Section 13. Technical sciences

Ikramova Malika, PhD
Scientific Research Institute of Irrigation and Water Resources, head of laboratory
E-mail: Malika.ikramova56@gmail.com

Estimation of sediment loads: the Tuyamuyun reservoir on Amudarya river

Abstract: Dams and reservoirs greatly influence flow and sediment discharge regimes of rivers and can have significant impact on downstream reaches water quality. Bed load sediment management in reservoirs is required to save the reservoir capacity. In the paper a method for estimation of sediment accumulation/and removal is presented. The method allows determining future trends of the reservoir sedimentation.

Keywords: Reservoir, sedimentation, water turbidity, river runoff, removal, elevation.

Background. The Amudarya River is one of main water source for the Central Asian countries which plays a key role in their development. Water deficit is bound to increase, especially in the light of climate change and increase in demand for food production. Anthropogenic pressure has changed a natural hydrologic regime of the river. An original sediment concentration in the Amudarya water was broken due to its accumulation in the reservoirs as Nurek and Tuyamuyun Hydro Complex (THC) and huge volume of water diverting to the irrigation canals in the mid-stream (KMK, ABMK and Karakum canal). Average monthly turbidity along with the river varies within the following ranges/UZGIDROMET/: at the Kerki station — from 0.72 to 19 kg/m^3, at the Darganata station — from 0.30 to 7.0 kg/m^3, at the Tuyamuyun station — from 0.02 to 1.8 kg/m^3 and the Kipchak station — from 0.04 to 0.89 kg/m^3. Because of accumulation of sediments in the Channel reservoir of the THC the water flow in the lower sides of the Amudarya River has a low turbidity, the water is cleaner. Totally suspended matters and bed load varies from 4 to 10 Mio ton a year. In Fig.1 water inflow to the reservoir and outflow (a) and accordingly sediment transportation (b) is presented.

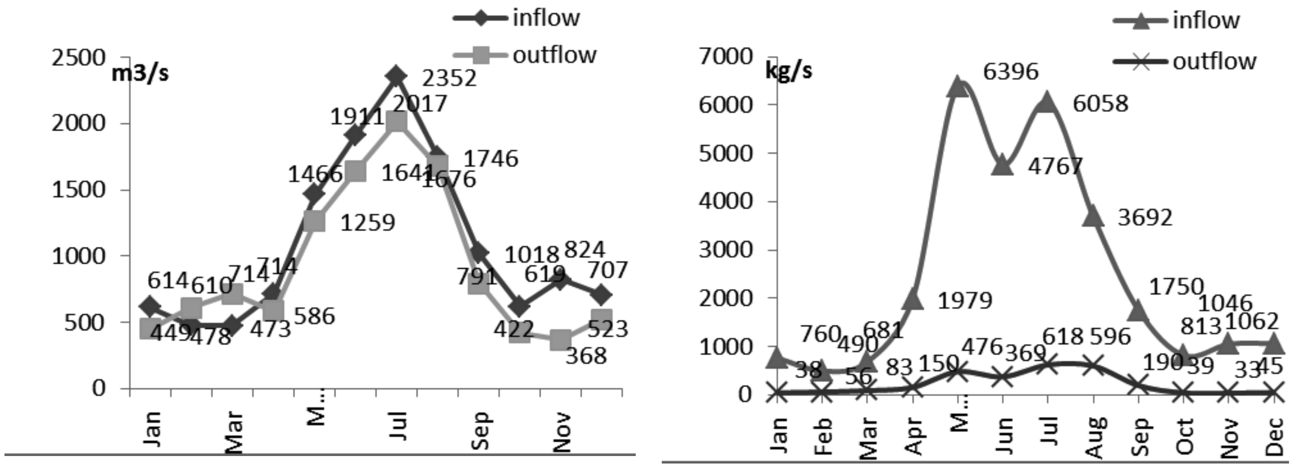

Fig. 1. Average water and sediments inflow and outflow from the Channel reservoir

The reservoir operation was started in 1981 and during this period the reservoir has been deformed significantly and lost over 40% of operational capacity. The field investigations conducted by SANIIRI 1985–2005 and the last by the BMC in 2008 and the data provided by the THC Management Unit allowed analyzing sediment accumulation and removal processes in the Channel reservoir. Average annual sedimentation volume for operation period (from 1981 to 2015) consists of 22.0 Mio m^3 a year. The most intensive accumulation of sediments took place in 1991–1992 (222 Mio m^3) and in 1998 (108 Mio m^3). Maximum removal of sediments has been observed in 1986 (135 Mio m^3) at the 20, 8 km^3 runoff, 1997 (56 Mio m^3) at the runoff of 18, 3 km3 and 2000–2001 (110 Mio m^3) at the runoff of 18,7 and 13,6 km^3.

As a result of study of sediment accumulation and transport through the Channel reservoir allow to divide it into 3 sections according to sedimentation rate: **the first section** (15 km section from the dam) consisting 110 Mio m3 of the reservoir capacity is totally covered by sediments. By 2015 an elevation of its bed has increased by 5 m. Sediment volume consisted 11% of total accumulated volume in the reservoir. Next 30 km is **the second section,** characterized by fluctuation of the accumulated 17.7% volume. After 25 years operation a sediment volume in this section consisted 36% of the initial volume. Sediments arriving from the third (upper located) section and its transition depend on the dam operation regime and inflowing and outflowing runoff. **The third section** with a length of 45–50 km is the most liable to water level change and the main sediment accumulation area. Regular replacement of sediments takes place depending on operational regime of the dam. In this area often an accumulation process can be alternated with removal and vice versa. For example, according to the data from 2011 the removal volume at the 3-section reached to 80–100 Mio m^3, at the same time at the 2-section took place a sedimentation up to 100 Mio m^3. A percentage of sedimentation relatively to the total volume of the reservoir is 71,3% in the III-section.

The reservoir morphology has been studied based on measurement data for the period from 1985 to 2008, and calculated to 2014. Allocation of sediments by the reservoir bed elevation is presented in Fig. 2.

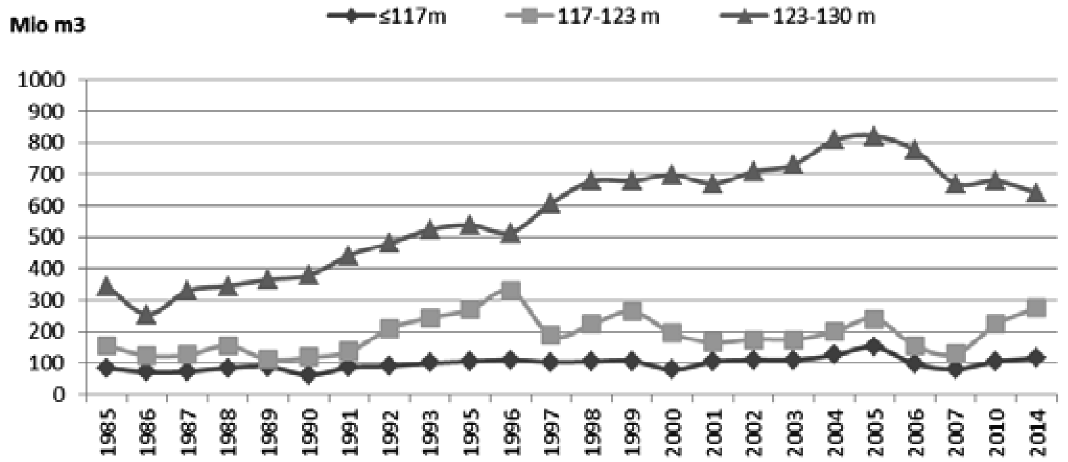

Fig. 2. Sediment accumulation dynamics in the Channel reservoir by elevations

The THC Channel reservoir sedimentation computing. The initial capacity of the reservoir is $W_i = W_r = \omega L$, i. e. water volume in the reservoir is equal to the original river volume, where the flow transports all suspended matters. Here, ω is a river cross-section area, m^2; L — is a length of a dam influence (backwater length). In this case, at $\frac{W_r}{W_i} = 1$, water cleaning (lightening) rate is $\varepsilon = 0$. But in the case, if $W_i > W_r$ and $\frac{W_r}{W_i} < 1$ then, $\varepsilon > 0$. Accordingly, $\varepsilon = f\left(\frac{W_r}{W_i}\right)$.

Water cleaning (lightening) rate is divided into two stages: at the 1-stage $\varepsilon = 1$, at the 2-stage as the $\frac{W_r}{W_i}$ increases and "ε" decreases from 1 to 0. Criteria of a transition from the 1-stage to the 2 — stage is $\frac{W_r}{W_i} = 0.12$.

For calculation of reservoir sedimentation the following input data is required: a design volume of a reservoir — W_d (Mio m^3); an initial volume of a reservoir (it may be the last measured volume) — W_m (Mio m^3); average monthly inflow — Q (m^3/s); water level elevation by the 1 day of a considering period (month) — $H_{i.}$ (m); water level elevation by the last day of the period (month) — H_l (m); initial joint level elevation — H_{ijl} (м); calculated full volume of a reservoir — W_c, W_{c-1}, ...W_{c-n}.

Water volume in the reservoir on a joint level elevation will be calculated by the formula $W_i = \frac{W_r\left(H_{ijl} - W_r\right)}{H_{nl} - H_d}$. Where, $W_r = 165$ Mio m^3 is an original river flow volume on average discharge of 1800m^3/s for the period of last 30 years on 110 km distance of the Channel reservoir; $W_r = 110m$ — dam invert level elevation, $H_{nl} = 130$ м — normal operating level (Fig. 3).

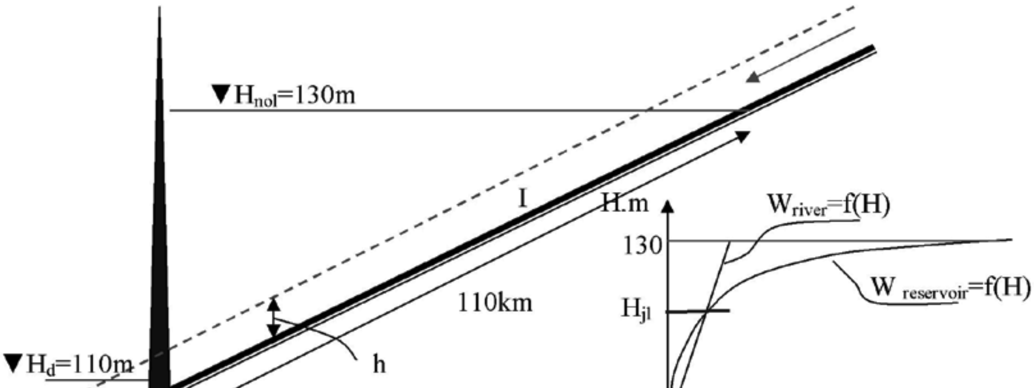

Fig. 3. Scheme for the calculation

Width of a considering part of the river stream is estimated by the formula $B = \frac{Q}{Vh}$. Here, $V = 1.2\, m/s$ – average flow velocity for Amudarya, h = 2.5 m – average flow depth at the THC. Water turbidity – ρ (kg/m^3) depends on flow discharge and turbidity coefficient – $\rho = KQ^{0.9}$. Here, K – a turbidity coefficient: for the January-May period K=0.0035; June-December K=0.0025/by SANIIRI/. Other characteristics for computing are identified by the following relations:

• river runoff for a considering period (Mio m^3) – $R = Qt$, t – period (s).

• inflowing sediment runoff for a the period (month) (Mio m^3) – $R_s = 0.0012 V \rho$

• initial sediment volume by the last measurement (Mio m^3) – $W_s = W_d - W_m$;

• average sedimentation level elevation – H_{Ws} (m), for the Channel reservoir at $W_s > 1000$ Mio m³, then $H_{W_s} = -10^{-6}W_s^2 + 0.0067W_s + 119.66$;

• water volume in reservoir (Mio m³) – $W_i = \frac{W_c(H_i - H_d)(H_i - H_{jl})}{(H_{nl} - H_{jl})(H_{nl} - H_d)}$, where i=1,2, … n;

• additional turbidity at a sediment removal (kg/m³), at $H_i < H_{jl}$ and $H_f < H_{jl}$ then $\rho_{add} = 0.83B\mu \cdot \frac{H_{W_s} - H_f}{IQ}$, here $\mu = 0.0008$ – sediment removal intensity (mm/s), $I = 0.00018$ – the river gradient;

• water lightening coefficient – $\varepsilon = 0$ at $H_i \le H_{jl}$ and $H_f \le H_{jl}$; if $H_i > H_{jl}$ then $\varepsilon = 0.041 \cdot \left[\frac{W_r(H_{nl} - H_{jl})}{W_r(H_i - H_{jl})}\right]^{-1.5}$;

• sedimentation/removal volume at filling up of the reservoir – W_{st}. At $H_i > H_{jl}$ and $H_f > H_{jl}$ and $H_i < H_f$, then

$$W_{st} = 1.2\rho \cdot \frac{R - [VW_i(1-\varepsilon)]}{W_f}$$

If $H_i < H_f$ and $H_f > H_{jl}$ and $H_i < H_f$, then below H_{jl} (removal) $W_{st} = 1.2\rho_{add} \cdot \left[\frac{R(H_i - H_{jl})}{H_i - H_f} + W_i - W_{jl}\right]$, and above H_{jl} (sedimentation)

$$W_{st} = 1.2\rho_{add} \cdot \left[\frac{R - R(H_i - H_{jl})}{H_i - H_f}\right] - \frac{V[1 - W_{ij}(H_i - H_{jl})]}{W_f(H_i - H_f)} \cdot (1-\varepsilon)$$

• sedimentation/removal volume at outflowing (month)–W_{st}: at $H_i > H_{jl}$ and $H_f > H_{jl}$ and $H_i > H_f$, then $W_{st} = 1.2\rho V\varepsilon$; if $H_i > H_{jl}$ and $H_f < H_{jl}$ and $H_i > H_f$, when $H > H_{jl}$ (sedimentation) then $W_{st} = 1.2\rho_{add}\varepsilon R \cdot \frac{H_i - H_{jl}}{H_i - H_f}$; at $H < H_{jl}$ (removal) then

$$W_{st} = 1.2\rho_{add} \cdot \left[\frac{R - R(H_i - H_{jl})}{H_i - H_f}\right] + W_{jl} - W_f.$$

• joint level elevation by the end oa period (month) at $H_i < H_{jl} < H_f$ (sedimentation process) $H_{jl(i)} = H_{jl(i-1)} + \Delta h_s$. Here, $\Delta h_s = \frac{W_s I}{3B_r(H_{jl(i-1)} - H_d)}$ – sediment layer height, m; at $H_i < H_{jl} > H_f$ (removal) $H_{jl(i)} = H_{jl(i-1)} + \Delta h_r$.

Here, $\Delta h_r = \frac{W_s I}{B_r(H_{jl(i-1)} - H_d)}$ – removed layer thickness, m.

The Channel reservoir capacity calculation and future trends. Firstly, the estimation was carried out based on the hydrological data and real operation regimes of the reservoir. In that case 1996, 1999, 2002 and 2003 were mean water years, 1997, 2000, 2001 and 2008 – dry and 1998, 2011 were wet years. Estimation results at different water years are given in the table 2.

Table 2. – Sediment accumulation depending on the river runoff

Water rate	Description	Unit	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
High water year	Water turbidity	kg/m³	0,96	1,45	1,56	1,79	4,42	4,95	4,85	3,10	1,77	1,05	0,94	1,05	
	Sediment inflow	Mio m³	1,58	3,44	4,42	5,68	39,68	48,79	70,17	27,26	8,10	2,78	2,11	2,76	216,78
	Accumulated sediment volume	Mio m³	1,43	3,44	3,57	4,28	29,95	27,16	56,99	15,97	3,05	1,72	1,13	1,82	150,50
	Removed sediment volume	Mio m³	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Low water year	Water turbidity	kg/m³	1,40	0,84	0,67	0,50	1,12	1,05	1,03	0,75	0,60	0,45	0,45	0,58	
	Sediment inflow	Mio m³	3,53	1,09	0,73	0,39	2,19	1,83	2,68	1,37	0,82	0,46	0,44	0,80	16,33
	Accumulated sediment volume	Mio m³	2,69	0,72	0,20	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,20	0,48	4,28
	Removed sediment volume	Mio m³	0,00	0,00	0,00	8,97	4,00	17,79	26,13	17,70	13,91	10,36	3,37	0,00	102,23
Mean water year	Water turbidity	kg/m³	1,04	0,58	0,40	1,36	2,30	1,98	1,91	1,17	0,92	0,71	0,53	0,61	
	Sediment inflow	Mio m³	1,86	0,49	0,25	3,16	9,98	7,01	9,81	3,50	2,03	1,20	0,65	0,89	40,83
	Accumulated sediment volume	Mio m³	1,31	0,27	0,05	1,67	5,78	2,68	2,69	0,24	0,43	0,70	0,42	0,35	16,58
	Removed sediment volume	Mio m³	0,00	0,00	1,39	6,76	0,00	0,00	0,00	6,05	8,65	0,00	0,00	0,00	22,86

In order to assess an accuracy of the results the actual data were compared with estimated, which showed its precision. In addition, the method developed can be used for prediction of the reservoir capacity loss. Calculation results are shown in Fig. 4.

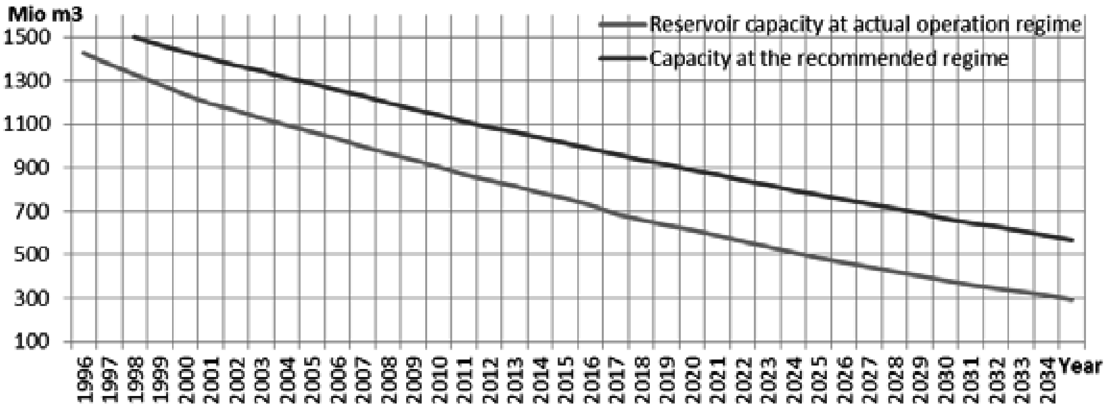

Fig. 4. Dynamics of the reservoir capacity change and its prognosis for future

Comparison of the estimation results carried out to identify of effective dam operation regime showed that at the operation regime developed by SANIIRI the reservoir sedimentation intensity is lower for 1.4 times than at the real one. Incoming and outflowing balance of sediments in the reservoir will happen at the reservoir capacity of 680–700 Mio m^3 (what means 30% of design volume), what will take place at the present operation regime by 2019–2020, but at the improved operation terms — by 2030.

References:

1. Barishnikov N. B. Anthropogenic impact on river bed evolution. – Leningrad publishing. LGM, – 1990.
2. Berkovich K. M. Channel processes in the rivers in the area of influence of reservoirs. Faculty of Geography, – Moscow State University, – 2012.
3. Ikramova M., Khodjiev A. Tuyamuyun water works operation improvement. Agriculture of Uzbekistan, – Vol. 4, – 2008.
4. Estimation of channel water balances. Methodical instructions for Hydro Meteorological Services. Saint Petersburg, GIDROMETEOIZDAT, – 2007.
5. Savitchev O. G., Krasnoshyokov S. Y., Nalivayko N. G. Regulation of river flow. Tomsk Polytechnic University. – Tomsk, – 2009.
6. Shmakova M. V. The methodology of calculation of sediment discharge for unstudied rivers. – Cheboksary, Perfectum edition, – 2012.
7. Skrilnikov V., Keberle S., Beleskov B. Improving efficiency of water reservoirs. – Tashkent, Mekhnat Printing, – 1987.

Yusubov Faxraddin Vali,
Azerbaijan State Oil and Industry University,
Department «Technology of oil and industry ecology»
Baku, professor in technical sciences,
E-mail: yus_fax@mail.ru

Shixaliyev Karam Seyfi,
Azerbaijan State Oil and Industry University,
Department «Orqanic substances and technology
of high molecular composition», professor of chemical sciences
E-mail: kerem_shixaliyev@mail.ru

Abdullayeva Maya Yadigar,
Azerbaijan State Oil and Industry University,
Department «Technology of oil and industry ecology»
Baku, PhD in chemical sciences,
E-mail: mayaabdullayeva@hotmail.com

Determination of optimal parameters of purification water surface from oil and oil products by sorbent on the basis of worn automobile tires

Abstract: The article describes an identification of optimal parameters for surface water purification from oil and oil products by sorbent based on worn automotive tires. In thus Optimal parameters for water surface purification from oil and oil products by sorbent have been found out on the basis of constructed regression model of the process.

Keywords: rubber crumb, sorbent, purification of water surface, method of experiment planning, mathematical model.

Sorbents are known to be used on eliminating environmental pollution in case of oil and oil product spills from tankers and oil pipes in reservoirs. However, all known sorbents don't provide required extent of purification and it takes much time to absorb oil and oil products. Rubber, being an elastomer material with a unique complex of properties is a large-tonnage product of chemical technology, one of the final products of oil and gas refining chain which is widely applied in different branches of industry and every day life. The scale of production of rubber products as well as formed rubber wastes are rather high [1; 2].

The tread of tires is produced from tread rubber (TR) on the basis of butadiene-styrene and divinyl rubber mixture BSR + SDR (70: 30), containing 50 mass fraction of technical carbon [3; 4].

The investigations carried out by us showed that crumb of rubber tread (CRT) differs from other tire rubber crumbs because of high rigidity, when crushed it doesn't roll up but has elastic grid structure, thus it has high adsorption surface.

Besides all mentioned characteristics of tread tire allowed to obtain on its basis not conglutinated rubber crumb with dimensions 0,06–0,08 mm, without applying additional materials and to use it successfully. Obtained results are shown in Tables 1; 2

Table1. – Association between water surface purification rate and amount of sorbent

Sorbent amount, gr	Amount of oil spill	Amount of absorbed oil, gr	Oil absorption coefficient	Rate of water surface purification,%
0,5	10	2,5	5	25
1,0	10	5,0	5	50
1,5	10	7,5	5	75
2,0	10	10	5	100