем бьефе плотины и разработана схема эффективной работы гидравлического промывочного узла. В условиях ограниченности информации по данным измерений расхода наносов реки Тартар использовались три параллельных метода определения этого расхода, полученные в результате исследований на региональных водотоках. Был проведен сравнительный анализ трех значений расхода наносов и установлена его расчетная величина, на основании чего был определен годовой объем наносов, подлежащих отложению перед головной плотиной и допустимое количество наносов в верхнем бьефе. С учетом объема отложений, геометрических характеристик головной плотины и ее верхнего бьефа было представлено эффективное расположение отверстий, предназначенных для промывки отложений.

Ключевые слова: водоприемник, бассейн, наносы, сток, плотина, заиление, гидрометрический пост.

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