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EVALUATION OF THE ACTUAL STATE OF THE MATAGHIS RESERVOIR, W-H CHARACTERISTICS AND FORECASTING OF FUTURE CHANGES

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Abstract

The sediment flowing into the reservoir is mainly deposited in the conservation zone and over a certain period of years reduces the ability to regulate operation of the structure. Evaluation of the change in the W-H characteristic of the reservoir rim during operation, especially for small to medium-sized reservoirs, is of great scientific and practical importance. The studies of Mataghis reservoir enable for different stages of operation to find out the amount and deposition pattern of the accumulated sediment. As a result of the obtained data processing, the actual appearance of the W-H characteristic of the reservoir was obtained after 20 years of its commissioning and in its current state. The obtained results show that during 47 years of operation of the reservoir the accumulated sediment has already occupied about 70% of the reservoir volume. The change of the useful volume for the coming two decades has also been predicted. If no hydraulic flushing measures are taken, the reservoir may become completely full of sediment in 20-25 years. Hydraulic reservoirs flushing is an essential component of upkeep. To avoid operating problems and ensure a long equipment lifecycle, hydraulic reservoirs should be cleaned regularly as part of their preventive maintenance. The proposed technique designed for predicting sediment accumulation in the

reservoir bowl and its further behavior can be used to evaluate changes in the useful volume of the reservoir in operation.

Key words: water, reservoir, river, sediment, reservoir rim, outlet, solid flow, sedimentation, deposition of silt, accumulation density, hydraulic flushing.

Introduction

Reservoirs sedimentation, because of the reduction of the difference between the normal headwater level and the river bed marks, will gradually displace the volume that was previously used for water storage until eventually the reservoir becomes completely filled with sediment. It occurs due to coastal area weathering, transportation of suspended silt, the destruction of aquatic biomass, the penetration of sand into feeding rivers by winds and other causes. Thus, during operation, the sediment carrying along by the water flow, accumulates in the reservoir rim and continuously reduces its design volume. The sedimentary regime of the river has a great influence on the problem of estimating of the settled amount of sediment and adjustment of actual volume in the reservoir. Therefore, in addition to possible scientific and practical justification, it also has great economic importance. Experience in the operation of large and medium-sized reservoirs shows that most of the inflowing sediment deposits at the initial section of the reservoir, occupying a useful volume [1, 2].

Over a period of years, the large sediment loads will gradually cause deposition build-up and as a result water storage capacity will be lost, the beneficial uses that depend on water storage will eventually be lost. This description of sediment accumulation is very similar to the hydrodynamic phenomena taking place in the Mataghis reservoir under study [2].

The Mataghis reservoir, built on Tartar river, was put into operation in 1974. The maximum headwater horizon of the reservoir is 416.7 m, the dead volume horizon is 401.5 m, the total volume of the reservoir is 5.56 million m^3, the useful volume is 5.21 million m^3. The dam is earthen, its maximum height is 28 m [3]. The Sarsang reservoir with a useful volume of 500 million m^3 and 2160 km^2 catchment area was built in 1976 on Tartar river upper bank. Since 1976 the unregulated river flow feeding the Mataghis reservoir arises only on an area of 330 km2, half of which falls on the Trghi river and the rest to the lateral inflows. In order to compile the water balance of the Mataghis reservoir, it is necessary to study the lateral inflows of the Trghi river and to perform hydrological calculations [2].

Using the results of data processing of water flow measurement, the sediment inflows into the Mataghis reservoir were estimated [2]. The surface fluid flow of the Tartar river, which occurs during spring floods and rain poured down in torrents, is enriched by decomposed organic and weathered grounds in the river basin. The river is fed not only by sediment but also by destruction of the riverbanks.

To determine the total volume of accumulated sediment the data of hydrometric measurements were used for the entire period of operation of the reservoir (about 50 years), the balance of sediment was compiled, the accumulated volume was determined by calculation. The total volume of accumulated sediment was formed by sediment flows conditioned by the following three factors [2].

1.The main volume of the accumulated sediment was formed by accumulation of the sediment carrying along Tartar river during three years before the operation of Sarsang reservoir.

2. After commissioning of the Sarsang reservoir, the tributaries flowing into Tartar river in the Sarsang-Mataghis river section had an impact on the total volume. The sediment

carrying along these tributaries also have accumulated in the Mataghis reservoir (most of which is brought by the Trghi tributary).

3. Water discharge from the Sarsang hydroelectric power station forms the floods in the Tartar riverbed. As a result, the decayed soil of that section was transported to the Mataghis reservoir.

In the conditions of the current climatic and especially erosion situation of the Tartar catchment basin, the average annual total flow of sediments flowing into the Mataghis Reservoir will be about 35 thousand m^3 [2].

Materials and methods

The object of research and its formal description. Studies on the phenomenon of sediment accumulation in reservoirs have shown that most of the sediment settles in the useful volume of the reservoir. As a result, the structure gradually loses its prescribed ability to regulate river water. The results of the studies on determination of the sedimentation mode, amount of the sediment and the volume of the sediment accumulation in the Tartar river and Mataghis reservoir should be verified by comparison with the data obtained by field measurement.

In this connection, assessment of the volume reduction extent and forecasting future changes, especially for small to medium-sized reservoirs, is of significant economic importance. From a scientific point of view, especially from a practical point of view, this problem has not been sufficiently studied. There are no works in the professional literature, which reveal the regularity of reducing the storage capacity of a reservoir under operation. Most of the reservoirs in the South Caucasus are considered to be small to medium in size. Therefore, the above-mentioned issue is of primary importance for the countries of the South Caucasus. This study attempts to carry out investigation on the Mataghis reservoir built on Tartar river to answer some of the basic problems related to sedimentation of reservoirs.

Methods of research. The aim of this work is to evaluate the current state of the main $W = f(H)$ characteristic of the depth and volume of water in the reservoir, to make a forecast for its future change, based on the results of the study of the sediment accumulation in the Mataghis reservoir rim. It should be noted that in reservoirs research practice there are no published works to clarify this characteristic and predict further behavior.

Results and discussion

The first field studies of the Mataghis reservoir and its dam hydroscheme were conducted about ten years ago, when the reservoir was completely empty. Within the framework of these studies, the technical condition of all units of the structure, including the reservoir rim, was evaluated. Based on the obtained results, the operation declarations of Mataghis hydroelectric generating complex were developed. The carried out investigations have shown that of the total 5.56 million m^3 volume of the reservoir about 3.53 million m^3 was filled with sediment [2]. Taking into consideration that the dead volume is only 0.35 million m^3, it is not difficult to see that the 5.21 million m^3 useful volume of the reservoir was reduced by 3.15 million m^3.

New studies of the Mataghis reservoir rim were carried out in 2020. They were designed to find out the changes in the sedimentation regime and the state of accumulations in the reservoir during the last decade, make predictions about their possible developments, put forward proposals for the effective organization of the hydraulic flashing of the accumulated sediment.

Based on the results of geodetic measurements and calculations made in the first stage of the study (2011-2012), making use of the data presented in the bulletin on small reservoirs [3], the design plot of the $W = f(H)$ characteristic of the Mataghis reservoir volume and therein water depth was restored (Fig. 1).

These studies showed that during the first two decades of operation (1974-1993) by accumulation of the reservoir amounting 3.5 million m^3 sediment the upper surface of the sediment raised to 411 - 411.5 m [4]. Making use of the obtained data the real curve of the reservoir rim (Fig.1) corresponding to 1993 state was also plotted from which it appears that there were about 2.1 million m^3 left in the reservoir for regulation. For the next two decades, the reservoir was entirely empty and incoming fluid and sedimentary flows were removed from the reservoir by flowing round the dam, for the deep valves of the dam were failed. During those years, the water flow washed away about 700 thousand m^3 accumulated in the reservoir sediment, opening a rather large flood plain in the sediment [5].

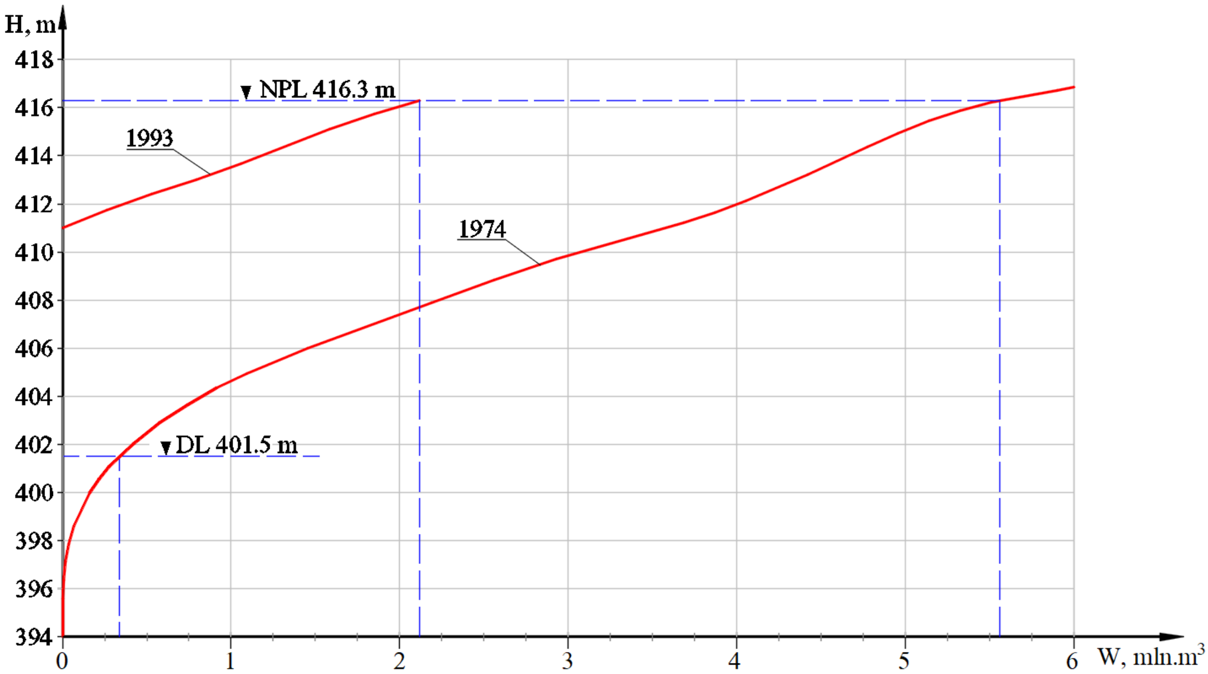

Fig. 1 Curves of $W = f(H)$ function – design (1974) and after two decades (1993)

Based on the structural description of mountain flows of rivers, it can be stated that the concentration of the sediment in the upper banks of rivers is smaller than the carrying capacity, due to which in such sections the river bed walls and the bed ground are washed out and the lack of sediment concentration is supplemented. In the lower parts of the border section the opposite phenomenon occurs: due to the high concentration of the carrying capacity, sediments are disconnected from the water body and sit on the floor along the entire length of the bed. The slope of the bed floor is changed over time, which also changes the boundaries of the boundary section and the carrying capacity. This creates new bed-formation conditions and, accordingly, new situational changes. In the case of dam construction, a prop stay is created on the riverbed, due to which the hydraulic slope becomes zero and the sediments settle. Deposition of the sediment in the reservoir occurs at the mouth of the estuary, where there is a change of the hydrodynamic regime and of the carrying capacity decline, as a result large particles settle on the bottom of the bed, causing a change in the bed slope geometry. As a result, the slope of the bed floor assumes a limit value in which case the amount of solid silt corresponds to the carrying capacity. In general, the sedimentation develops in three directions: mainly the height of the accumulations increases, in parallel with which the sedimentation front begins to move in the opposite direction of the flow. At the same time, a certain amount of sediment, in case of favorable conditions provided by the river bed, is transported to the interior sections of the river. Over time, depending on the flow hydrograph and the shape of the longitudinal profile of the bed, the vertical growth of sediment accumulations and the intensity of the backward motion begin to slow down [5].

That is why the volume of water in the Mataghis reservoir has increased in 2011-2012 and the $W = f(H)$ characteristic of the rim is somewhat different from that of 1993 (Fig. 2). Note that the volume of the sediment accumulated from 1974 to 1993 accounted for 3.5 million m^3 , of which 0.7 million m^3, transported from the Tartar river basin, was built-up in the first three years of the reservoir operation. According to the measurements made by the Mataghis hydrometric station, the average multi-year flow of suspended sediments was 13.9 kg/s [4]. About 60 per cent of the wash load is comprised of particles typically less than 0.05 mm in diameter and without being deposited in the reservoir they pass through the river. In parallel with the use of the measurement data, hydrological calculations for the determination of the sediment outflow were performed based on the proposed formula for the study area [6]

$$R = 0{,}72\, Q^{0{,}95}, \tag{1}$$

where Q is the average annual value of the fluid flow.

According to the calculations, the average multi-year flow of suspended sediment account for 13.4 kg/s, which is a good coincidence with the measurement data. As a result of the obtained data development the average total flow of suspended and bedded sediment entering the reservoir from 1974 to 1993 is about 15 kg/s. Three years later, after the construction of the Sarsang reservoir above the Mataghis hydropower plant, the solid flows have significantly decreased, averaging about 9.7 kg/s. Moreover, more than 5 kg/s part of the latter flows into the Tartar river through the mudflow Trghi tributary [4]. Assuming that the water and sediment regimes of the Tartar river and its Trghi tributary during 2012-2020 period have not undergone significant changes (no hydrometric measurements have been performed for three decades) let us determine the volume of sediment filled the reservoir in the last eight years

$$W = T\,\frac{Q_T}{\rho_T}, \tag{2}$$

where T is the calculation time span (315×10^6 seconds), Q_T is the total sediment flow (9.7 kg/s), r_T is the accumulation density (2000 kg/m^3).

According to the calculations the volume of additional accumulated sediment that entered the reservoir during the mentioned period was 1.2 million m^3, of which about 700 thousand m^3 was deposited during 1993-2012 in an occurred gulley and completely fill it. The remaining 520 thousand m^3 volume was distributed on the surface of the accumulations previously raised to 411 m mark, bringing it to 412-412.5 m marks. Thus, the results of studies carried out in 2020-2021 show that in 5.56 million m3 total volume of the reservoir was accumulated around 4 million m3 sediment. Therefore, no more than 1.6 million m3 is left for water regulation (Fig. 2).

It is quite difficult to make quite reliable predictions for the sedimentation regime of Tartar river and ongoing accumulation process in the reservoir, as changes occur regularly in the river basin. They are conditioned by climatic, especially anthropogenic factors. In the absence of regular measurements, it is impossible to accurately assess the impact of these changes. In particular, in the last decade, three small hydropower plants have been built on the Trghi tributary. Most part of the sediment carrying along by tributary flows is accumulated in their heading units, reducing the amount of the sediment inflows to the Mataghis reservoir. At the same time, climate change has led to a reduction of the fluid flows formation in the river basin.

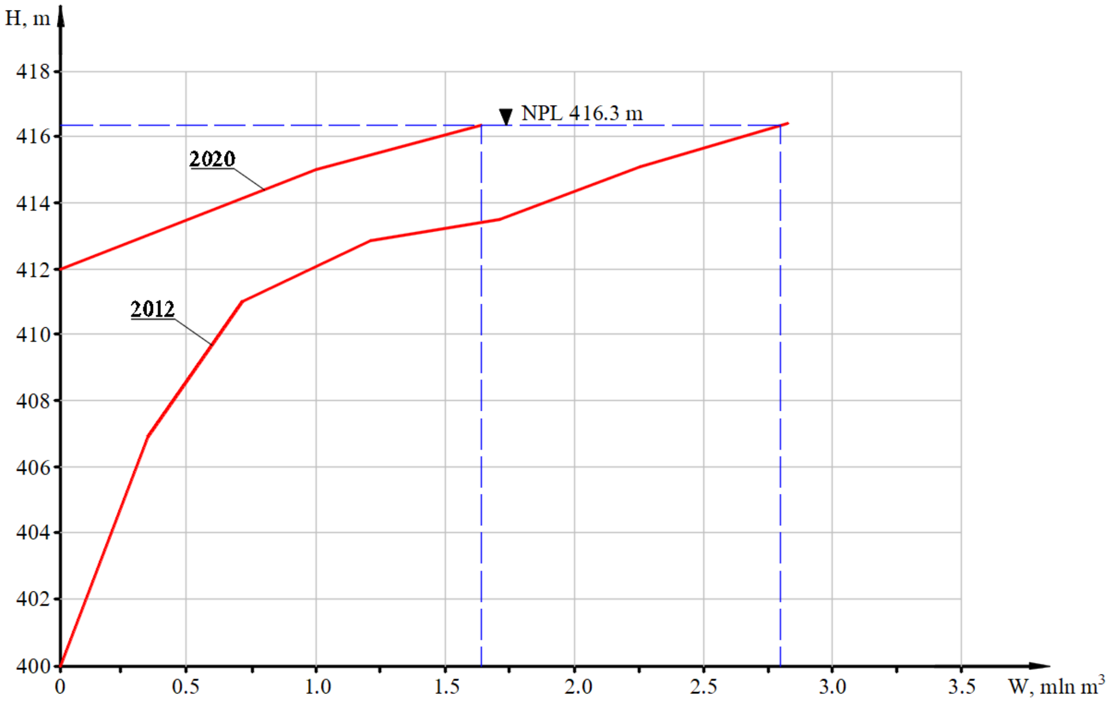

Fig. 2 Curves of $W = f(H)$ function according to studies carried out in 2011-2012 and 2020-2021

It can be stated that in such a situation the average sediment flow emptying into Mataghis reservoir cannot exceed 4.5-5 kg/s. In the presented conditions, let us try to estimate the changes in the volume of the Mataghis reservoir during the next one or two decades.

The volume of the sediment to be accumulated in the next ten years according to Eq.2 will increase by about 0.7 million m^3, and in the next twenty years – by 1.4 million m^3. Considering that there are currently about 4 million m^3 in the reservoir, then it can be predicted that the entire volume of the Mataghis reservoir will be practically completely filled with the sediment in the next 20-25 years.

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Conclusions

The example of Mataghis reservoir revealed the decrease of the useful volume of the reservoir due to the accumulation of the sediment. Adjustments to the reservoir rim $W = f(H)$ characteristic and predicting future behavior are novelty and allow the experience to be used to accurately evaluate the amount of water body in other reservoirs in operation.

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ՄԱՏԱՂԻՍԻ ՋՐԱՄԲԱՐԻ W-H ԲՆՈՒԹԱԳՐԻ ՓԱՍՏԱՑԻ ՎԻՃԱԿԻ ԳՆԱՀԱՏՈՒՄԸ ԵՎ ԱՊԱԳԱ ՓՈՓՈԽՈՒԹՅՈՒՆՆԵՐԻ ԿԱՆԽԱՏԵՍՈՒՄԸ

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Ջրամբար լցվող բերվածքները հիմնականում տեղադրվելով օգտակար ծավալում շարունակաբար փոքրացնում են կառուցվածքի կանոնավորման հնարավորությունը:

Հատկապես փոքր և միջին չափի ջրամբարների համար շահագործման ընթացքում ջրամբարային թասի W-H բնութագրի փոփոխման գնահատումը ունի կարևոր գիտագործնական նշանակություն:

Մատաղիսի ջրամբարի ուսումնասիրությունները հնարավորություն են տվել շահագործման տարբեր փուլերի համար պարզել կուտակված ջրաբերուկների քանակը և տեղաբաշխման ձևը: Տվյալների մշակման արդյունքում ստացվել է ջրամբարի W-H բնութագրի փաստացի տեսքը գործարկումից 20 տարի անց և ներկայիս վիճակով: Այդ արդյունքները ցույց են տալիս, որ ջրամբարի շահագործման 47 տարիների ընթացքում կուտակված բերվածքները արդեն զբաղեցրել են ջրամբարի ծավալի շուրջ 70%:

Կատարվել է նաև օգտակար ծավալի փոփոխման կանխատեսում ապագա 2 տասնամյակի համար: Կուտակումների հիդրավլիկական լվացման միջոցառումներ չիրականացնելու դեպքում, 20-25 տարի հետո ջրամբարը կարող է ամբողջովին լցվել ջրաբերուկներով:

Ջրամբարային թասում ջրաբերուկների կուտակման և դրանց հետագա վարքի կանխատեսման առաջարկվող եղանակը կարել է կիրառել շահագործման մեջ գտնվող ջրամբարում օգտակար ծավալի փոփոխությունները գնահատելու համար:

Բանալի բառեր. ջուր, ջրամբար, ջրամբարի թաս, գետ, ելք, ջրաբերուկ, կոշտ հոսք, տղմակալում, հիդրավլիկական լվացում, կուտակումների խտություն:

ОЦЕНКА ФАКТИЧЕСКОГО СОСТОЯНИЯ W-H ХАРАКТЕРИСТИКИ МАТАГИССКОГО ВОДОХРАНИЛИЩА И ПРОГНОЗИРОВАНИЕ БУДУЩИХ ИЗМЕНЕНИЙ

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Поступающие в водохранилище наносы, откладываясь, в основном, в полезном объеме, постоянно снижают возможность регулирования сооружения. Оценка изменения W-H характеристик чаши водохранилища в процессе эксплуатации, особенно для водохранилищ малого и среднего размеров, имеет большое научно-практическое значение.

Исследования Матагисского водохранилища дали возможность выяснить количество отложения наносов и форму их размещения для разных этапов эксплуатации. В результате обработки данных был получен фактический вид W-H характеристики водохранилища через 20 лет после его запуска и в его нынешнем состоянии. Эти результаты показывают, что наносы, накопившиеся за 47 лет эксплуатации водохранилища, уже заняли около 70% его объема.

Также было сделано прогнозированию по изменению полезного объема в течение следующих двух десятилетий. Если не будут приняты меры по гидравлическому промыву отложений, через 20-25 лет водохранилище может быть полностью заполнено наносами.

Предлагаемый способ определения количества наносных отложений в чаше водохранилища и прогнозирования их будущего поведения может быть использован для оценки изменения полезного объема находящегося в эксплуатации водохранилища.

Ключевые слова: вода, водохранилище, чаша водохранилища, река, выход, нанос, жесткий поток, заиление, гидравлический промыв, плотность отложений.

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