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Perennial fluctuations of river runoff of the Yesil river basin

Lyazzat Makhmudova [1], Marat Moldakhmetov [2], Aynur Mussina [3], Adilet Kanatuly [1]
[1] Department of Water Resources and Melioration, Kazakh National Agrarian Research University
[2] Agrobiological Research Institute, Taraz Innovative-Humanitarian University
[3] Department of Meteorology and Hydrology, Al-Farabi Kazakh National University

ABSTRACT

The features of perennial fluctuations in the river runoff of the Yesil Basin Rivers are considered. The purpose of study is to analyze the spatial and temporal variability of various characteristics of river runoff in the F river basin. In the presented work, the series of annual and maximum water discharges were analyzed, as well as the series for the minimum runoff, based on analysis of runoff long-term fluctuations of the Yesil river basin and the authors' own researches. Hydrological calculations and statistical analysis were carried out using standard Excel and Statistica packages. Based on the processing of surface-based observations (1933-2016 years), as well as the analysis of literature data, conclusions were conducted about the presence of intra-century cycles in the series of the annual river runoff of the Yesil river basin. It was revealed that the Yesil Basin Rivers are characterized by a cyclic runoff with a period of 15-25 years. As a result of the analysis of the long-term variation of the values of the maximum water discharge, noticeable differences in the long-term variation of both the direct values of the maximum discharge and their absolute variability were revealed; it was revealed that the series of the minimum winter and summer-autumn runoff at a significant part of the gauging stations of the Yesil river basin are heterogeneous. The heterogeneity of the runoff series characteristics in the Yesil basin is due to both factors: climatic changes and anthropogenic pressure.

Keywords: Water resources, Hydrological characteristics, Air temperature, Gauging station, Climate change, Perennial fluctuations of river runoff.

Corresponding Author:

Lyazzat Makhmudova
Department of Water Resources and Melioration
Kazakh National Agrarian Research University
050010, 8 Abai Ave., Almaty, Republic of Kazakhstan
E-mail: makhmudova6970@tanu.pro

1. Introduction

The problem of global climate change and its forecast is now given great attention in the world; this problem is reflected, in particular, in the following scientific works [1; 2; 3-5]. According to scientific studies, given in [4], it follows that, at least since the beginning of the twentieth century, there has been an increase in the global problem – by smoothed values on 0.75°C. After a temporary cold snap from the middle of 1940s to the mid-1960s of the last century, there was already a continuous rise in temperature, but this is very indicative, an extremely powerful warming has been taking place since the middle of 1970s. This phenomenon was noted much earlier – so, O.A. Drozdov [4-9] pointed out that a new warming in the world began in 1973, and on this basis, doubts were expressed about the possibility of predicting future water resources based on long-term observation series.
According to the researches of V.P. Meleshko [2;10] the probability of warming since the middle of the twentieth century is associated with the concentration of greenhouse gases over 90 %, it follows that warming will be continue. Furthermore, the gases emission into the atmosphere constantly is increasing, but even with a reduction in emissions, the greenhouse gases already accumulated there anyway will cause an

increase in temperature. Consequently, a return to the situation that was, for example, in the middle of the last century, until the mid-70s, is unlikely, and the temporary hydroclimatic situation should be assessed based on the data of only the last 10 years.

In Russia, warming is greater than the global average, for the period 1972-2006 years the surface air temperature increased by 1.35±0.4°C [3; 11-20], while during the cold period it increased on average even by 2.5°C [4]. In Kazakhstan, by the 1990s the temperature rise was 1-1.3°C [21; 22], according to [23] only for the period 1954-2003 years the annual air temperature increased by 1.5°C, as showing by the data of long-term series meteorological stations, and at some meteorological stations (Pavlodar, Semipalatinsk), an increase by 2-2.5°C.

A significant change of temperature naturally entails changes in other meteorological characteristics, as well as in river runoff, and these changes have been especially noticeable since the 1970s, in particular, since the middle of 1970s the repeatability of zonal forms of atmospheric macro circulation is systematically increasing. At comparing water resources in a significant part of the European territory of Russia for the period 1978-2005 years with the previous period 1946-1977 years it increases is observing [24]. Scientific studies [2; 3; 25-30] contain the following statement in the water resources distribution in the future: in areas of excessive moisture, water resources will be increasing, and in areas where water availability is now insufficient, its further decrease is forecasting. Apparently, this dynamic feature of water resources is also typical for Kazakhstan. Indeed, in the inland regions of middle latitudes, an increase in temperature is causes an increase in evaporation, a decrease in the period of snow accumulation [9; 31-42], which negatively effects on the river runoff.

2. Material and methods

The Yesil River is a left-bank tributary of the Ertis, the river length is 2450 km, the catchment area is 177000 km^2, and including an active is 141000 km^2. The main climatic factors that determine the value of the spring and, consequently, the annual runoff of the Yesil Basin Rivers are snow reserves in the river basin by the beginning of the spring flooding, the intensity of snow melting, rainfall during floods, the degree of autumn moisture and the depth of freezing of soils in the catchment area. Snow reserves are the main source of power for the river. Precipitation during the spring flooding period is of secondary importance in the formation of runoff in the consideration area it amounts to 5-10 % on average, and only in rare years is consist 20-30 % of the amount of snow reserves [43-48].

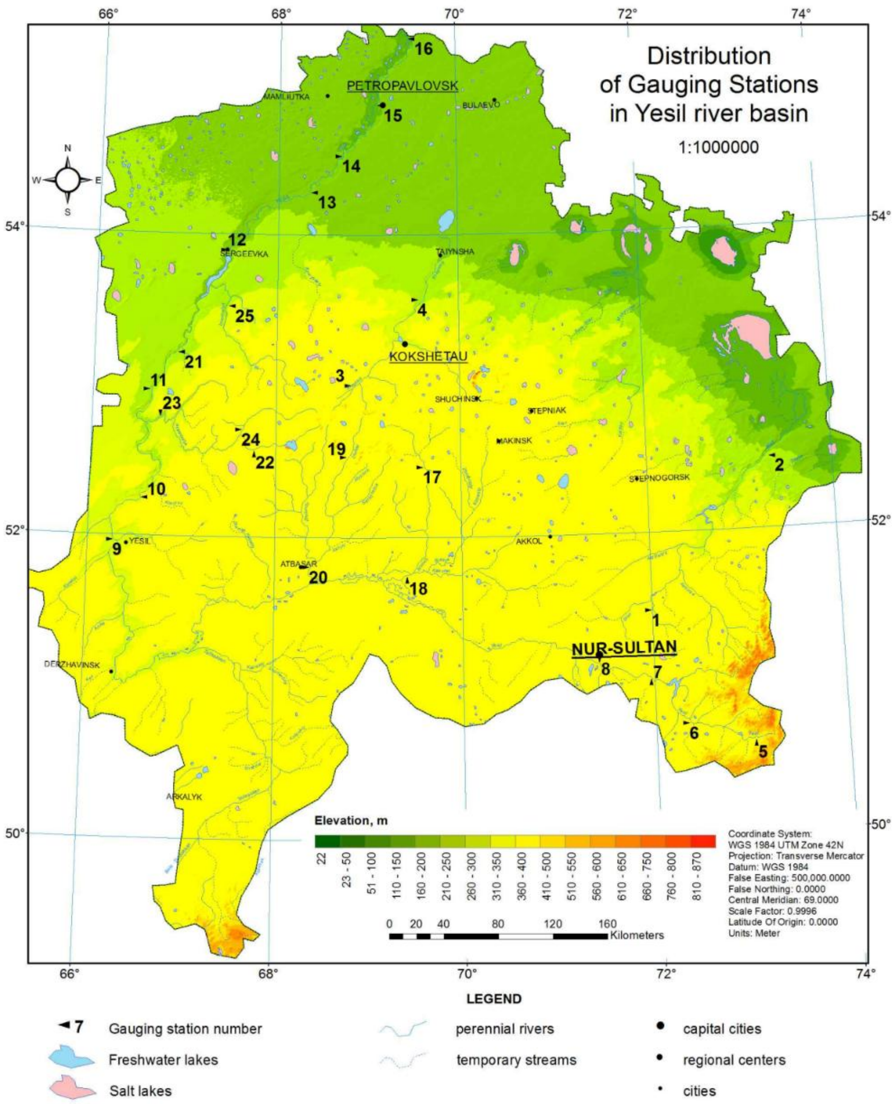
An important formation feature of river runoff in the Yesil river basin consists in the surface retention of melt water, which is quite degree facilitated by a relatively flat relief and a large number of macro depressions. In dry years, almost all runoff is spending on filling the relief depressions, runoff is negligible, and hydrological conditions approach those to the deserts. In high-water years, the relief depressions overflow and produce runoff into the main channel, the existing drainage area is increasing many times over. The main determinants of the minimum runoff are climatic and hydrogeological conditions. The territory of the Yesil river basin is characterized by a sharply arid climate and deep bedding groundwater. Due to the extremely limited reserves of groundwater in river basins, a significant part of the watercourses dries up in summer and the runoff to it resumes only in the spring season of the next year. The rivers runoff, in the feeding of which the groundwater takes a noticeable part, also periodically ceases, but mainly only in winter due to freezing of ripple areas, and sometimes reaches [49-55].

Low-water period on the Yesil River along its entire length lasts an average of nine months (from July to March). In the summer period, the minimum water discharges were observed in July-August, in the winter period – in January-March. Least of the minimum water discharges accounted on the winter low-water period. In the presented work, the series of annual and maximum water discharges were analyzed, as well as the series for the minimum runoff (minimum average monthly and minimum daily water discharges). Initial materials – observational data on the network of the RSE Kazhydromet published in the Hydrological Yearbooks, the State Water Cadastre (Figure 1, Table 1) (annual data on the regime and surface water resources of land) [10; 11; 12; 13 ;14; 56-60].

Selecting the boundaries of the calculation periods is based on the results of an earlier analysis of runoff long-term fluctuations of the Yesil river basin and the authors' own researches [15; 16; 61; 62-66]. Hydrological calculations and statistical analysis were carried out using standard Excel and Statistica packages; maps are executed by using means of software ArcGIS 10.6 (spatial analysis method). All calculations were performed in accordance with the normative document Code of Rules CR 33-101-2003 "Determination of the main calculated hydrological characteristics" and "Methodological recommendations for determining the calculated hydrological characteristics in the presence, insufficiency, absence of hydrometric observations and for assessing the homogeneity of hydrological characteristics and determining their values based on heterogeneous data” [17; 18; 19; 67-70].

Analysis of long-term fluctuations in Yesil river runoff is includes an assessment of quasiperiodicity, trend and statistical homogeneity of the series. For the studied series were obtained estimates of the mathematical expectation Q_0, variance S_2, standard deviation S, variation coefficient Cv, autocorrelation coefficients of the study series between the runoff of adjacent years r_1 and their errors [20; 71]. The evaluations were carried out using the moment’s method. For autocorrelation, offset corrections are introduced. Difference integral curves were used to isolate phases of increased and decreased water content.

The series homogeneity (stationarity) was checked by using the Student and Fisher criteria. Student's test is used to check the homogeneity of hydrological series in terms of mathematical expectation. Applying by the Fisher criterion is estimated the series homogeneity in terms of variance, the Fisher criterion is designed to analyze independent series obeying a normal distribution, the asymmetry coefficients Cs and autocorrelation r_1 were taken into account in the calculation [21; 72; 73].



Gauging N	River	Hydrological alighnment	Gauging N	River	Hydrological alighnment	Gauging N	River	Hydrological alighnment
1	Silety	Prirechnoe	10	Yesil	Kalachi	18	Kalkutan	Kalkutan
2	Silety	Izobilnoe	11	Yesil	Zapadnoe	19	Zhabay	Balkashino
3	Shagalaly	Pavlovka	12	Yesil	Sergeevka	20	Zhabay	Atbasar
4	Shagalaly	Severnoe	13	Yesil	Pokrovka	21	Akkanburlyk	Privolnoe
5	Yesil	Priishimskoe	14	Yesil	Novonikolskoe	22	Akkanburlyk	Kovylnoe
6	Yesil	Turgen	15	Yesil	Petropavlovsk	23	Akkanburlyk	Vozvyshenka
7	Yesil	Volgodonovka	16	Yesil	Dolmatovo	24	Babykburlyk	Rukhlovka
8	Yesil	Nur-Sultan	17	Moiyldy	Nikolaevka	25	Imanburlyk	Sokolovka
9	Yesil	Kamennyi Karier						

Figure 1. Location of gauging stations used in the study

Table 1. Characteristics of hydrological gauging stations in the Yesil river basin

GaugingNo.	River	Hydrological alighnment	Distance to the river mouth, km	Observation period	Area, km^2	The average altitude of the catchment, m
1	Silety	Prirechnoe	343	1961-2016	1670	358
2	Silety	Izobilnoe	134	1959-1965, 1968-2016	14600	340
3	Shagalaly	Pavlovka	185	1939-2016	1750	395
4	Shagalaly	Severnoe	78	1955-1962, 1964-1995, 1997	$\frac{5040}{8360}$	317
5	Yesil	Priishimskoe	202	1949-1991, 2005-2016	2437	606
6	Yesil	Turgen	2367	1974-2016	3240	524
7	Yesil	Volgodonovka	2299	1977-2016	5400	-
8	Yesil	Nur-Sultan	2241	1933-2016	7400	209
9	Yesil	Kamennyi Karier	1416	1947-1997, 2003-2016	86200	358
10	Yesil	Kalachi	1461	2009-2016	87250	-
11	Yesil	Zapadnoe	1302	1974-1995, 2001-2016	90000	342
12	Yesil	Sergeevka	1079	1971-2016	$\frac{117}{109000}$	-
13	Yesil	Pokrovka	1043	1948-2002	$\frac{104000}{115000}$	319
14	Yesil	Novonikolskoe	885	1976-1991, 1993-1994	$\frac{105000}{117000}$	-
15	Yesil	Petropavlovsk	879	1926-1984, 1986-2016	$\frac{106000}{118000}$	314
16	Yesil	Dolmatovo	627	1982-1984, 1988-2016	$\frac{142000}{113000}$	-
17	Moiyldy	Nikolaevka	22	1973-1995, 2001-2016	472	530
18	Kalkutan	Kalkutan	44	1937-1940, 1955, 1956, 1958-2016	16500	361
19	Zhabay	Balkashino	144	1960-2016	922	440
20	Zhabay	Atbasar	16	1936-1940, 1944, 1945, 1947-2016	8530	364
21	Akkanburlyk	Privolnoe	152	1956-1985, 1987-1999, 2001-2008	910	388
22	Akkanburlyk	Kovylnoe	164	2008-2016	910	388
23	Akkanburlyk	Vozvyshenka	12	2008-2016	$\frac{5620}{6250}$	315
24	Babykburlyk	Rukhlovka	7.2	1958-1998	1320	366
25	Imanburlyk	Sokolovka	29.9	1950-2016	$\frac{3870}{4070}$	282

3. Results and discussion

Assessment of changes in air temperature and precipitation. According to WMO data for 1906-2005 years the air temperature in the earth's surface has increased by 0.74°C, the last 50 years, the temperature has increased at a rate of 0.13°C every 10 years. In [22], estimates of changes in the annual and seasonal surface air temperature are presented. The increase in air temperature in the winter season of the Yesil water basin is reaches 0.43°C/10 years, the spring air temperature increased at a rate of 0.44°C/10 years, in the summer air temperature the trend was 0.19°C/10 years, the increase in air temperature in the autumn season was 0.46°C/10 years.

Modern climate changes on the territory of the considered region are researched in [23; 24; 22; 74-85]. In general, in the last 20 years in Kazakhstan were prevailed significant positive deviations of the average annual temperature of the surface layer and this is typical for all seasons of the year (0.39°C/10 years). On the territory of the Yesil water basin, the annual precipitation increases everywhere up to 300-380 mm. The maximum precipitation in the annual cycle occurs in the summer period, the minimum – in the winter with large amplitude. The precipitation of the warm period is 2.5-3.0 times higher than the precipitation of the cold period. The amount of precipitation at the Nur-Sultan meteorological station: annual – 308 mm, warm half of the year – 219 mm. The standard deviation ranges are from 25-30 mm in July (the maximum value at the Petropavlovsk meteorological station is 42 mm), to 5-10 mm in February (the minimum value at the Yesil meteorological station is 4 mm).

The precipitation regime varied ambiguously over the Kazakhstan territory and over the seasons. On the Yesil water basin territory the winter precipitation is increased significantly; positive trends are insignificant for anomalies of annual precipitation amounts (0.1-0.4 mm/10 years). An assessment of trends over the past 40 years showed that, with the exception of the Zhaiyk-Caspian basin, precipitation began to increase in the rest of the basins, and on average for the Aral-Syrdariya, Balkash-Alakol, Nura-Sarysu and Shu-Talas basins, as well as for the average for Kazakhstan, these tendencies were 6.4-18.1 mm/10 years with the values of the determination coefficient 5-8 % [22; 86-97].

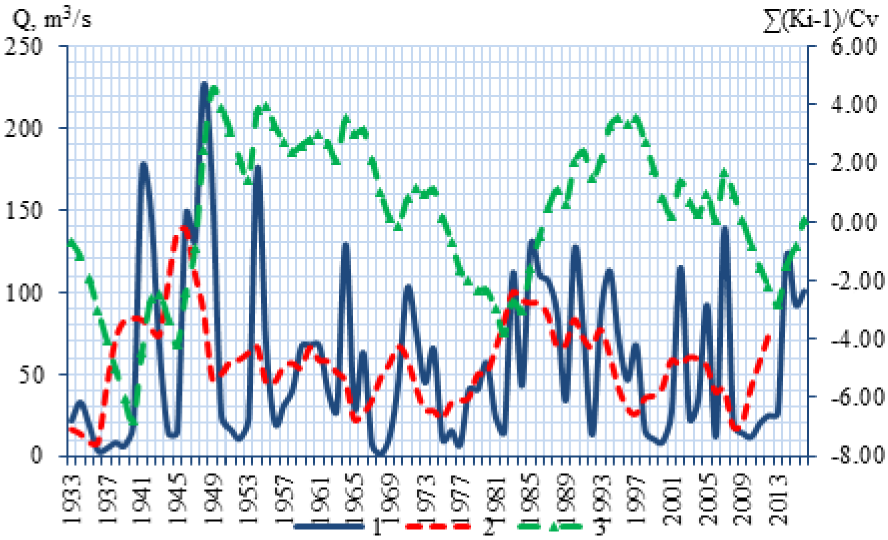
Assessment of changes in annual, maximum and minimum runoff. Analysis of annual runoff fluctuations. The selection of the calculation period in a changing climate condition for such a large and orographically complex territory like Kazakhstan is very difficult. First, it is difficult to expect complete consistency of fluctuations in hydroclimatic characteristics in all basins. Secondly, the river runoff is influenced by economic activity, but it is not the same in different parts of the territory and changes significantly over time. Further, it is quite obvious that general hydroclimatic laws should be better appeared in large basins. In almost all large and medium-sized rivers of Kazakhstan, the climatic runoff is strongly distorted, in particular, by reservoirs, including in the Yesil river basin. At analyzing, it is necessary take account of the features of the runoff series in a significant part of Kazakhstan: exceptional, due to no analogues, low water period in the 1930s, and a very high runoff in the 1940s.

Difference integral curves are widely applied to identify the phases of increased and decreased water contents of rivers, the moments these phases change. However, it should be taking account of that it illustrates the course of the accumulated anomaly only relative to the average sample. Analysis of the river runoff dynamics of the Yesil river shows that runoff fluctuations occur cyclically (Table 2, Figure 2,), which has been repeatedly noted by most researchers [25; 26; 98-110]. High-water phases lasting 10-23 years are replaced by low-water phases lasting from 4 years. During the period of hydrological observations, two complete cycles were identified (1940-1982 and 1983-2013). The lowest average annual water discharges were observed in the Petropavlovsk in 1968 (1.38 m^3/s) and in 1977 (7.26 m^3/s). The highest average annual water discharges were observed in 1941 (175 m^3/s), in 1948 (227 m^3/s), in 1990 (127 m^3/s) and in 2007 (139 m^3/s).

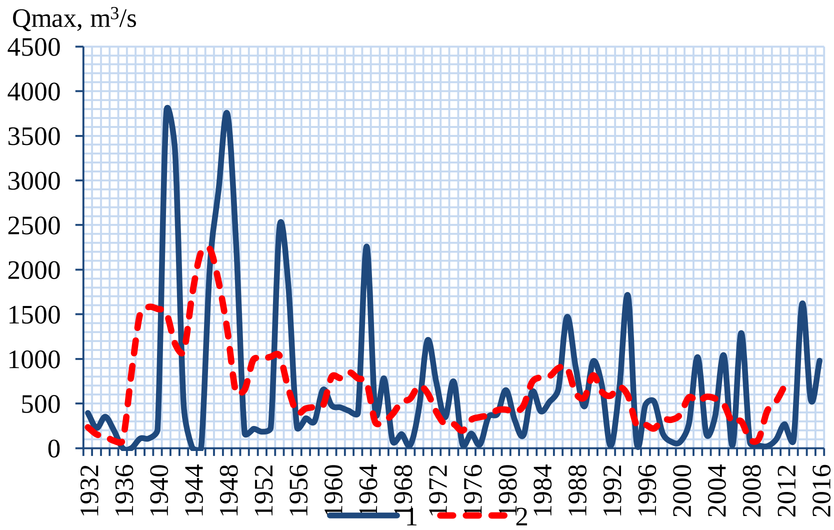
Table 2. High-water and low-water periods of the Yesil river in the gauging station of the Petropavlovsk city

Low-water periods			High-water periods			Cycle duration	Average water discharge for the period, m^3/s
Period, years	Duration, years	Average water discharge for the period, m^3/s	Period, years	Duration, years	Average water discharge for the period, m^3/s		
1933-1939	7	13.9	1940-1949	10	111	17	70.7
1950-	4	18.7	1954-	11	66.8	15	54.0

Low-water periods			High-water periods			Cycle duration	Average water discharge for the period, m^3/s
Period, years	Duration, years	Average water discharge for the period, m^3/s	Period, years	Duration, years	Average water discharge for the period, m^3/s		
1953			1964				
1965-1969	5	22.8	1970-1974	5	67.2	10	45.0
1975-1982	8	26.5	1983-1997	15	81.9	23	62.7
1998-2001	4	15.5	2002-2007	6	69.6	10	48.0
2008-2013	6	19.5	2014-2016	3	105	9	48.1



a)



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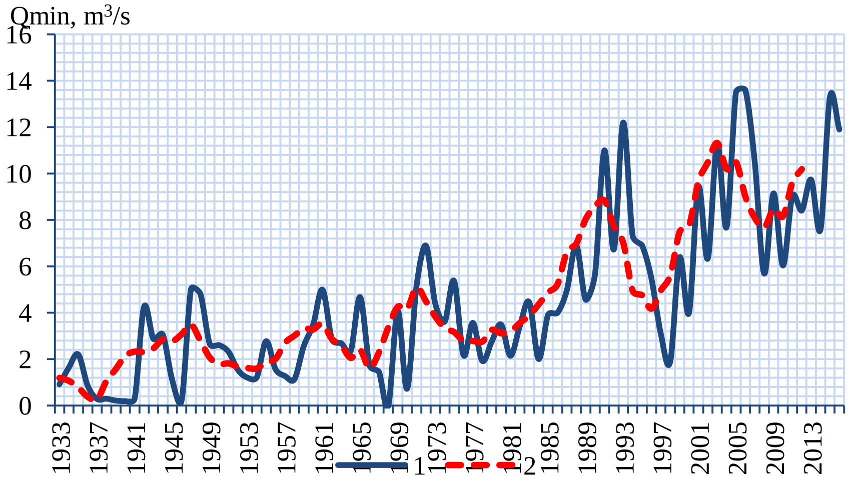

c)

Figure 2. Fluctuations of the average annual (a), maximum discharge (b) and minimum winter 30-daily (c) discharge of the Yesil river – Petropavlovsk s. (1 – actual values, 2 – moving 5-years average, 3 – differential integral curve)

At comparing the annual runoff dynamics of the tributaries of the Yesil river are detected the asynchrony of its fluctuation (Figure 3).

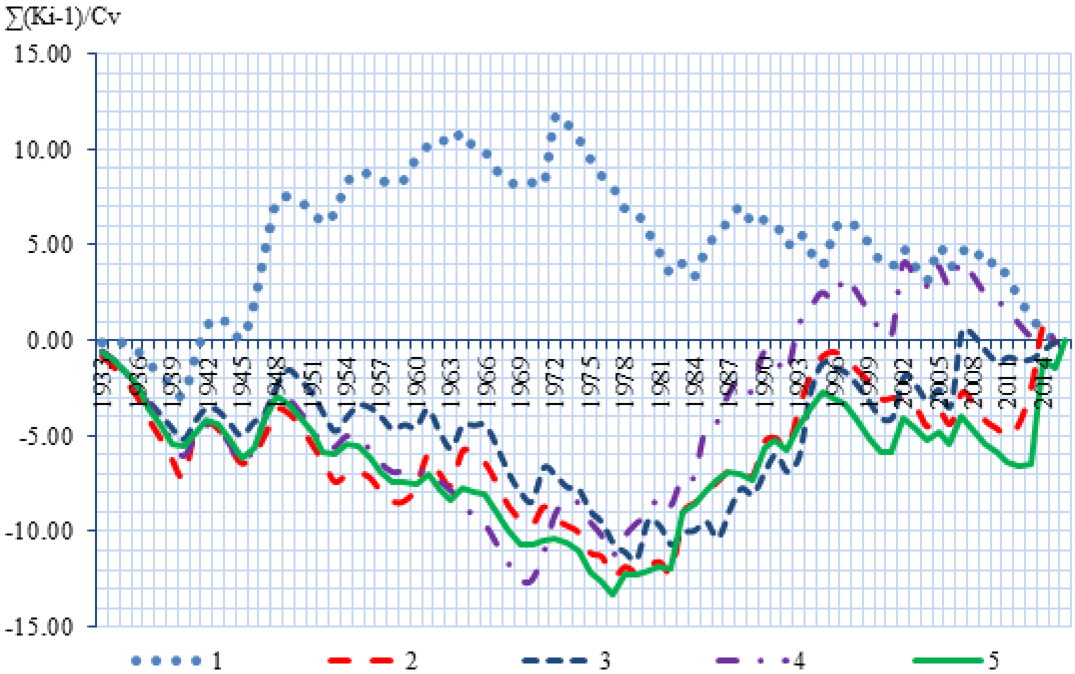

Figure 3. Difference integral curves of the annual runoff of the Yesil river tributaries
1 – River Silety – Izobilnoye village, 2 – River Shagalaly – Pavlovka village, 3 – River Akkanburlyk – Kovylnoye village, 4 – River Kalkutan – Kalkutan village, 5 – River Zhabai – Atbasar city

Runoff Zhabay river (the right tributary of the Yesil River) after 1974 is increased 2.5-2.8 times with compared to the period before 1973 (the annual runoff norm for the period 1933-1973 is 6.60 m^3/s, and for the period 1974-2016 years is 9.98 m^3/s). Runoff Kalkutan river (the right tributary of the Yesil River) after 1974 increased by 1.5 times with compared to the period before 1973 (the annual runoff norm for the period 1933-1973 years is 6.00 m^3/s, and for the period 1974-2016 years it is 8.75 m^3/s). In the runoff of the Ertis – Yesil Interfluve Rivers, a decrease in runoff is observed on the Silety River (the runoff has decreased by 1.5 times, the annual runoff norm for the period 1933-1973 years is 7.53 m^3/s, and for the period 1974-2016 years it is

4.64 m^3/s). On the Shagalaly River is a slight increase in runoff – the annual runoff norm for the period 1933-1973 years is 1.06 m^3/s, and for the period 1974-2016 years is 1.51 m^3/s.

A negative trend is observed at four gauging stations, the series of average annual water discharges were verified for homogeneity (stationarity) by using Fisher's and Student's criteria, the runoff series were divided into two periods: 1933-1973 years and 1974-2016 years, while, as the analysis indicated changes in the standard deviation of the annual runoff are often perceptible than changes in the runoff value itself (respectively, Fisher's statistics for the two parts of the series confirm to be more significant than Student's statistics).

The processes of atmospheric circulation have a decisive influence on the cyclic phase's distribution of the climate elements and the hydrological regime over the territory. In addition, the conditions of the underlying surface also act a significant role in this distribution, especially with regard to cyclical phases of atmospheric precipitation and river runoff. The identified runoff cyclicality can be associated with both the regulating capacity of catchments and other factors (features of atmospheric circulation, etc.). Climatic variability can also be reflected in the variation in runoff over time. Water content cycles are understood as a series of adjacent years of runoff, including one low-water and one high-water group of years of the same duration. Changes in water content in the indicated periods are due to the predominance of specific types of atmospheric circulation.

The primary reason for the formation of cyclical fluctuations of climate elements and hydrological regime on the Earth's surface is geoactive radiation from the Sun. Solar activity is characterized by regular cyclic fluctuations of different orders. The following cycles are considered to be established: an 11-year cycle lasting 9-14 years; 22-year or double cycle of 19-25 years; age-old cycle lasting 80-90 years; a centuries-old cycle lasting about 1800-1900 years. The duration of such epochal changes in atmospheric circulation is commensurate with the duration of 11-year cycles of solar activity [27; 28; 111; 112-120]. For the rivers of the Kazakhstan territory V.V. Golubtsov [29; 121-125] indicate a rather close dependence of the water content of rivers on changes in solar activity and the development of macrocirculation. He identified in Kazakhstan regions with the same nature of fluctuations in the water content of rivers in relation to secular changes in solar activity; for each type of atmospheric circulation, two to four components with a cycle duration of 2-3 to 25-35 years are statistically significant.

In Kazakhstan, 5-7-year cycles are manifested in a large number of cases in river runoff. The second most reliable are 2-3 years old, and the third – 3-4 years old. Sometimes 8-9, 17-22- and 13-15-year cycles are detected. For the rivers of the Yesil water basin, a rather pronounced tendency to the formation of groups of high-water and low-water years was discovered, the probability of following a high-water low-water year is 50%, after a low-water low-water year 55%. On the other hand, after a high-water year, a dry year should be expected on the river. Yesil with a probability of only 14%, for a dry year the probability of a high-water year is 30%. Thus, on the lowland Kazakhstan rivers is a clearly expressed tendency to the formation of a group of low-water years. Here, in the 30s, the low water period lasted until 10-11 years. The duration of the high-water cycles of the rivers of Central Kazakhstan is short and is 3-5 years.

Analysis of the maximum runoff fluctuations. For most of the considered hydrological gauging stations, the following features prevail: a decrease over a long-term period in the values of both Q_{max} itself and its absolute variability σ_Q. A decrease in its absolute variability to a certain extent is associated with a number of features of the long-term runoff in general and maximum runoff norm in particular: the proximity in time of very low-water years 1930s and several outstanding maximum runoffs in 1940 year (3750 m^3/s – 1948 in the Petropavlovsk gauging station). Naturally, in the series that includes both these decades, the runoff variability is increased. It was the presence of several high-water years in 1940 the general subsequent decrease in Q_{max} with time can also be explained.

However, these are only the most general features of the long-term course; in different sections, its own characteristics can be observed. In the Yesil river basin after a decline in Q_{max} values (1.5-2 times) from the 20th anniversary of 1956-1975 years – a new increase in the maximum discharge values, and along the Kalkutan river – more than 2 times. On the Zhabay River is observed a slight decline in Q_{max} over a long period, for Imanburlyk River since 1950 is a slight increase in the maximum runoff is observed. Relative to the absolute variability of runoff – on the rivers of the Yesil, Zhabay and Kalkutan basins, the decrease in σ_Q was more gradual, the indicator of runoff variability decreased by half by the 20th anniversary of 1973-1992 years, then its growth began, but in general the value of σ_Q is decreased.

Analysis of minimum runoff fluctuations. Regarding the minimum water discharges of the Kazakhstan Rivers, its long-term course and state in the modern period is still complete uncertainty. The low-water phase on rivers is observed during the summer-autumn and winter periods. Its total duration can reach 200-300 days or more. On the territory of the Yesil river basin, not only small streams, but also relatively large rivers with a catchment area of the order of 5000-10000 km^2 are drying up. The frequency of drying up of watercourses significantly depends on the hydrogeological characteristics of river basins and it sizes. A number of small tributaries of the Yesil, Silety and Zhabai rivers belong to the non-drying small streams.

The cessation of runoff in the summer low-water period is typical for watercourses in the southern part of the catchment. All watercourses located south of the Yesil River, to one degree or another are drying up. On the territory of the catchment's northern part, where moisture conditions are more favorable, along with temporary watercourses, there are also non-drying rivers. The lack of runoff in summer is mostly observed on rivers with a relatively small catchment *e* area ($F<3000\ km^2$). Drying up of larger rivers is observed only in some years. In particular, during the 80-year observation period, the Yesil River dried up for a short time 8 times, and more than a month – only one time. The Zhabai River near the Atbasar city for the 1937 to 2016 period dried up only twice.

Cessation of runoff due to freezing is typical for all watercourses in the territory that retain it runoff until the beginning of the winter season. Small non-drying streams freeze through annually in the second half of November (Yesil river – Prishimskoye). The lack of runoff is observed for about 120-140 days. On relatively large rivers (the Yesil River – Nur-Sultan and the Zhabai River – Atbasar) the duration of freezing is reduced to 80-100 days. During the period with a natural runoff regime (up to 1973) in some rare years, runoff on these rivers was observed once for 5-10 years and less often throughout the year. After 1980, as a result of releases from reservoirs, runoff in these rivers is observed throughout the year.

The minimum daily water discharges of the Yesil River – Nur-Sultan during the winter period did not have zero values (after 1980) and varied from 0.018 to 1.73 m^3/s, the average runoff was 0.54 m^3/s. On the Zhabay river – Atbasar the minimum daily water discharge varied (after 1980) within the range from 0.094 to 0.80 m^3/s and averaged 0.45 m^3/s. Low-water period on the Yesil river is lasts an average of nine months along its entire length (from July to March). In the summer period, the minimum water discharges were observed in July-August, in the winter period – in January-March. The smallest of the minimum water discharges accounted for on the winter low-water period.

4. Conclusion

For flat Kazakhstan, the following trends are expected:

1. The comparatively simple structure of the surface favors the consistency of fluctuations in both meteorological characteristics and river runoff.
2. The large size of the territory can contribute to certain meteorological and hydrological differences.
3. The Yesil water basin rivers are characterized by a cyclic runoff with a 15-25 years period.
4. It is expedient to calculate the runoff norm in two versions: for a long-term period and for a period characterizing the current climate phase and the current level of anthropogenic influences on runoff. The modern phase of the climate is mainly characterized by the period from the mid-1970s.
5. As an analysis result of the long-term variation of the values of the maximum water discharge, the following conclusions can be drawn:
   a) Noticeable differences in the long-term course of both the direct values of maximum water discharges and its absolute variability.
   b) For most rivers, the long-term variation of Q_{max} partly repeats the features of the course of the annual runoff (a general decrease in water discharge, a noticeable decrease since the first half of 1970, an indefinite course even a slight increase in water discharges in the last 10 years).

As a result of the analysis of the long-term variation of the values of the minimum discharges, the following conclusions can be received: It was revealed that the series of the minimum winter and summer-autumn runoff at a significant part of the gauging station of the Yesil river basin are heterogeneous. The inhomogeneity of the runoff characteristics series of the Yesil basin is due to both factors: climatic changes and anthropogenic pressure. So, the concept of runoff stationarity at assessing water resources cannot be accepted as the only one. In a continental climate and poor groundwater supply, many rivers are temporarily active, it dries up in summer and freeze to the bottom in winter. The total duration of the period without runoff can reach 10-11 months.

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