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THE EFFECT OF THE VOLGA-KAMA CASCADE OF WATER RESERVOIRS ON THE LOWER VOLGA HYDROLOGICAL REGIME

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The general operation structure of the Volga-Kama cascade of water reservoirs is described. The effect of the Volga-Kama cascade of water reservoirs on the inter-annual variability and intra-annual distribution of the Lower Volga runoff is appraised. Changes in the main parameters of hydrological high water regime, i.e., the period and starting dates of the main phases, the water level change rate at high water rise and decline, and water discharge and water temperature are considered.

KEY WORDS: Volga-Kama cascade of water reservoirs, Lower Volga, runoff, inter-annual variability, intra-annual distribution, high water regime

VPLYV VODNÝCH NÁDRŽÍ KASKÁDY VOLGA-KAMA NA HYDROLOGICKÝ REŽIM DOLNEJ VOLGY. V tomto článku je popísaná a zhodnotená všeobecná prevádzková štruktúra kaskády vodných nádrží Volga-Kama a jej vplyv na medzimesačnú variabilitu a medziročné rozloženie odtoku Dolnej Volgy. V štúdii sú zohľadnené zmeny hlavných parametrov hydrologického režimu s vysokou vodou, t.j. obdobie a začiatky hlavných fáz, rýchlosť zmeny hladiny vody pri vysokom náraste a poklese vody, vypúšťanie vody a teplota vody.

KĽÚČOVÉ SLOVÁ: vodné nádrže kaskády Volga-Kama, Dolná Volga, odtok, medzimesačná variabilita a medziročné rozloženie, režim vysokej vody

Introduce

The Lower Volga, including the Volga-Akhtuba floodplain, the Volga delta, and the Western lake-hillock district, is a unique natural object, the specifics of which are determined by seasonal and long-term changes in the Volga hydrological regime. After the Volga-Kama cascade of reservoirs was put into commission, the Lower Volga hydrological regime changed, affecting the high water phase most of all. A considerable shortening in the period of inundation and high water stand on the Lower Volga floodplains resulted in changes in the living and development conditions of unique ecosystems. Territories that used to be flooded in the past but have now become completely dry rapidly change in appearance, which is true primarily for their vegetation cover.

In this study the effect of the Volga-Kama cascade of water reservoirs on annual variability and intra-annual distribution of the Lower Volga runoff are considered, as well as the high water period, starting dates of high water phases, water level change rate at high water rise and decline, and water discharge and temperature.

Volga-Kama cascade of water reservoirs

Volga is a lowland river of 3694 km in total length, with a total basin catchment area of 1360000 km^2 (Collective, 2012b). There are 150717 rivers flowing across the catchment, and their total length is 574414 km. The Volga basin drainage density is 0.42. The Volga refers to rivers with mainly snow alimentation (60%), while the other 30 and 10%, respectively, fall to the share of subterranean and rainwater alimentation. The share of precipitation (the input fraction) in the Volga basin water balance is 673, 486 and 187 mm of which are spent on evaporation and runoff, respectively (Collective, 2012b).

The Volga basin has more than 100 reservoirs, including nine large reservoirs and three reservoirs of its main tributary Kama (Collective, 2012a). These 12 large reservoirs constitute the Volga-Kama cascade of water reservoirs (Figure 1). As a result of the formation of this cascade, the Volga flows in a backwater regime all the way from Tver to the Volgograd waterworks facility, except for a small area below the dam of the Gor'kovskayaHydroelectro Power Plant (HPP). The runoff through the dam of the Volgograd waterworks facility comes to the Lower Volga and spreads further right to the water area of the Caspian Sea in a backwater-free regime.

The main morphometric indexes of the Volga-Kama cascade reservoirs are given in Table 1, using materials from (Collective, 2012b).

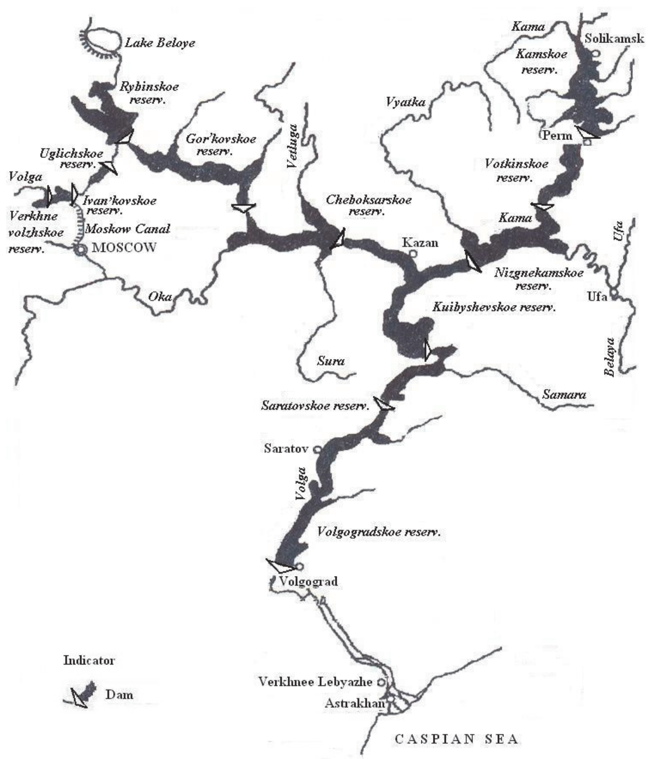

Fig. 1. The Volga-Kama cascade of water reservoirs (Avakyan, Sharapov, 1977).
Obr. 1. The Volga-Kama kaskada vodnych nadrzi (Avakyan, Sharapov, 1977).

Table 1. Main morphometric parameters of the Volga-Kama cascade of water reservoirs
Tabuľka 1. Hlavne morfologicke parameter kaskad vodnych nadrzi na Volge-Kama

Reservoir	Year of filling	Capacity, km^3		Surface area, km^2	Average depth, m	Length, km
		full	efficient			
Verkhnevolzhskoe	1843,1944	0.52	0.47	183	2.8	85
Ivan'kovskoe	1937	1.12	0.81	327	3.4	120
Uglichskoe	1939–1943	1.25	0.81	249	5.0	146
Rybinskoe	1940–1949	25.42	16.67	4550	5.6	110
Gor'kovskoe	1955–1957	8.82	3.90	1591	5.5	430
Cheboksarskoe*	1981	4.6/12.6	0/5.40	1080/2170	4.3/5.8	340
Kuibyshevskoe	1955–1957	57.30	33.90	6150	9.3	510
Saratovskoe	1967–1968	12.87	1.75	1831	7.0	312
Volgogradskoe	1958–1960	31.45	8.25	3117	10.0	540
Kamskoe	1954–1956	12.20	9.80	1915	6.4	300
Votkinskoe	1961–1964	9.40	3.70	10.75	8.8	360
Nizhnekamskoe*	1978	2.8/13.8	0/4.60	1000/2570	2.8/5.3	270
Total	-	**167.75**	**80.06**	**22004**	-	-
* The parameters of these reservoirs are given at the current normal water level in the numerator and at the target normal water level (NWL) in the denominator						

The cascade reservoirs differ in importance, and neither of them can solve per se the problem of using the water resources of the cascade and of the Lower Volga in general. Six Upper Volga reservoirs (Verkhnevolzhskoe, Ivan'kovskoe, Uglichskoe, Rybinskoe, Gor'kovskoe, and Cheboksarskoe) and three Kama cascade reservoirs (Kamskoe, Votkinskoe, and Nizhnekamskoe) control up to 95% of the Volga basin water resources that flow to the Kuibyshevskoe, Saratovskoe, and Volgogradskoe reservoirs. The Kuibyshevskoe reservoir is the largest reservoir and main water object of the Volga-Kama cascade; it serves as the basis for seasonal runoff control.

Lower Volga hydrography

The Lower Volga has no tributaries. Almost immediately below the Volgograd waterworks facility begins the Akhtuba River, the left branch of the Volga. Between the Volga and the Akhtuba, the Volga-Akhtuba floodplain with a width of 20–40 km and an area of 14000 km^2 (Levit-Gurevich, 2013), is located. The floodplain is mottled all over with many branches, anabranches, skidways, shallow channels, shallow lakes, and islands. The Volga-Don navigation canal is situated 47 km to the south of the Volgograd waterworks facility. In the vicinity of the KamennyiYar village, the Akhtuba comes very close to the Volga. In the vicinity of the VerkhneeLebyazhe village, the boundary between the floodplain and the Volga delta lies (Shiklomanov, Kozhevnikov, 1974; Bolgov, Levit-Gurevich, 2013). The area of the Volga delta is 19000 km^2, and the distance between the western and the eastern branches is 170 km. The delta is divided in three zones: the upper and middle zones with 482 water courses, and a lower zone with many (about 800) riverbed branchings. Twenty two kilometers down from the mouth of river Buzan, there is the Volga water separator, which supplies water to the Buzan river system to ensure better watering of the eastern part of the delta (Collective, 2012a). Below Astrakhan, the left branches KrivayaBolda and Kizan and the right branch Baktemir deviate from the Volga.

Inter-annual variability of the Volga runoff at the Volgograd gauging station

The appraisal of inter-annual runoff variability is based on findings of hydrological observations at the Volgograd gauging station, obtained during instrumental measurements, i.e., in 1881–2009. The chronological changes in the annual runoff volumes in 1881–2009 are given in Figure 2, in which the successive alternation of periods with differing water content is seen.

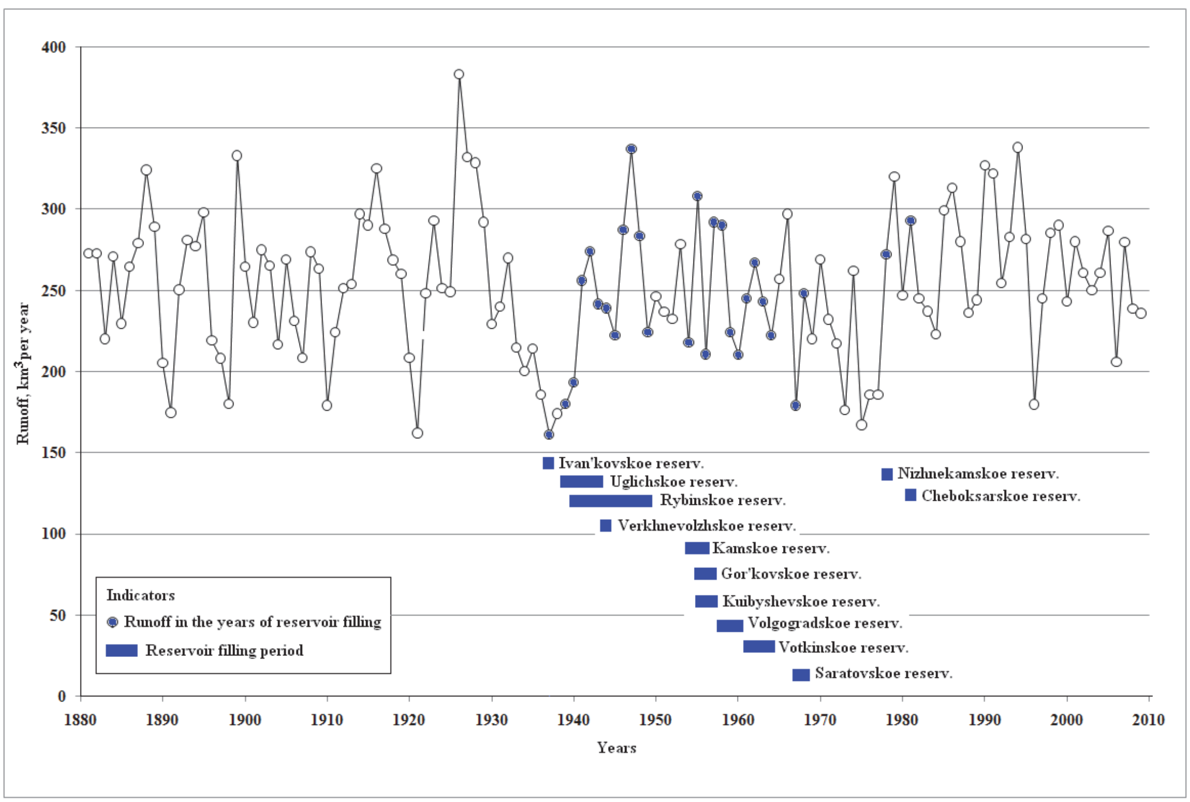

Fig. 2. Annual variability of the Volga runoff in the Volgograd gauge (Shumova, 2014).
Obr. 2. Ročná variabilita odtoku Volgy v stanici Volgograd (Shumova, 2014).

In the period of instrumental observations (1881–2009), the average long-term annual Volga runoff in the Volgograd gauge was 252 km^3, with a standard deviation σ=44 km^3. At the Volgograd gauge, the Volga reaches its peak watering level, but watering decreases to the south mainly because of water losses upon evaporation from the delta and the enormous areas of the Volga-Akhtuba floodplain, which is flooded during high water. The differences in runoff volume between the Volgograd gauge and the Caspian Sea are estimated to be 14.2 km^3 (Shiklomanov, Kozhevnikov, 1974). Floodplain runoff losses account for 3.4 km^3 (24%) and delta runoff losses account for 10.8 km^3 (76%).

As for the intensity of the effects of the construction and filling of Volga-Kama cascade of reservoirs on the Lower Volga runoff, two essentially different periods are distinguished: the arbitrarily natural runoff in 1881–1960 and control runoff (i.e., discharge to the bottom pond of the waterworks facility) in 1961–2009. The average annual runoff volumes recorded in these periods are almost the same, being 251 and 254 km^3, respectively (Figure 3). The increase indicated above in the Lower Volga average annual runoff volumes is caused by the fact that climate conditions formed in the period of the largest runoff control (especially in recent decades) are more favorable for runoff formation than under arbitrarily natural conditions (Koronkevich et al., 2007).

Naturally, the period of control runoff is characterized by lower runoff variability, with σ=41 km^3, while under arbitrarily natural conditions σ=45 km^3. In 1881–1960, the difference between the peak and the bottom Volga runoff volumes in the Volgograd gauge was 222 km^3, while it decreased to 171 km^3 in the control period.

In the period of arbitrarily natural runoff (1881–1960), three types of runoff are distinguished: normal, slightly disordered, and heavily disordered (Collective, 2010).

The time from the beginning of instrumental observations until 1936 is considered the period of the undisturbed Volga runoff; the average annual runoff was 255 km^3, with σ=45 km^3.

The time from 1937 until 1956 was the period of waterworks facility construction and reservoir filling. In that period, the runoff was slightly disordered and the average annual runoff was 240 km^3 (σ=46 km^3). In Figure 2 the duration of the filling of the Volga-Kama cascade reservoirs is shown. In 1937–1956, the Ivan'kovskoe, Uglichskoe, Verkhnevolzhskoe, Rybinskoe, and Kamskoe reservoirs were filled; about 12 km^3 of water was spent on filling their dead storage capacity, while their total capacity is 40.51 km^3 (Table1). In 1955, the Gor'kovskoe and Kuibyshevskoe (the biggest of the kind in the Volga-Kama cascade) reservoirs began to be filled, the dead storage capacities of which are estimated to be 4.92 and 23.4 km^3, respectively, and their total capacity is 66.12 km^3.

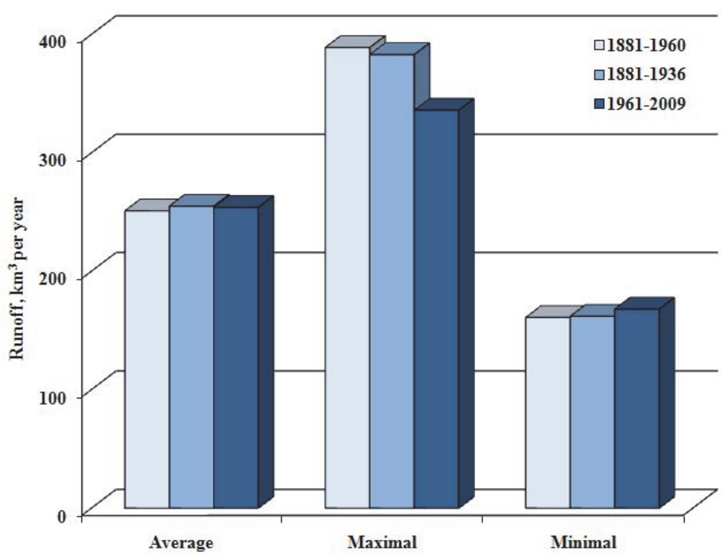

Fig. 3. Average volumes of the Volga annual runoff in the Volgograd gauge under arbitrarily natural runoff in (1881–1960), undisturbed runoff (1881–1936) and control conditions (1961–2009).

Fig. 3. Priemerné objemy ročného odtoku Volgy v stanici Volgograd počas prirodzeného odtoku (1881 – 1960), neprerušeného odtoku (1881 – 1936) a pri podmienkach riadeného odtoku (1961 – 2009).

From 1957 until 1960, the Volgogradskoe reservoir (dead storage and total capacity are 23.2 and 31.45 km^3, respectively) was actively filled, and the filling of the Gor'kovskoe and Kuibyshevskoe reservoirs was completed. That period is considered the time of heavily disordered runoff. According to certain estimations (Lindberg, 1970), the Volga runoff withdrawals back then reached 50–60 km^3 per year. At the same time, the average annual runoff at the Volgograd gauge from 1957 to 1960 was quite high and is estimated to have been 254 km^3 (σ=43 km^3), i.e., nearly as high as in the period of normal runoff.

After the Volgogradskoe reservoir was commissioned, the runoff coming to the Lower Volga at the Volgograd gauge has been the water discharging into the bottom pond of the hydraulic system. In terms of the Lower Volga hydrological regime, the time from 1961 to the present has been the period of control runoff regulated according to the Main Regulations of Operation of the Volgograd Reservoir Resources in Volga River (Collective, 1983). In the years following, the Votkinskoe (1964), Saratovskoe (1968), Nizhnekamskoe (1978), and Cheboksarskoe (1981) reservoirs were commissioned.

The Volga runoff volumes in the Volgograd gauge under undisturbed (1881–1936) and control (1961–2009) runoff conditions were even closer, being 255 and 254 km^3, respectively (Figure 3).

As a result of the control runoff period, the peak annual runoff decreased by 14% in 1961–2009, as compared to 1881–1936, while the minimal runoff rose by 4%. Similar changes are observed while comparing the arbitrarily natural (1881–1960) and the control (1961–2009) runoff.

Intra-annual distribution of the Volga runoff in the Volgograd line gauge

Although the averages of annual runoff volumes under arbitrarily natural and control conditions that flow to the Lower Volga at the Volgograd gauge are quite similar (Figure 3), the intra-annual distribution of runoff underwent considerable changes after the commissioning of the Volga-Kama cascade. In Figure 4, drawn according to the information from (Collective, 2004), the intra-annual distribution of runoff before and after the commissioning of the Volgograd waterworks facility is shown. After the control period (1961–2009), the runoff volume in December, January, February, and March almost doubled; in August, September, October, and November, it increased by 7–15%, and in April it increased by 27%. In June the runoff volume decreased by more than a half (by 58%), and in May and July it decreased by 20 and 27%, respectively.

In the period of arbitrarily natural conditions (1881–1960), the main part of the Volga annual runoff (about 67%) occurred during spring high water in April–July, 21% occurred in summer and fall (August–November), and 12% occurred in winter (December–March), (Figure 5). The control period greatly affected the Lower Volga hydrological regime and led to a considerable inter-seasonal distribution of runoff. Compared to the preceding period (1881–1960), the runoff volume in the control period decreased by 28% in April–July (high water) and almost doubled in December–March (the winter runoff low). In summer and fall, the changes were not as significant, and the runoff volume in August–November increased by 15% compared to the period of arbitrarily natural conditions.

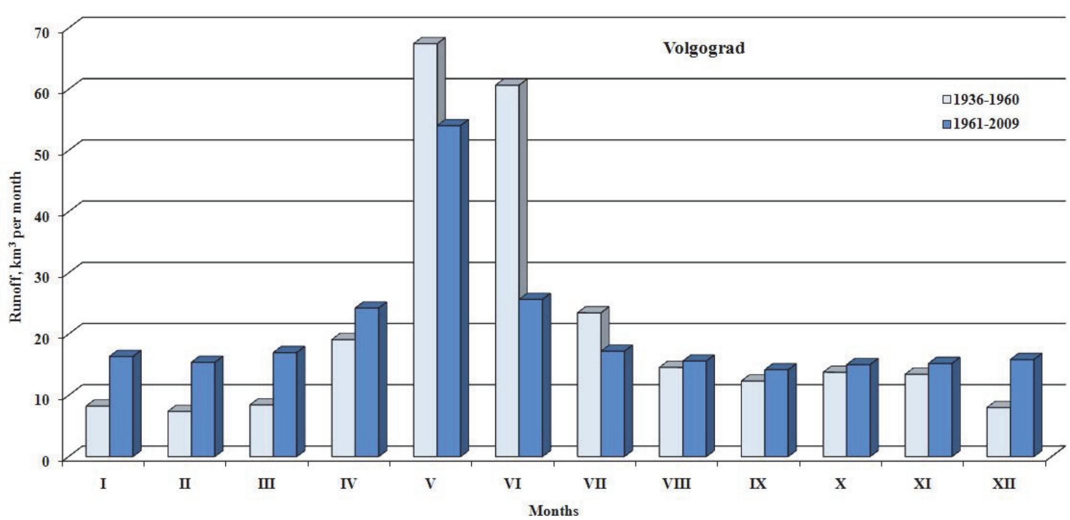

Fig. 4. Intra-annual distribution of the Volga runoff volumes in the Volgograd gauge under arbitrarily natural (1936–1960) and control runoff conditions (1961–2009).
Fig. 4. Medziročné rozloženie objemov odtoku Volgy v stanici Volgograd počas prirodzeného odtoku (1936 – 1960) a pri podmienkach riadeného odtoku (1961 – 2009).

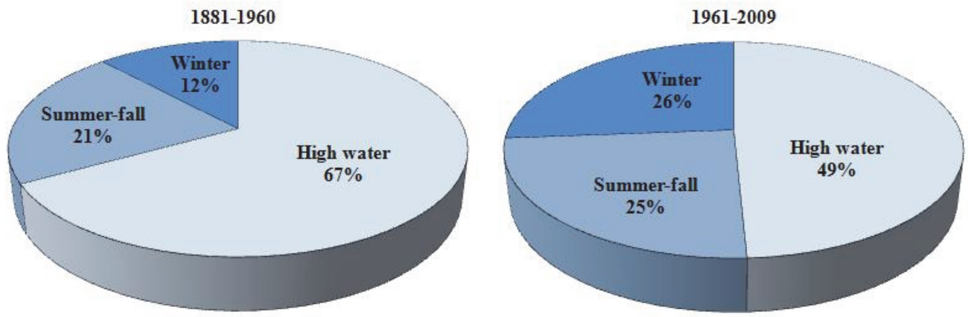

Fig. 5. Seasonal distribution of the Volga runoff volumes in the Volgograd gauge during the periods of arbitrarily natural (1881–1960) and control runoff (1961–2009).
Fig. 5. Sezónne rozloženie objemov odtoku Volgy v stanici Volgograd počas prirodzeného odtoku (1881 – 1960) a pri podmienkach riadeného odtoku (1961 – 2009).

Lower Volga hydrological conditions during high water

The main parameters of hydrological high water regime (high water duration, starting dates of high water phases, water level change rate at high water rise and decline, water discharge, and water temperature) are considered on the basis of data of observations in the Volgograd (the highest part of the Volga-Akhtuba floodplain) and the VerkhneeLebyazhe (the highest part of the Volga delta) gauges from 1936 to 2009, which are given in (Collective, 2010). The observations were divided in two periods: arbitrarily natural runoff conditions (1936–1960) and control runoff conditions (1961–2009).
The duration of high water in the highest part of the Volga-Ahtuba floodplain (Volgograd) decreased from 95 days under arbitrarily natural conditions to 64 days under control conditions (Figure 6). The decrease occurred mainly at high water rise, the duration of which fell by 19 days (almost twofold). The duration of high water decline decreased by 12 days on average.
Compared to the period of arbitrarily natural conditions (April 18), the starting date of high water in the highest part of the Volga-Akhtuba floodplain under control conditions remained almost the same (April 19). The high water under control conditions reaches its summit earlier (May 11) than under arbitrarily natural conditions (May 29) and finishes almost one month earlier (June 22 vs. July 23).
The high water period in the highest part of the Volga delta (VerkhneeLebyazhe) was shortened from 108 days under arbitrarily natural conditions to 74 days under control conditions (Figure 6). The period decreased mainly in the phase of high water rise, which was shortened by 22 days. The period of high water decline was shortened by 12 days. The high water in the VerkhneeLebyazhe would now start six days later (from April 16 to April 22), reach its peak earlier (May 22 vs. June 6), and finish almost a month earlier (July 4 vs. August 1), than under natural conditions.
Such considerable changes in high water duration and initial dates of main high water phases entail changes in arbitrarily other parameters, including water discharge, water level increase, and water temperature increase during high water rise.
At the beginning and at the end of high water periods, the water discharge in the Volgograd gauge under control conditions do not differ much from the water discharge under arbitrarily natural conditions; the differences are 1–2%; during high water rise, the water discharge under runoff control decreases by 8%. At the beginning and at the end of high water periods, the water discharge in the VerkhneeLebyazhe gauge under control conditions increases by 35 and 5%, respectively, compared with arbitrarily natural runoff regime; at high water peak, the water discharge decreases by 15%.
Considerable changes occurred under runoff control to the water level change rate at high water rise. Because of the early high water peak and the artificial decrease in the duration of high water rise in that period (during water rise), the rate of water level variations near the Volgograd more than doubled, i.e., from 15 cm a day under arbitrarily natural runoff conditions to 33 cm a day under control runoff conditions (Figure 7). The rate of water level variations near the Verkhnee-Lebyazhe increased from 8 cm a day under arbitrarily natural runoff conditions to 12 cm a day in control regime. A considerable rise in the water level change rate as compared to the period of arbitrarily natural conditions is also observed at high water decrease: from 12 to 19 cm a day near the Volgograd and from 7 to 9 cm a day near the VerkhneeLebyazhe.
An unnaturally rapid water level rise over a short period of time cannot ensure a normal water temperature regime. In the early high water phase, the water temperature in the Volga river bed in the highest part of the Volga-Akhtuba floodplain (Volgograd) increased

from 2.7°C under arbitrarily natural runoff conditions to 3.4°C under control runoff conditions. The water temperature rise in the early high water phase upon control runoff conditions is determined by the fact that water comes to the bottom pond of the Volga HPP only through the turbine water intakes in the lower part of the dam (Collective, 2010).

In winter and early spring, right after ice melting, the water temperature in the near-bottom layer of the reservoir is higher than on the surface. As of the starting date of high water, the average water temperature near the VerkhneeLebyazhe, which is located quite far to the south of the Volgograd, increased from 4.6°C under arbitrarily natural runoff conditions to 7.5°C under control runoff conditions.

The average long-term water temperature in the Volgograd gauge at the high water peak under arbitrarily natural runoff control conditions was 14.8°C, and under runoff control conditions the water temperature at the high water peak would rise only to 8.6°C on average. Similar changes also occurred in the highest part of the Volga delta (VerkhneeLebyazhe), where the average water temperature at the high water peak decreased from 18.4 to 14.1°C. As a result of the short rising phase and highly intensive water level increase, the water does not have time to heat up.

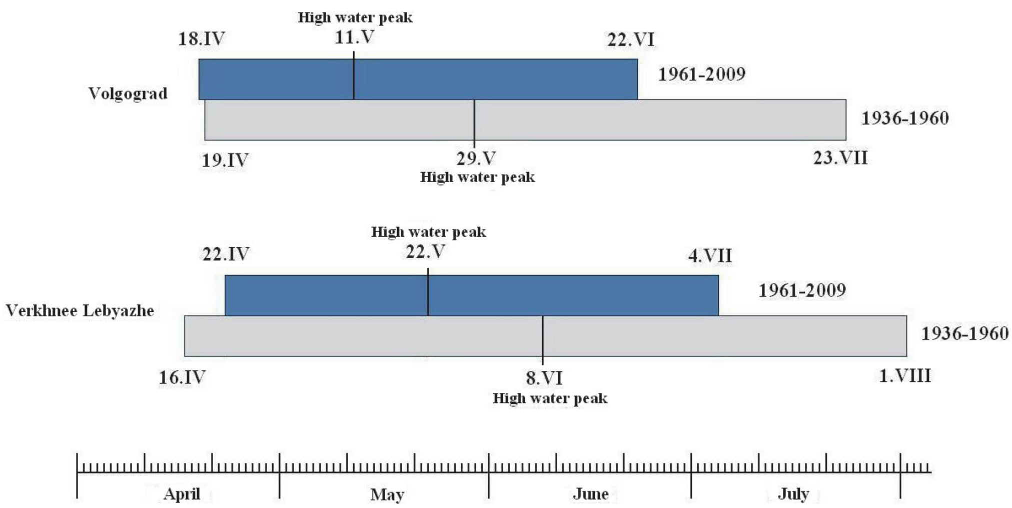

Fig. 6. Initial dates of the main phases and periods of high water in the Volgograd and the VerkhneeLebyazhe gauges in 1936–1960 and 1961–2009 (Shumova, 2014).
Fig. 6. Začiatok hlavných fáz a obdobia vysokých vôd v staniciach Volgograd a VerkhneeLebyazhe v rokoch 1936 – 1960 a 1961 – 2009 (Shumova, 2014).

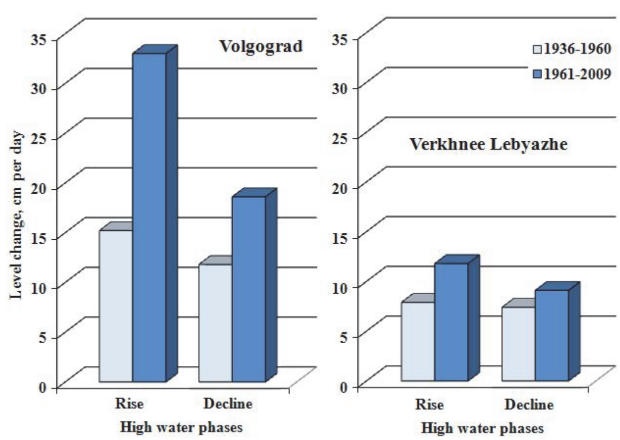

Fig.7. Water level change rates in the main high water phases in the Volgograd and the VerkhneeLebyazhe gauges in 1936–1960 and 1961–2009.
Fig.7. Chod zmeny úrovne hladiny vody v hlavných fázach vysokej vody v staniciach Volgograd a VerkhneeLebyazhe v rokoch 1936 – 1960 a 1961 – 2009.

By the end of high water, the average water temperature near the Volgograd under arbitrarily natural runoff conditions was 22.5°C and only 18.4°C in control regime, which is 4.1°C lower than under the former conditions. Under arbitrarily natural runoff conditions and in the control runoff regime, the water temperature in the VerkhneeLebyazhe gauge by the end of high water was 23.7 and 22.2°C, respectively.

Conclusion

The average annual runoff volumes of the Lower Volga in the Volgograd gauge in the periods of arbitrarily natural (1881–1960) and control (1961–2009) conditions were similar, as they were 251 and 254 km^3, respectively. Under control conditions the runoff volume of high water in spring (April–July) decreased by 30%, while in December–March (low-water season) and August–November it increased twofold and by 14%, respectively. Whereas the starting date of high water remained almost the same, the duration of high water in the Volgograd gauge decreased from 95 days in the period of arbitrarily natural runoff to 64 days in the period of control runoff. The high water peak shifted back 20 days, which leads to earlier floodplain area flooding. The period of high water rise was halved, which sharply increased the water level rise rate and therefore changed the Lower Volga thermal regime. During high water peak, the water temperature in the Volgograd gauge decreased by 6.2°C.

Within the framework of the UNDP / GEF Project 00047701 "Conservation of wetland biodiversity in the Lower Volga River", the Institute of Geography of the Russian Academy of Sciences has developed a Strategy and Action Plan for the conservation of the biodiversity of the Volga-Akhtuba floodplain and the Volga delta. One of the points of this document concerns a high degree of risk for wetlands in connection with the operation of the hydropower complex of the Volga-Kama cascade of hydropower plants and the Volgograd hydroelectric complex. Amendments are required to the regulatory documents on the environmental releases of the spring flood and the harmonization of the interests of energy, agriculture, fisheries and forestry and recreation during spring releases to the downstream of the Volga Hydroelectric Power Plant. Wetlands must enter the water management system of the Lower Volga as an equal water user. For this, it is necessary to determine their needs in the volume, mode, quality of flood waters and the development of appropriate regulations for releases (volume and mode) to the downstream of the Volgograd hydroelectric complex.

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VPLYV VODNÝCH NÁDRŽÍ KASKÁDY VOLGA-KAMA NA HYDROLOGICKÝ REŽIM DOLNEJ VOLGY

Dolná Volga, vrátane záplavovej oblasti Volga-Akhtuba, delty Volgy a Západného jazera, je unikátnym prírodným objektom, ktorého špecifiká sú určovane sezónnymi a dlhodobými zmenami v hydrologickom režime Volgy. Na povodí Volgy je viac ako 100 nádrží, vrátane deviatich veľkých nádrží a troch nádrží jej hlavného prítoku Kama. Tieto veľke nádrže tvoria kaskádu vodných nádrží Volga-Kama. Odtok cez priehradu vodného diela vo Volgograde smeruje do Dolnej Volgy a ďalej priamo do Kaspického mora – voľný režim.

V období prístrojových pozorovaní (1881 – 2009) bol priemerný dlhodobý ročný odtok Volgy v stanici Volgograd 252 km^3 so štandardnou odchýlkou $\sigma = 44\ km^3$. V stanici Volgograd dosiahla Volga vrchol úrovne zavodnenia, ale zavodnenie smerom na juh postupne klesalo. Rozdiely v objeme odtoku medzi stanicou Volgograd a Kaspickým morom sa odhadujú na 14,2 km^3.

Pokiaľ ide o intenzitu vplyvu konštrukcie a plnenia kaskády Volga-Kama z nádrží na odtok Dolnej Volgy, rozlišujú sa dve podstatne rozdielne obdobia prirodzený odtok v rokoch 1881 – 1960 a kontrolo-vany odtok (t.j. vypúšťanie do rybníka vodárne) v rokoch 1961 – 2009. Priemerné ročné objemy odtokov zaznamenané v týchto obdobiach sú takmer rovnaké, t.j. 251 a 254 km^3.

Aj keď sú priemerné ročné objemy odtoku pri prirodzených a kontrolných podmienkach veľmi podobné, po uvedení kaskády Volga-Kama do prevádzky prešlo medziročné rozloženie odtoku značnými zmenami.

V období prirodzenych prírodných podmienok (1881 – 1960) sa hlavná časť ročného odtoku Volgy (približne 67 %) vyskytla počas jarnej vysokej vody v apríli až júli, 21 % ďalej v lete a na jeseň (august – november) a 12 % počas zimy (od decembra do marca). Kontrolné obdobie výrazne ovplyvnilo hydrologický režim Dolnej Volgy a viedlo k značnému medzisezónnemu rozdelenu odtoku. V porovnaní s predchádzajúcim obdobím (1881 – 1960) sa objem odtoku v kontrolnom období v apríli až júli znížil o 28 % (vysoká voda), a v decembri až marci sa takmer zdvojnásobil (nizky zimný odtok). V lete a na jeseň zmeny neboli také významné a objem odtoku v auguste až novembri vzrástol o 15 % v porovnaní s obdobím prirodzenych prírodných podmienok.

Doba trvania vysokej vody v najvyššej časti záplavovej oblasti Volga-Ahtuba (Volgograd) klesla z 95 dní pri prirodzenych prírodných podmienkach na 64 dní pri kontrolovanych podmienkach. Pokles sa vyskytol hlavne pri vysokom náraste vody, ktorého trvanie kleslo o 19 dní (takmer dvojnásobok). Dĺžka trvanie poklesu vysokej vody sa v priemere znížila o 12 dní. Takéto značné zmeny v odbobí vysokej vody a počiatočných termínoch hlavných fáz vysokej vody vedú k zmenám v iných parametroch, vrátane vypúšťania vody, zvýšenia hladiny vody a zvýšenia teploty vody počas vysokého stupaňa vody.

Taktiež sa zaznamenali výrazné zmeny pri riadenom odtoku na rýchlosť zmeny hladiny vody pri vysokom stupani vody. Vzhľadom na skorý vrchol vysokej vody a umelé zníženie trvania vysokého nárastu vody počas tohto obdobia (počas nárastu vody), sa miera kolísania hladiny vody v blízkosti Volgogradu viac ako zdvojnásobila, tj z 15 cm denne podľa prirodzenych prírodnych podmienik odtoku na 33 cm denne pri podmienkach riadeného odtoku.

Priemerná dlhodobá teplota vody v stanici Volgograd počas vrcholu vysokej vody pri prirodzených podmienkach odtoku bola 14,8 °C a pri podmienkach riadeného odtoku by teplota v priemere vzrástla iba na 8,6 °C. V dôsledku kratšieho trvania stúpajúcej fázy a rýchlemu zvyšovaniu hladiny vody nemá voda čas na ohrev. Na konci vysokej vody bola priemerná teplota vody v blízkosti Volgogradu pri podmienkach prirodzeneho odtoku 22,5 °C a iba 18,4 °C v kontrolovanom režime, čo je o 4,1 °C nižšie ako v predchádzajúcich podmienkach.

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