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МАТЕРИАЛДАРЫ
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ВОДНЫЕ РЕСУРСЫ ЦЕНТРАЛЬНОЙ АЗИИ И ИХ ИСПОЛЬЗОВАНИЕ

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Книга 3

WATER RESOURCES OF CENTRAL ASIA AND THEIR USE

MATERIALS
International Scientific-Practical Conference
devoted to the summing-up of the "Water for Life"
decade declared by the United Nations
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О-72 Орта Азия су ресурстары және оларды пайдалану: БҰҰ жариялаған «Су – өмір үшін» онжылды-дығының қорытындысына арналған Халықаралық ғылыми-тәжірибелік конференциясының мате-риалдары (22–24 қыркүйек, 2016 ж.) = Водные ресурсы Центральной Азии и их использование:мат-лы междунар. научно-практ. конф., посвященной подведению итогов объявленного ООН деся-тилетия «Вода для жизни». = Water resources of Central Asia and their use: materials International Scientific-Practical Conference devoted to the summing-up of the "Water for Life" decade declared by the United Nations. – Алматы, 2016. – 285 с. – каз., рус., англ.

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БҰҰ жариялаған «Су – өмір үшін» онжылдығының қорытындысына арналған «Орталық Азияның су ресурстары және оларды пайдалану» атты Халықаралық ғылыми-практикалық конференция баяндамаларының жинағында климаттық өзгерістер жағдайында Орталық Азияның су ресурстарын бағалау және болжам жасау; су ресурстарын басқару әдістерін жасау; су шаруашылықтық кешен дерінің геоақпараттық жүйелерін құру және математикалық үлгісін жасау; жерасты және жер беті суларының трансшекаралық алаптарындағы ынтымақтастық; экстремалдық гидрологиялық құбылыстар сияқты маңызды бағыттар бойынша материалдар ұсынылған. Аталған мәселелерді шешу ұланғайыр Орталық Азия аймағының әлеуметтік-экономикалық дамуы мен саяси тұрақтылығы және экологиялық қауіпсіздігін қамтамасыз ету стратегиясында ерекше маңызды рольге ие.

Жинақ су ресурстарын бағалау, болжам жасау, пайдалану және басқару салаларындағы мәселелермен айналысатын мамандардың ширек тобына арналған.

В сборнике докладов Международной научно-практической конференции «Водные ресурсы Центральной Азии и их использование», посвященной подведению итогов объявленного ООН десятилетия «Вода для жизни», предоставлены материалы по важным направлениям: оценка и прогноз водных ресурсов Центральной Азии в условиях изменения климата; разработка методов управления водными ресурсами; создание геоинформационных систем и математическое моделирование водохозяйственных комплексов; водное сотрудничество в трансграничных бассейнах подземных и поверхностных вод; экстремальные гидрологические явления. Решения перечислен ных проблем имеет исключительно важное значение в стратегии социально-экономического развития и обеспечения политической стабильности и экологической безопасности обширного Центрально-Азиатского региона.

Сборник предназначен для широкого спектра специалистов, занимающихся решением широкого спектра проблем в области оценки, прогноза, использования и управления водными ресурсами.

In reports of the International scientific-practical conference "Water Resources of Central Asia and their use", dedicated to summing up of the UN Decade "Water for Life", are provided materials on the following issues: evaluation and forecast of water resources in Central Asia in the context of the climate change; development of water management; creation of geoinformation systems and mathematical modeling of water systems; water Cooperation in transboundary basins, groundwater and surface water; hydrological phenomenon. Solutions to the above issues are of crucial importance in the strategy for socio-economic development and political stability as well as an environmental safety of Central Asian region as a whole.

The collection is designed for a wide range of professionals involved in the decision of significant issues in the field of assessment, forecasting, use and management of water resources.

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Dear reader!

Before you Materials of the International scientific-practical conference "Water Resources of Central Asia and Their Use" devoted to summing up the decade "Water for life" announced by the UN.

Problems of sustainable water supply of the countries of Central Asia gain sharp social-economic, ecological and political character in the last decades that is caused, on the one hand, by increase of a role of anthropogenous factors, the bound to water consumption for needs of the population, the industry and agriculture, and with another – the natural factors caused by climate changes.

The main threats and calls in the field of water supply in the countries of Central Asia are global and regional climate changes, incoordination of the interstate water relations, use of water expensive technologies and imperfection of technical means of water regulation and water distribution. The aggravation of interstate contradictions, development of the new centers of ecological instability, failure of programs of social and economic development can become corollaries of realization of water dangers.

The purpose of a scientific and practical conference was demonstration and discussion of the existing experience of water resources management as bases of sustainable development at the regional and national levels.

The presented collection – the fruit of labor and scientific researches of experts of Russia, Kyrgyzstan, Uzbekistan, Turkmenistan, Tajikistan, Belarus, Serbia, Italy, Great Britain, the USA, Germany, Switzerland, the Netherlands, Serbia, France, UNESCO, Kazakhstan.

You will find materials on burning issues and the important directions in the collection of reports: assessment and the forecast of water resources of Central Asia in the conditions of climate change; development of methods of management of water resources; creation of geographic information systems and mathematical model operation of water management complexes; water cooperation in cross-border pools of an underground and surface water; extreme hydrological phenomena. The solution of the listed problems has extremely important value in the strategy of social and economic development and ensuring political stability and ecological safety of the extensive Central Asian region.

The collection is of interest for a wide range of the experts who are engaged in the solution of the whole range of problems in the field of assessment, the forecast, use and water resources management.

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WATER RESOURCES OF KAZAKHSTAN AND THEIR USE

Қазақстан Республикасының су қауіпсіздігін қамтамасыздандыру концепциясы құрастырылған. Ұзақ мерзімді келешекке биліктегі су қорына болжамалық баға беру. Су тапшылығы мәселелерің шешу бағыттары анықталған. «2050 жылы кезеңіне дейін Қазақстан Республикасының су қауіпсіздік стратегиясын» құрастыру қажеттілігі негізделген.

Разработана концепция обеспечения водной безопасности Республики Казахстан. Дана прогностическая оценка располагаемых водных ресурсов на долгосрочную перспективу. Определены пути решения проблемы дефицита воды. Обоснована необходимость разработки «Стратегии водной безопасности Республики Казахстан на период до 2050 года».

The concept of support of water safety of the Republic of Kazakhstan is developed. The prognostic assessment of the located water resources on a long-term outlook is given. Water deficit problem solutions are defined. Need of development "Strategy of water safety of the Republic of Kazakhstan for the period till 2050" is justified.

Introduction. In the Message of the President of the Republic of Kazakhstan it is noted to the people of Kazakhstan: "Water – extremely restricted resource and fight for possession of water sources becomes the most important factor of geopolitics, being one of the reasons of strength and conflicts on the planet. 2050 – The real term by which the development of world community is guided [1] today.

According to the UN, already now more than 1, 2 billion people live in conditions of constant shortage of fresh-water, about 1 billion people have no access to pure drinking water, about 2 billion people suffer from the regular short-changing water during droughty seasons. According to forecasts of the Food and Agriculture Organization of the United Nations (FAO), to the middle of the third decade of the 21st century population suffering a permanent shortage of water will exceed 4 billion human. Similar forecasts are submitted very reasonable [2-4]. It is possible to call the come century safely "a century of water problems" (Figure 1).

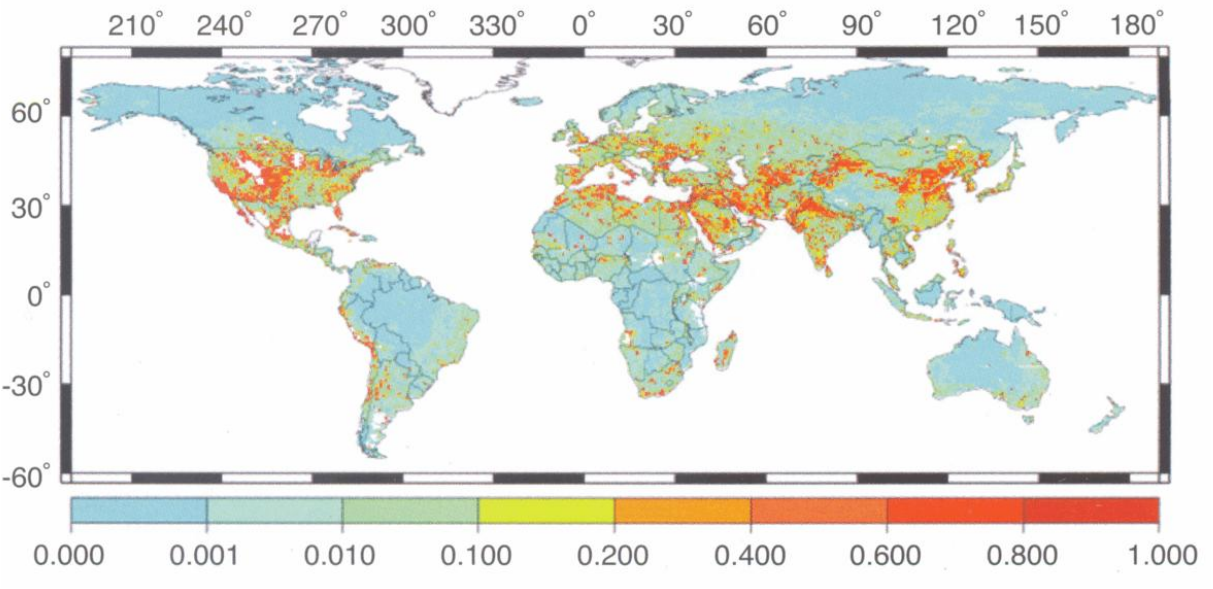


Figure 1 – The expected water stress in the world (2050)

In the conditions of an aggravation of water problems in the world taking into account a role of fresh water as irreplaceable natural resource the United Nations proclaimed the International decade of actions "Water for life" (International Decade for Action "Water for Life") for 2005-2015.

Formulation of the problem. The problem of water safety of the Republic of Kazakhstan (safety of water management activity) in the conditions of limitation and vulnerability of water resources is considered as components of national security. It is defined by the fact that fresh (fresh) water – the major natural resource without which any activity of the person is impossible and which cannot be replaced with anything. On the other hand, water – an integral part of all nature and the main component of a surrounding medium. At last, water – threatening natural element bringing destructions and disasters. It causes larger complexity of interaction of society with an water environment which has many features for various regions of Kazakhstan and undergoes essential changes in process of development of society and change of climatic conditions.

The main threats and calls in the field of water supply of the Republic are global and regional climate changes, incoordination of the interstate water relations, use of expensive water technologies and imperfection of technical means of water regulation and water distribution. The aggravation of interstate water contradictions, development of the new centers of ecological instability, failure of programs of social and economic development of [5, 6] (Figure 2) can become consequences of realization of water dangers.

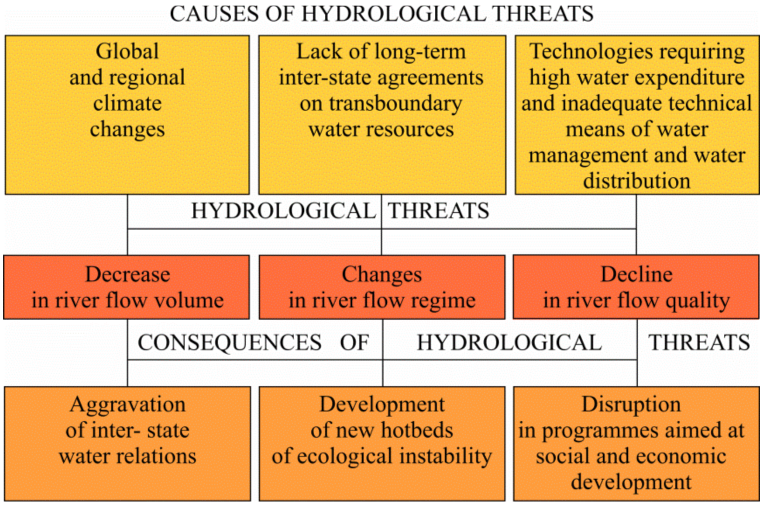


Figure 2 – Hydrological threats: causes and effects

Assessment of resources. Almost worldwide, according to characteristics of a river runoff, the size of renewable water resources, their dynamics in time and distribution across the territory is estimated. The river system’s runoff provides the main volume of water consumption in the world, defines degree of water security of the territory and the population, surplus and deficiency of water resources. The river runoff in the course of circulation considerably restores quality of fresh water due to natural self-cleaning which is possessed by river systems.

Cooperative resources of the surface water of the Republic of Kazakhstan (household drain) during observations of 1974-2008 make 91,3 km^3/year (50% of security) from which 44,3 km^3 enters from the adjacent states, 47,0 km^3 makes a local drain (Figure 3) [7].

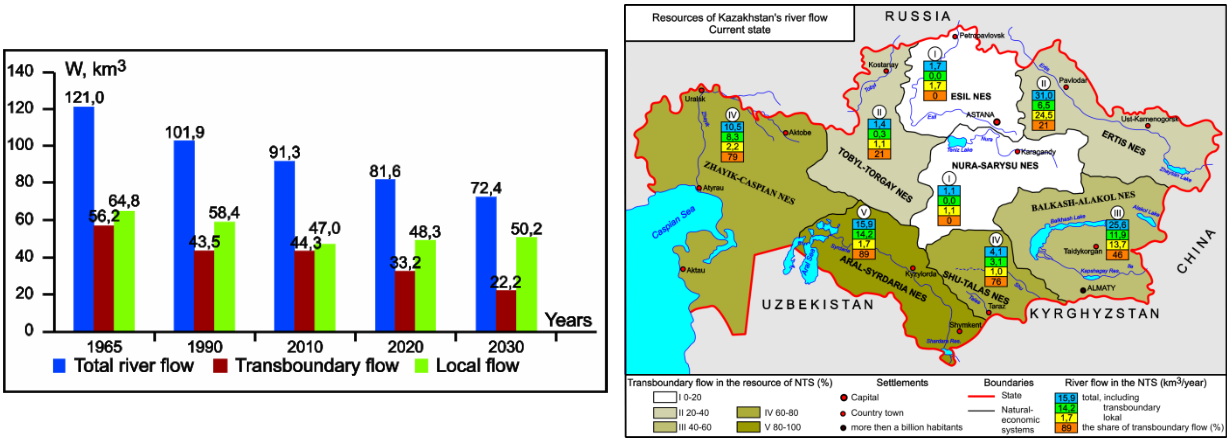


Figure 3 –The current situation and forecast of resources of a river runoff.

Due to the economic activity resources of a river runoff of the Republic of Kazakhstan decreased on 23,8 km^3/year (by 21%), including a cross-border runoff – on 15,9 km^3/year (for 26%), a local drain – on 7,9 km^3/year (for 14%) (fig. 4).

Proceeding from a possibility of adverse realization of climatic and cross-border hydrological threats decrease of resources of a river runoff in general across Kazakhstan by 2020 to 81,6 km^3/year, including cross-border – to 33,2 km^3/year, local – to 48,3 km^3/year is in the long term real; by 2030 – respectively 72,4; 22,2 and 50,2 km^3/year. Aral-Syrdariya (89%), Zhayyk-Caspian (79%), Chu-Talas (76%) natural and economic systems (PHS) are the most dependent on a cross-border runoff (Figure 4). The specified prerequisites have to be taken in a basis of strategy of ensuring water safety of the republic.

Figure 4 –Anthropogenous transformation of a river runoff in basins of natural and economic systems (PHS) of Kazakhstan (current situation)

In the process of the water cycle in nature, the surface water of river basins are hydraulically connected to groundwater, forming a single water potential of the territory.

Being inferior by the volume to the resources of river runoff, underground water have enormous value for the individual water consumers (for example, drinkable water supply) or for some specific regions of Kazakhstan.

General operating groundwater reserves are 15.44 km^3 / year, of which about 10% are used. According to its intended purpose proven reserves of underground water are divided into: domestic water (5.8 km^3 / year) and the production and maintenance (1.4) water supply; land irrigation (8.3 km^3 / year) [8].

Taking into account the world experience, the age-long reserves of underground water reserves are encouraged to consider as a strategic reserve of clean water for drinking water supply. Groundwater resources at a reasonable management may become an important factor in meeting the demand for water in the future and adapt to climate change.

Due to the development of hydraulic connection of proven reserves of groundwater (in the amount of 15.44 km^3 / year) would reduce the river flow resources to 5 km^3 / year (Figure 5). The most significant impact on the river flow will have a water intake in the river valleys and alluvial fans of rivers.

Figure 5 – Influence of water selection of underground water on the surface runoff

It was found that the glaciers of the mountains of Central Asia from the middle of the XIX century. It was mostly in a state of degradation, accelerated since the beginning of the 1970s. The pace of degradation of glaciers in Central Asia - one of the highest in the world - 0.8% per year in area and 1% per year in terms of ice. Ice flow as glaciers shrinking degradation [9].

It is expected that the background level of the Caspian Sea, taking into account climate change and will decrease can come close to the level of minus 25 m in 2020 and to around minus 25.7 meters by 2035 [10]

It is shown that due to reduced cross-border flow of rivers Ili and Syr Darya with China and Uzbekistan territories level of drainage basins Balkhash and the Small Aral will decrease relative to the established legal parameters (markers) - 341.0 and 42.0 m (Figure 6). [11].

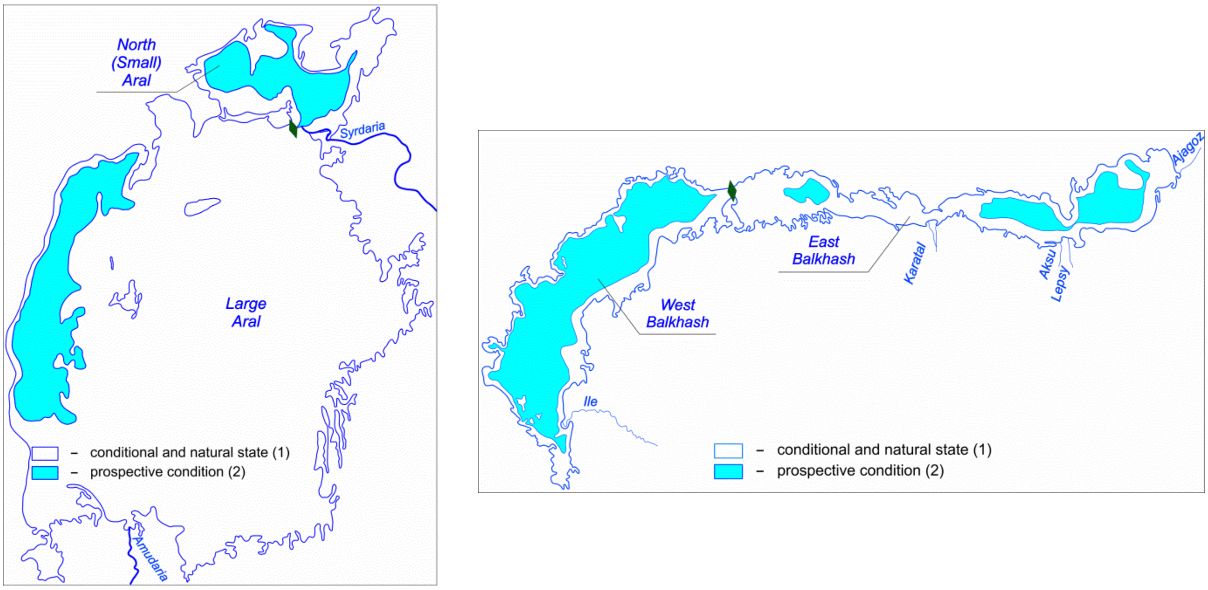


Figure 6 – Forecast of levels of the Aral Sea (a) and lake Balkash

The use of water resources. Renewable resources of river runoff in Kazakhstan are the integral component of the environmental environment, providing stability of the water-salt mode of internal and suburban reservoirs, flood of floodplains and deltas and in general maintaining of water and resource equilibrium of the territory.

Total ecological (environmental) demand of natural and economic systems of the republic for water resources is established in volume of 64,2 km^3/year, including requirements of natural objects, obligatory including cross-border releases, and also unproductive losses as restriction of production use of water resources (Figure 7). Standards of ecological demand for water are established by the political decision proceeding from need of balancing of ecological, social and economic targets of development of the country. Over time the established constants can change both toughening, and mitigation of a threshold of permissible anthropogenous pressure [6].

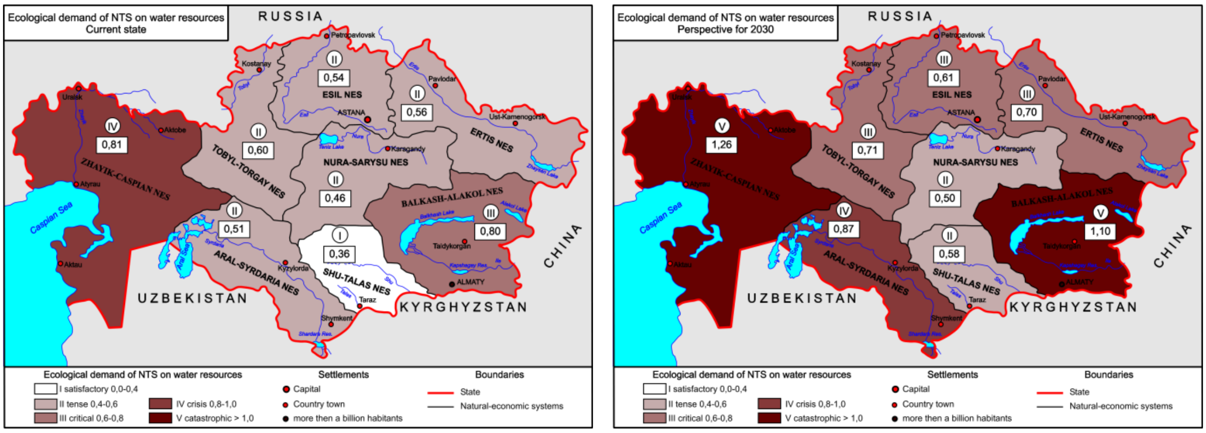
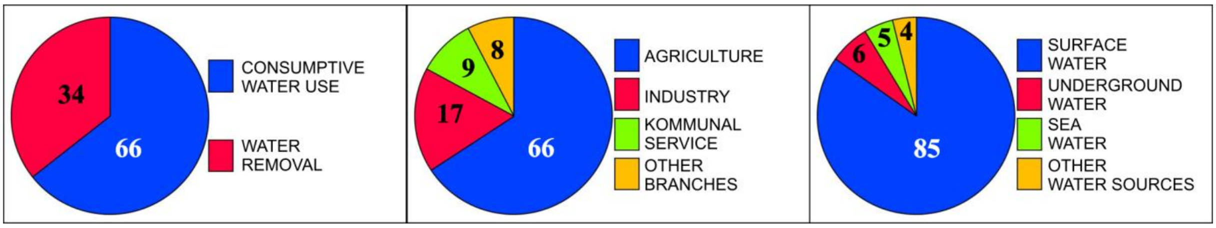


Figure 7 – Environmental natural and economic systems (PHS) demand on water resources: the current state of (a) and the outlook for 2030 (b)

In the field of the forecast of development of water capacious productions the complex of actions for decrease in anthropogenous load of water resources, to introduction of the water preserving technologies in the industry, rural and municipal services providing stabilization of economic water consumption by 2020 and decrease by 10% by 2030 is recommended.

The intensive increase in production expected on prospect in Kazakhstan has to be provided in the maximal degree with an intensification of use of water resources, but not body height of consumption of fresh water. Economic water intakes in the long term should not exceed the actual volumes at the level of 2010 (23,3 km^3/year, including irrevocable water consumption – 15,3, water disposal – 8,0 km^3/year) with distribution on branches: agriculture – 15,4; the industry – 4,0; municipal services – 2,2; other branches – 1,8 km^3/year (Figure 8) [12].



a b c

Figure 8 – Limits of an economic water intake: irrevocable water consumption and water disposal (a), on branches (b), from water sources (c)

Problem solutions. Two ways of elimination of deficiency of fresh water in the republic are defined: decrease in load of water resources and increase in resources of fresh water. The first path provides realization of actions for decrease of rates of development of water capacious productions and to use of more modern technologies for reduction of consumption of fresh water in the industry, rural and municipal services. The second path assumes increase in the water resources located for use due to long-term and seasonal regulation of a river runoff, use of reserves of underground fresh waters, desaltings of salty and saltish waters, territorial, including cross-border redistribution of water resources (Figure 9) [6].

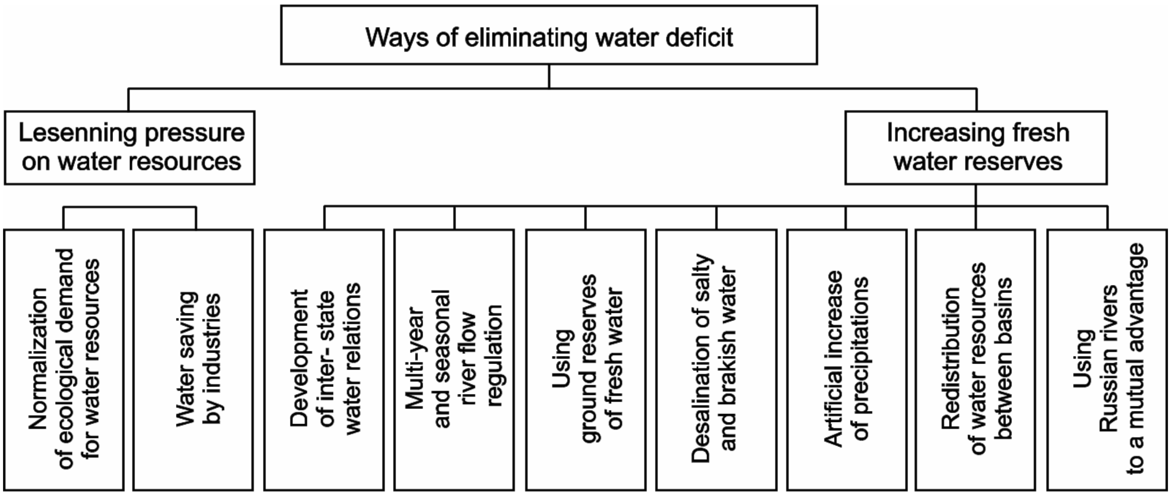


Figure 9 – Ways of elimination of deficiency of fresh water in Kazakhstan

According to scientists, the investment cost for receiving padding water resources or economy 1 km^3 fresh water make at a desalting of salty and saltish waters 600-1800 million dollars, a sewage disposal – 200-1500, reconstruction of irrigating systems – 700-900, territorial redistribution of a river runoff – 100-800 million dollars (fig. 10) [13].

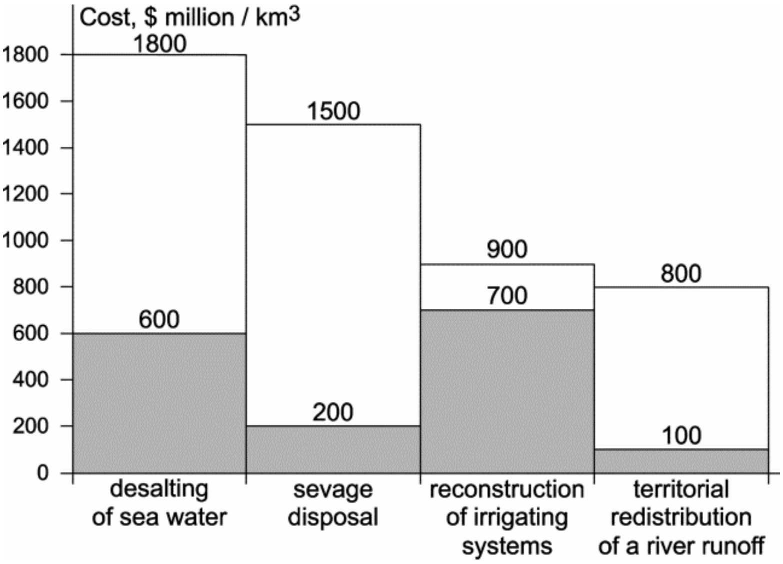


Figure 10 – Comparative cost of actions on elimination of deficiency of fresh water

It is recommended to carry out till 2020 reconstruction of irrigated lands on the area of 1,55 million hectares with introduction of the mechanized waterings and microirrigations on the square: at the surface watering – 830 thousand hectares, overhead irrigation – 630 thousand hectares, a dropwise irrigation – 115 thousand hectares, having provided increase in efficiency of irrigating systems to 0,75, economy of water resources for 30%, increase in productivity by 1,5–2,0 times.

It is recommended to improve water security of pasturable territories of Kazakhstan on the total area of 183,4 million hectares due to construction of simulated water sources, including mine wells and water wells. At the modern volume of the water consumption of 208 million m^3 the perspective volume of water consumption will make 236 million m^3 by 2020 and 279 million m^3 by 2030.

It is planned to introduce systems of reverse and self-contained water supply in water capacious industries for 75% of the enterprises by 2020 and 95% by 2030 with a water intake respectively 5,9 and 6,8 km^3/year, including with the irrevocable water consumption of 1,7 and 1,3 km^3/year.

It is planned to provide priority steady water supply of objects of municipal services in volumes 1,08 km^3/year by 2020 and 1,22 by 2030, including at the expense of underground waters – 0,51 and 0,58 km^3/year.

Development of hydropower in Kazakhstan is recommended by construction of large hydroelectric power stations – sources of peak powers of power supply systems and small hydroelectric power stations – sources of power supply of the territories remote from power networks. In general across Kazakhstan it is planned to increase by 2020 the rated capacity of hydroelectric power station by 1,1 GW with body height of annual power generation on 5,2 GW h, by 2030 – respectively on 1,8 GW and 8,8 GW h [14].

It is recommended at preservation of the existing fishery volume in internal reservoirs significantly to increase production of an aquaculture. For achievement of the recommended norm (14,6 kg of fish on the person in a year) production of fish production has to make in 2020 267 thousand tons, including due to development of an aquaculture – 184 thousand tons; in 2030 – 295 and 212 thousand tons respectively [15].

In the field of perfecting of the interstate water relations the principles and standards of water division in cross-border pools considering a geographical location, social and economic and ecological features of Kazakhstan (fig. 11) [6] are offered.

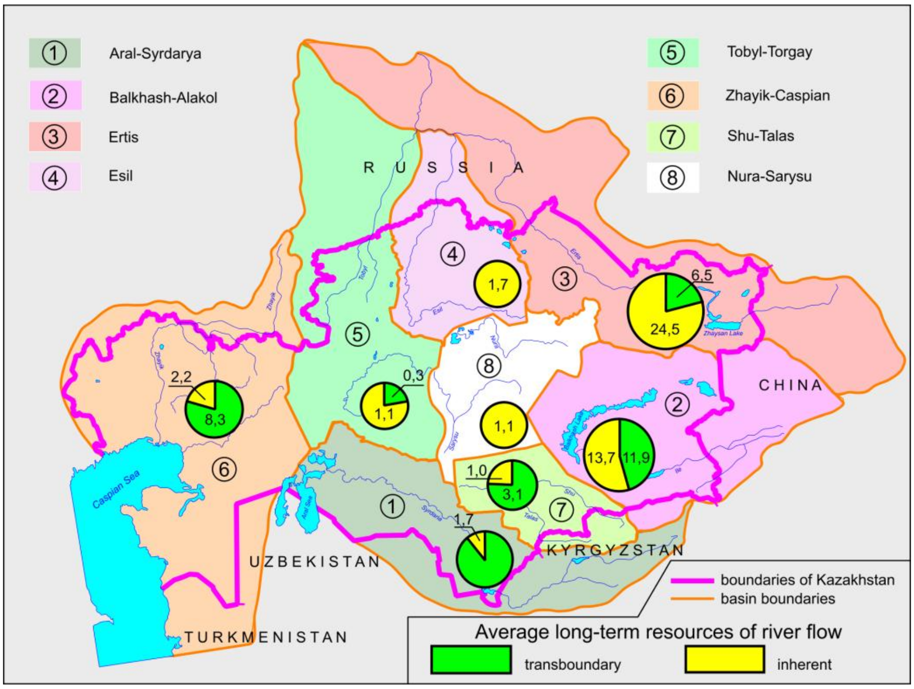


Figure 11 – Cross-border basins of Kazakhstan

On the basis of the rules accepted in world practice to establish a share of receipt of a drain of Ertis to Russia at a rate of a half of the drain which is formed in the territory of Kazakhstan that makes 12,5 km^3/year (in mean annual value).

Being guided by the rules accepted in world practice it is recommended to set a limit of river inflow to Kazakhstan from the People's Republic of China in the Yertis basin in volume of not less than 4,5 km^3/year that makes a half of the drain which is formed in the Chinese part of the pool Kara Yertis.

Within negotiations with the People's Republic of China on use of water resources of the cross-border basin of the river Il it is recommended to define a limit of inflow to the lake Balkash as self-contained water user of interstate value. For maintaining of marginal state variables of the lake (average annual level – 341,0 m, the limiting salinity – 1,6 g/l) the standard of river inflow to the lake has to make 14,0 km^3/year, including on river Il – 10,8 km^3/year.

Within development of the long-term agreement between the states of Central Asia it is recommended to accept the limits of cross-border inflow of river of Syrdariya to Kazakhstan set by the Nukus declaration of 1994 and signed by heads of states of Central Asia. The guaranteed mean of annual inflow to Kazakhstan from the territory of Uzbekistan is defined in volume of 12,0 km^3/year with admissible decrease in shallow years to 10,0 km^3/year with ensuring the guaranteed quality of water with a mineralization no more than 1 g/l.

So far the bulk net volume of water reservoirs in Kazakhstan makes about 50 km^3 that increased on average the volume of a steady river runoff on 25%. Regulation of a drain of the rivers has the essential restrictions bound to negative consequences of construction and operation of reservoirs that causes a preferable construction them in mountain and the poorly developed areas. Application of specific methods of counterregulation of a river runoff for the purpose of coordination of contradictory requirements of water of components of natural and economic systems, and also an artificial surface water recharge with use of underground storage tanks in combination with traditional reservoirs [16] is perspective.

Wider use of a desalting in Kazakhstan restrains, mainly, the high cost of the received fresh water and larger expenses of the electric power and fuel. The water desalting in large scales puts forward the complex problem of utilization and processing of salt on which prime cost of a desalting and state of environment in many respects depends.

The international experience shows that volumes of possible increase in water resources due to inducing of loss of rainfall are small – 5%. At the same time there can be environmental, legal and political problems of the fissile impacts on the clouds caused by possible influence on climate of the neighboring regions and the countries.

Objective prerequisite of territorial redistribution of water resources in Kazakhstan is limitation of the located water resources, nonuniformity of their distribution across the territory, the considerable variability in time, high extent of pollution. In size of renewable water resources Kazakhstan takes the last place among the adjacent states (Russia, Uzbekistan, Kyrgyzstan). The largest volumes of a river runoff in the republic are formed in Yertis natural and economic system (to a third of the common resources and a half of local). In Nura-Sarysu, Yesil and Tobyl-Torgay natural and economic systems less than 6% of a river runoff are formed, and in shallow years the local drain is less than average approximately by 10 times [6].

At the same time demand for water in the southern and western regions of Kazakhstan makes about 70% on the republic in general. In the long term this visibility tends to increase in connection with possible reduction of a cross-border drain from China, Uzbekistan and Kyrgyzstan. The keyest directions of interbasin and cross-border routes of transfers of a river runoff to water scarce regions of Kazakhstan are offered.

It is shown that the potential donor pool for water scarce areas is the basin of the river Yertis where it is formed to a half of renewable water resources of the republic. The route of the Transkazakhstan channel (fig. 12) as bases of formation of Uniform system of water supply of the Republic of Kazakhstan is offered [6, 17].

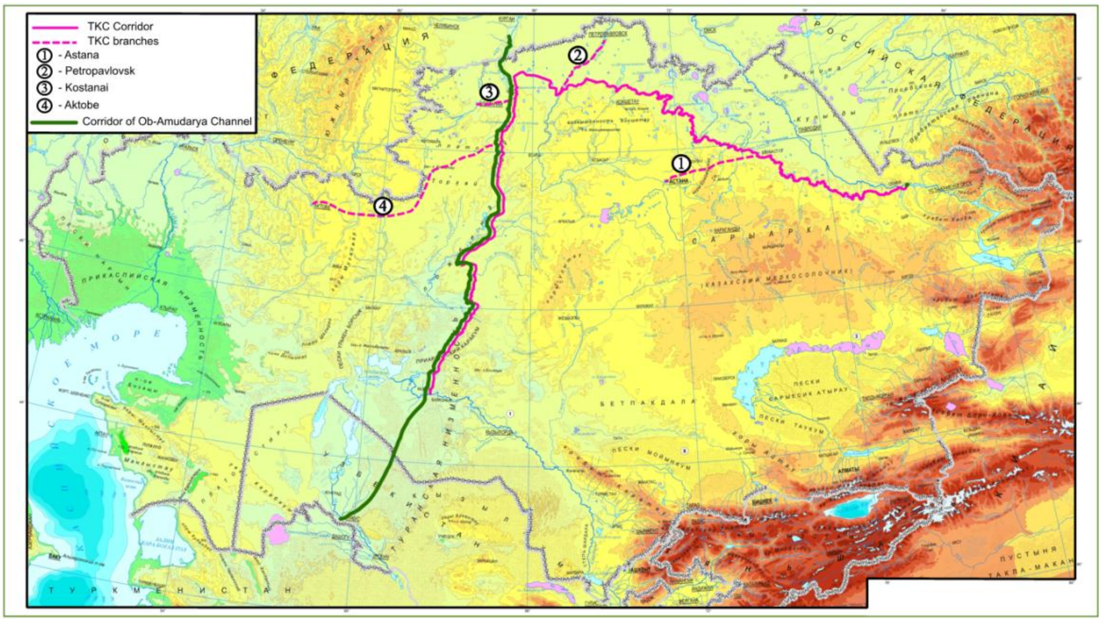


Figure 12 – Estimated route of Trans Kazakhstan channel

In the conditions of decrease in a cross-border drain of river Il from the territory of the People's Republic of China, it is recommended to consider options of preservation of the lake Balkash – a water object of special state value by transfer of a part of a drain of river of Yertis in the Buktyrma — Balkash direction (fig. 13) [6, 17].

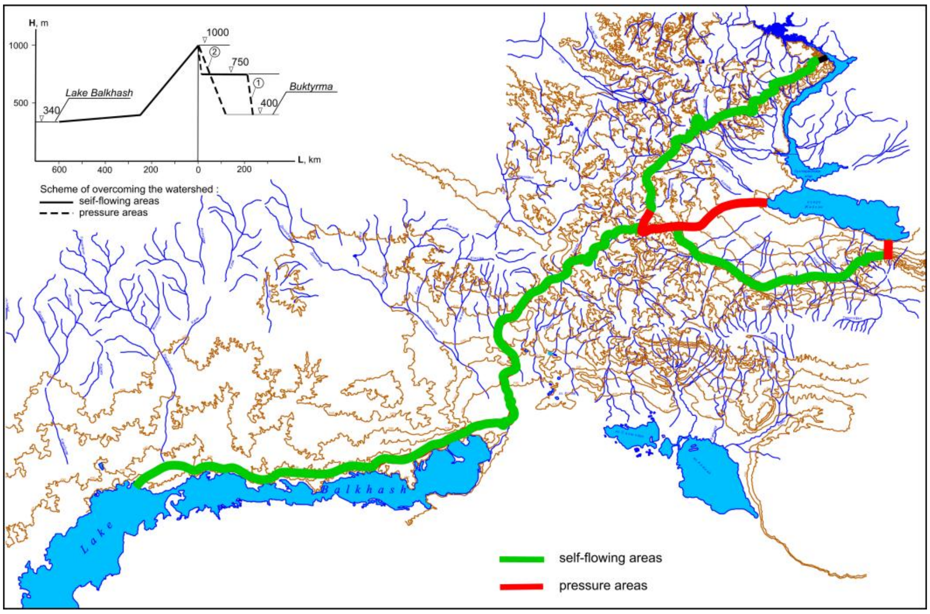
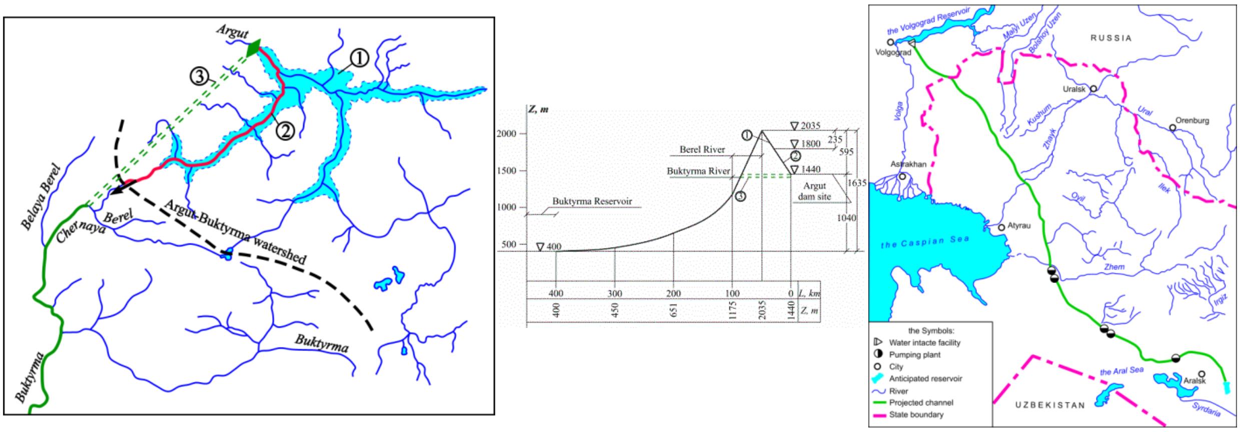


Figure 13 – Transfer of a drain of river Yertis to the lake Balkash

For compensation of depriving of a river runoff of river Yertis in the People's Republic of China is offered the updated scheme of mutually advantageous use of a drain of the Russian rivers in the direction Upper Katun excluding a construction of large reservoirs and focused on tunnel (or pump) option of overcoming a watershed (fig. 14-a, b) [6, 17].

For increase in water security of regions of the Western and Southern Kazakhstan construction of cross-border channel "Volga — Syrdariya" (fig. 14-c) is recommended.



a b c

Figure 14 – mutual beneficial using of Russian rivers flow. The scheme of overcoming of Argut-Buktyrma watershed. a – plan; b – profile. Version: 1 – dam; 2 – pump; 3 – tunnel. c – the scheme of transfer of part of Volga river flow to Kazakhstan.

Conclusion. In the conditions of an aggravation of water problems in the world functions, the principles, priorities and mechanisms of water resources management significantly change [6, 18].

The new water paradigm in economically developed countries along with "management of a resource" assumes "demand management" on water by water conservation and increase in effectiveness of water use [6, 18].

Priorities in use of water resources change with development of society. In developing countries the main priority is production. In economically developed countries – society and ecology.

Introduction of ecosystem approach means consideration of the nature as equal partner when using water resources. Ecological aspects of UVR are implemented in two directions: keeping of requirements of the nature to water and prevention of harmful effects of waters.

The basin principle of water resources management (WRM) which is widely used in the world for management of water use and in general by environmental management covers the pools of the different sizes, subjects of economic activity, the power and the population enclosed each other.

In conditions climatic and anthropogenically caused change of resources of fresh waters in the Central Asian region in the context of the purposes and problems of Strategy Kazakhstan-2050 is represented necessary development "To the strategy of water safety of the Republic of Kazakhstan for the period till 2050". Within Strategy it is planned: to give the forecast of the located resources and demand for water of the population, the nature, production for the calculated levels of development, to define system of the purposes of ensuring water safety, to develop strategic paths of achievement of the objectives, to plan the action program, to calculate terms and to define financing sources..

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WATER RESOURCES OF THE KYRGYZ REPUBLIC AND THEIR USE

Рассмотрена география водных объектов, водных ресурсов Кыргызстана. Исследована динамика использования водных ресурсов разными водопользователями страны, связанная с перестройкой системы водного хозяйства в новых условиях её социально-экономического развития. Приведен анализ официальных и экспертных мнений о позиции Кыргызской Республики по трансграничному использованию водных ресурсов в Центрально-Азиатском регионе.

The geography of water bodies and water resources of Kyrgyzstan was completely observed. Studied the dynamics of water management in different countries related to the restructuring of the water sector in the new conditions of socio-economic development. Analyzed official and expert opinions about position of the Kyrgyz Republic on using of transboundary water resources in Central Asia.

Water bodies and water resources. The basis of the hydrographic appearance of the territory of the Kyrgyz Republic consists of the river systems, watersheds of which are separated from each other by watershed mountain ranges. Hydrographic system of the river basin consists of lakes, glaciers, groundwater and their outlets to the surface (springs), marshes and wetlands. All of them, being the products of orography, topography, land surface and climate, are in a state of interaction and mutual influence, and are directly involved in the formation of the water balance of watersheds and river runoff regime. On the territory of Kyrgyzstan, covering the area of 198,5 thous. km^2, more than 2040 watercourses with a length of over 10 km - rivers, streams and their tributaries, total length of which is about 35000 km, form the runoff (Table 1).

Table 1 - Number and length of rivers in Kyrgyzstan

Gradation of watercourses		Number of watercourses		Total length	
	Length, km	Number	%	km	%
The smallest	10-25	1616	78,9	12117	34,7
Small	26-50	321	15,7	10916	31,2
	51-100	82	4,0	6061	17,3
Medium	101-200	24	1,2	3216	9,2
	201-300	1	0,05	253	0,8
	301-500	-	-	-	-
Large	501-1000	2	0,1	1239	3,5
	over 1000	1	0,05	1186	3,3
Total		2047	100,0	34988	100,0

The territory of Kyrgyzstan is divided into the areas of formation and dispersal of river runoff by the nature of direction of water balance [1;4]. The territory of runoff formation, the area of which is estimated to be 171800 km² (86,5% of the country’ territory), covers the mountain slopes and alpine elevations, on which a substantial portion of precipitation is spent on the formation of the surface, soil and channel runoff. The area of runoff dispersion is confined to the piedmont alluvial and diluvial gentle slopes and plains, on which irrigated agriculture is mainly focused. Its area in Kyrgyzstan is small, occupying 26700 km² (13,5 % % of the territory).

On the scale of regional hydrography, the river systems of the Kyrgyz Republic are related to the Aral Sea basin (76,5% of the territory), to the Tarim river basin (12,4%), to the inner basin of Issyk-Kyol lake (10,8%) and to the Balkhash lake basin (0,3 %) [3]. Across Kyrgyzstan, it is reasonable to consider its hydrographic systems at the level of large watersheds, isolated by orographic structures, and significantly differing from each other for geographical and hydrological conditions. In accordance with this approach, 9 systems are quite correctly distinguished:

- Naryn river basin;
- watersheds of the rivers of the mountain frame of the Fergana valley;
- Chatkal river basin;
- Issyk-Kyol lake basin;
- Balkhash lake basin;
- Chu river basin;
- Talas river basin;
- Kyzyl-Suu river basin (Alay, western);
- Tarim river basin.

Table 2 shows the main characteristics of these hydrographic systems. According to these data, the calculated average long-term total consumption of water in Kyrgyzstan's rivers is 1543 m³/s, and the module of runoff is 8,0 l/s.km².

Table 2 – Main characteristics of the hydrographic systems of Kyrgyzstan

Hydrographic systems	Area of the zone of formation of river runoff		Volume of average long-term runoff	
	km²	%% watershed area of the country	km³	%%
Naryn river basin	53700	31,4	14,6	30.0
Rivers of the Fergana valley	43100	25,1	12,4	25,5
Chatkal river basin	5700	3,3	2,74	5,65
Chu river basin	15900	9,3	3,84	7,90
Talas river basin	8300	4,8	1,72	3,54
Issyk-Kyol lake basin	11200	6,5	3,96	8,15
Balkhash lake basin	600	0,3	0,37	0,76
Tarim river basin	25500	14,8	6,99	14,4
Kyzyl-Suu river basin (Alay, western)	7800	4,5	1,98	4,10
Total	171800	100	48,6	100

Note: The table uses data of the Atlas of the Kirghiz SSR (3), hydrometeorological data of the MES of the KR (7;8), the Institute of Water Problems and Hydropower of the NAS of the KR (5) were used to calculate the characteristics of the volume of the runoff.

The total value of river runoff in the Kyrgyz Republic, according to our estimates, is 48,6 cubic km, and along with the return waters and runoff of sources such as "Karasu", the disposable surface water resources are close to 52 cubic km in an average for water content year. The river runoff resources are distributed across the country very unevenly and are concentrated mainly in the still uninhabited, economically underdeveloped areas. On average, there are 258 m^3 of water per 1 km^2 of the Kyrgyzstan's area per year.

Table 3 - Distribution of resources of river runoff by the regions

Region	Area, thous.km^2	Resources of river runoff			
		km^3/year	%	per 1 km^2 of the area, thous.m^3	per capita, thous.m^3/year, 2015(1992)
Osh	29,22	6,8	13,3	233	6,0 (6,6)
Batken	16,98	2,4	4,7	141	5,55 (5,5)
Jalal-Abad	26,9	10,7	20,3	386	10,2 (14,3)
Issyk-Kyol Within the basin	43,1 15,8	10,5 3,96	20,5	244 250	23,3 (24,3) 8,8 (9,2)
Talas	11,4	2,8	5,5	246	11,7 (10,7)
Naryn	52,2	14,2	27,7	272	54,2 (65,7)
Chu	18,7	4,1	8,0	219	2,3 (2,9)
Total in Kyrgyzstan	198,5	51,2	100	258	8,5 (11,2)

The most supplied is Jala-Abad region, which accounts for the average of 386 thous.m^3 of river runoff per 1 km^2; Naryn and Talas regions – respectively, 272 and 246 thous.m^3. Issyk-Kyol region accounts for 244 thous.m^3 of river runoff per 1 km^2, and if to take the Issyk-Kyol basin separately, where almost the entire population lives, the resources of river runoff make 250 thous.m^3. In the Chu valley and Osh region, where 62 % of the country's population is concentrated, the total value of the resources of river runoff makes up only 25,9 %.

According to the distribution of river water resources per capita, calculated as of 2015, Naryn region stands out, as there are 54,2 thous.m^3/year per one person, Jalal-Abad region - 10,2 thous.m^3/year, Issyk-Kyol region - 23,3 thous.m^3/year, in the economically developed districts of the Chu valley and Osh region, respectively - 2,3 and 6,0 thous.m^3/year. Data for 1992 are given in Table 3, in parentheses.

According to the investigations of the Hydrometeorological Service of the country and the Tien Shan Mountain Physiographic station of the National Academy of Sciences, there are 1923 lakes with a total area of 6847,2 km² [5; 7] in the territory of Kyrgyzstan. The average percentage of lake availability is 3,4%, ranging from 0,02% in the Chui valley, up to 30% in the Issyk-Kyol basin.

A significant part of these reserves is concentrated in the Chu (300 cu. km), Talas (75 cu. km), Issyk-Kyol (58 cu. km) and Ak-Sai (50 cu. km) valleys [1]. One of the main indicators characterizing the dynamics of the groundwater regime and determining the water content of the groundwater sources, are renewable resources. They represent a flow rate of the groundwater flowing in the hydrogeological structure though pores and cracks in the rock formations. This stream is fed by seepage into the ground of the part of rainfall, the waters of rivers, canals, lakes and reservoirs. The volume of renewable groundwater resources is given in Table 4.

Table 4 - Renewable resources of fresh groundwater of hydrogeological regions of Kyrgyzstan

Hydrogeological region	Renewable groundwater resources, m^3/s
Chu	93,7
Talas	28,3
Issyk-Kyol	71,3
Naryn	37,7
Ak-Sai-Arpa	32,3
Kan-Tenir	10,5
Fergana (within the KR)	23,0
Chatkal	12,0
Turkestan-Alai	12,1
Alai	5,0
Total	325,9

A special place among water resources is occupied by mineral and thermal waters. They are unjustly overlooked in assessing the potential of water resources of our country. This is due to the lack of attention to the development of their health and socio-economic opportunities. In the future, they should supply the population with health-improving resources and form a significant part of the resort and sanatorium services of the international market. Currently, more than 250 deposits of mineral waters are identified in Kyrgyzstan. Depending on the degree of mineralization and chemical composition, they are divided into salty water and brines, carbonic, thermal silica, radon, sulfide, ferrous and iodine bromine.

Mineralization of saline waters and brines of Kyrgyzstan vary from 10 to 350 g/l. Their main deposits, with a maximum salinity of 64 g/l are discovered in the coastal area of the Issyk-Kyol artesian basin; in the central part of the Chu valley – the Bishkek deposit with mineralization of 50 g/l; Tuz in Leilek district - 253 g/l; Zhyrgalan (138 g/l) and Uch-Kashka-Chaar-Kuduk (200 g/l) - the foothills and the midlands of the Issyk-Kyol basin; Uch-Terek in the Ketmen-Tyobyon-valley - 346 g/l. Such waters are used as therapeutic agents in the manufacture of drugs [7].

Carbonic waters of Kyrgyzstan, discovered in 30 deposits, are the analogs to medical-table waters such as Borjomi, Essentuki, Narzan and others. The content of carbon dioxide in them is more than 500 mg/l, mineralization ranges within 1,8-40 g/l. Most of the deposits is located on the Fergana ridge in the basins of Zhazy rivers (sections of Arkar-Shoro, Baibiche, Kara-Shoro, etc.), Tar (Kulun, Terek. Seok), Kara-Kulzha (Karakol, Kara-Kulzha), Arpa (Karakol, Kyzyl-Beles). Carbonated waters are spread in the Ak-Sai valley and its mountain framing (Besh-Belchir, Usyolyok, Chatyr-Kyol), in Jumgal valley (Kara-Keche, Chamyndy), Issyk-Kyol basin (Ulakol, Arabel, Tuura-Suu).

Siliceous thermal waters of Kyrgyzstan with temperatures from 20 to 100°C and low mineralization (0,4-2,0 g/l) are mainly confined to hydrothermal lines of regional faults of the crust, located on the northern slopes of the ridges of Kyrgyz and Teskei Ala-Too. The most famous are Kara-Balta, Alamyudyun, Issyk-Ata, Tuyuk on the Kyrgyz ridge, and Jeti-Ogyuz, Chon-Kyzyl-Suu, Kerege-Tash, Ak-Suu (Teploklyuchenka), Boz-Uchuk on Teskei Ala-Too. They are used for the treatment of diseases of the musculoskeletal and nervous system, gynecological diseases.

Radon waters in the country are formed in the zone of crustal fault, in which radioactive mineralization manifests. Radon waters of the Jeti-Ogyuz deposit located on the northern slope of the Teskei Ala-Too ridge, at altitudes of 2200-2400 m, have unique characteristics. The content of radon is in the range of 10-100 nKu/l, the water temperature reaches 20-44ºC, with mineralization equal to 0,9-13 g/l. The chemical composition is chloride-sodium-calcium. The approved reserves amount to 430 m³/s, of which only about 20% are used. Only slightly radonous waters (5-14 nKu/l) of the deposits of Kara-Balta, Kyokyomyoryon, Ak-Suu (Teploklyuchenka), Tuura-Suu are known. These waters are used for the treatment of nervous, gynecological diseases.

Sulfide waters are confined mainly to the adyr foothills of the Ferghana valley. Waters of the Rishtan deposit of chloride-sulfate calcium-sodium composition, with a mineralization of 3-6 g/l, contain 50-110 mg/l of total hydrogen sulfide (H_2S). The discharge of the source is 4 l/s. Mineral water of the Kyzyl Zhar area is hydro-chloride sodium with mineralization of 4-5 g/l in chemical composition, containing 175-240 mg/l of H_2S. Sodium-chloride water of the Chon-Kara deposit having a mineralization of 24 g/l, contains 480 mg/l of hydrogen sulfide. Sulfate-chloride sodium-calcium water of the Changyr-Tash area (550 mg/l) with a mineralization of 10-31 g/l is the most rich in hydrogen sulfide. Sulfide waters are effective in balneotherapy.

The focused discharges of ferruginous waters in Kyrgyzstan were found on the south-eastern slope of the Fergana range, in the upper reaches of Zhazy basin. The highest content of iron - 120 mg/l was recorded in the deposit of Kara-Shoro. Its waters lying at a depth of 80 m, sodium chloride in the composition, have mineralization of about 25 g/l. High iron content (45 mg/l), among the natural sources, is recorded in Arkar Shoro located in the Sabai tract, at the absolute altitude of 2870 m. High iron content (45 mg/l), among the natural sources, is recorded in Arkar Shoro located in the Sabai tract, at the absolute altitude of 2870 m.

There are outlets of 3 groups of springs, in which the iron content is 3 mg/l, in Jumgal valley in the Chamyndy river basin. In medicine, such waters are used to treat anemia.

Iodine-bromine waters in the territory of Kyrgyzstan are connected mainly to the oil-bearing geological structures of the foothills of the Ferghana valley. Mostly, they are found in the basins of Maily-Suu and Sharkyratma rivers in Nooken district at depths of 3-4 km. The iodine content in them ranges within 6-25 mg/l, bromine content - 3-390 mg/l. The water temperature reaches 55°C. Waters are of the sodium chloride chemical composition with a mineralization of 55 g/l. These waters are used in hospitals for aquatic therapy.

Water resources use. Water resources of the Kyrgyz Republic are a natural factor affecting both the development of the country and the formation of international relations in the Central Asian region. A significant part – 75-80%% of the total average annual volume of river runoff equal to 52 km³/year goes to the neighboring countries - Kazakhstan, China, Tajikistan, Turkmenistan and Uzbekistan. Such distribution of water resources was established in the Scheme of complex use and protection of water resources (CUPWR) and the Regulations on water allocation adopted in the 80s of the last century. They were drawn up in order to obtain maximum benefits for the USSR. Thus, according to the Scheme of the CUPWR, the quota of water intake of Kyrgyzstan in the basin of Syr Darya river was 4,03 km^3 out of 29,8 km^3 (14%); in the basin of Amu Darya – 0,2 km^3 out of 1,98 km^3 (5,2%) of the runoff formed on the territory of Kyrgyzstan. The runoff of Chu (3,84 km^3) and Talas (1,72 km^3) rivers was divided almost evenly between Kyrgyzstan and Kazakhstan, the runoff of Karkyra river (0,37 km³) – flows down to Kazakhstan. The runoff of the rivers of the Tarim basin (6,99 km^3), to which Sary-Jaz, Uzengyu-Kuush, Aksai and Kyzylsuu (east) on the territory of the Kyrgyz Republic relate, flows completely to China. As it is known, complicated water relations are formed in the region currently, they are associated with the initiatives of Kyrgyzstan, which offers neighboring countries to change the existing water allocation and adapt it to the new conditions, taking into account the national interests of sovereign states. Such initiatives supported by Tajikistan, do not get support from other Central Asian countries located in the lower reaches of rivers.

Currently, water supply to the users is provided by artificial hydrographic network of Kyrgyzstan, which in size, importance and impact on the environment has become comparable with the natural hydrographic system. According to the data of the Department of Water Resources and the country's Irrigation Institute, the total length of irrigation canals is 30836 km, or 88,1% of the length of all the rivers of Kyrgyzstan (34988 km), including the smallest (10-25 km). Of these, 6200 km accounts for the channels of inter-sector purpose, the cross-section of which is designed for the throughput of 2528 m³/s of water. It is almost 1000 m³/s higher than the value of runoff of all rivers in the year of average water content (1543 m³/s). The basis of artificial hydrographic network is formed by channels of inter-sector irrigation systems, with the length of 19200 km. The collector-drainage network is rather branched; its total length is 5436 km. The general pattern is complemented by artificial water bodies, with more than 620 reservoirs that can regulate the runoff of rivers in the period from 1 day to 2 years (18 reservoirs with total capacities from 13 to 19500 million cubic meters of water, more than 200 artificial reservoirs of the decadal and seasonal runoff regulation, with general volume of about 105 mln. m³, and 400 basins of daily and decadal regulation) [5,8]. The regulated by them river runoff is 23,5 cubic km or 47% of the volume of available surface water resources. 2200 wells supply groundwater for drinking and household purposes and irrigation of farmland.

Table 5 - Dynamics of water use in the Kyrgyz Republic (millions cubic meters)

Years	Withdrawn from water bodies	Total used	For household/ drinking w/s	For industrial w/s	For irrigation	Agricultural w/s	Losses during transportation/%
1983	12428	7979	190	681	6884	159	
1996	9596	6878	254	236	6278	107	1990/20
2000	8715	5262	183	58	4972	48	1962/ 22
2009	7600	4729	180	79	4417	8	1862/24
2010	7562	4478	206	90	4153	10	1768/23
2011	8634	4864	106	78	4620	14	1877/21
2012	9006	4863	243	82	4198	28	1955/21
2013	8327	5114	206	40	4544	28	1699/20
2014	7539	4768	143	81	4452	79	2005/26
2015	7569	5224	194	87	4853	70	2092/27

Note: the water resources are spent on feeding reservoirs, transfer outside the country

The dynamics and the basic directions of use of water resources of Kyrgyzstan are shown in Table 5. Since 1983, in the year when the water sector reached its greatest development, the water intake from water bodies was reduced by 40% by 2015. Water consumption for irrigation of the main water user in the country has decreased by 40% by 2010, and amounted to 70% of the figure of 1983 in 2015. Water consumption in the industrial sphere in individual years ranged from 5% (2013) to 12 % (2015). The amount of water used for drinking and household water supply, reflecting the state of urban water channels, also varied over a wide range - from 254 mln. m^3 (1996) to 106 mln. m³ (2011), i.e. by 2,5 times. There has been a significant degradation of agricultural water supply, which in the country is understood as the activity of water supply systems, transferred to the local government Its volume, which was equal to 159 million m³ in 1983, decreased to 8 million m³ in 2009 (by 95 %). In recent years, there is a trend to recover this important social component of water use, the volume of which increased to 70-79 mln m³.

Changes in the volumes of water use observed in recent decades were caused by a fundamental restructuring of the political, economic systems of the country, which has not yet been completed. Land reform, which has fragmented the tracts of agricultural land – especially arable land, became the cause of non-use of significant areas, reaching hundreds of thousands hectares per year. For example, according to the information of MA&WR of the KR, 100,4 thous. ha of arable land out of 1170,4 thous.ha were not used in 2013. The situation was the same in the subsequent years (Table 6).

Table 6 – Areas of lands, thous.ha

Total sown area, thous. ha			Unused arable land, thous.ha		
2013	2014	2015	2013	2014	2015
1170,4	1181,2	1185,9	100,4	94,5	90

Decrease in water consumption in industrial enterprises is associated with the decline of production in this sector. The deterioration of the state of the water supply system and urban irrigation networks is reflected in the significant reduction of water consumption in the towns and villages of the country. Water losses during transportation range within 20-27% of its intake from sources.

A promising trend in the use of water resources of Kyrgyzstan is the use of the enormous reserves of energy of the runoff of large and small rivers, the potential of which is estimated at 142,5 bln. kWh. Hydropower resources, which are cost-effective for use in the present stage, are estimated at 55 bln. kWh per year. Only 8-9,5% is currently used, which is 90% of the energy generated in the country. At the same time, only 3% of hydropower resources of small rivers are presently developed. Currently, Toktogul HPP with a capacity of 1200 MW, Kurpsai HPP – 800 thous. kW, Tash Kumyr -. 450 thous. kW, Shamaldy-Sai – 240 thous. kW, Uch-Kurgan – 180 thous. kW, Kambar- Ata 2 - 120 thous. kW and Atbashi - 40 thous. kW, are built and operating.

As it is known, after the collapse of the USSR, the Central Asian countries were faced with the problem of regulation of interstate water allocation and use of water resources. Every state in the region established their own positions on the issue in their national interests and formalized them by the appropriate documents at the public and government levels. The position of the KR in interstate water relations is formulated in the Constitution of the Kyrgyz Republic, in the Law of the KR "On the interstate use of water bodies, water resources and water management facilities of the Kyrgyz Republic" (from 23.07.2011), in the Decree of the President of the Kyrgyz Republic "About the bases of foreign policy of the Kyrgyz Republic in the field of the use of river water resources formed in Kyrgyzstan and flowing in the territories of neighboring states" from 06.10.1997 [2].

The Constitution of the KR states that "The land, its mineral wealth, water resources, air space, forests, flora and fauna, all the natural resources are the property of the state".

The Decree of 06.10.1997 states that the Kyrgyz Republic gives "special importance to solving the problems of joint water use, to the need to accelerate the development of new water allocation strategy and economic management levers in the field of protection and use of water and energy resources. The solution to these challenges is possible only on the basis of equitable taking into account the interests of both the KR and other interested countries through successive negotiations and the conclusion of the relevant international treaties, based on the characteristics of water use on each river flowing out of the KR. The issues of water supply, regulation of river runoff and the requiring of payment for water use or allocation of benefits from the use of water resources are the subject of intergovernmental negotiations".

The Law of the KR "On the interstate use of water bodies, water resources and water management facilities" provides for the formation of market mechanisms for transboundary water management.

These fundamental documents define the following main provisions in the position of the Kyrgyz Republic in water policy:

- the KR exercise its sovereign right to ownership of water resources, formed in its territory;

- the KR exercise its sovereign right to ownership of water resources, formed in its territory;

- the KR will consistently implement market mechanisms of transboundary water resources management.

Analysis and synthesis of the positions of the Experts Community of the KR presented, in the first place, by the experts of the Department of Water Resources and Land Reclamation of the MAWLR of the RK, the Problem Council on Water Issues at the Institute of Water Problems and Hydropower of the NAS of the KR shows that the implementation of the provisions of the Decree and the Law is in unsatisfactory state. The weakest circumstance in the water policy of the Kyrgyz Republic is the absence so far of the approved National Strategy and Concept for the development of water relations with the states joint in a single hydrographic system of the Aral Sea. It should be noted that for Kyrgyzstan as the state which is located in the upper reaches of the river basins of Syr Darya, Chu and Talas, it is vital to establish a procedure for the use of water resources originating in the territory of the country. The fundamental conceptual document for ordering the use of water resources should be the Water strategy of the KR based on the fact that water is one of the bases of life and activity of the Kyrgyz people, and is the property of the state in accordance with the Constitution of the Kyrgyz Republic. The National Water Policy, as the strategic objective, must ensure guaranteed satisfaction of needs of the population and sectors of the Kyrgyz economy in water resources in the required quantity and quality at present and in future.

These provisions do not exclude the fact that the Water Strategy should take into account the paramount importance of waters belonging to the KR to the life and the economy of the entire CAR. In accordance with such an approach, there should be established the principles of relations between Kyrgyzstan and other countries that use the water formed in the territory of the Kyrgyz Republic.

Draft strategic and conceptual documents on water policy were developed by the Department of Water Resources and Land Reclamation of the MA&M of the Kyrgyz Republic and the Institute of Water Problems and Hydropower of the NAS of the KR, they were sent to the higher state bodies, but have not been adopted so far. The experts believe that the lack of guidelines, defining and fixing the position of the country, is an obstacle in the regulation of issues by means of negotiations that often manifests itself in the inconsistency of the position of the Kyrgyz government and the fear of making responsible decisions.

According to their estimates, the intergovernmental treaties adopted in the period of 1992-2000 are the continuation of the water policy of the USSR, infringing upon national interests of the Kyrgyz Republic, preventing the development of hydropower engineering and agriculture sector of the Kyrgyz Republic.

At the same time, the existence of objective contradictions of national interests among the Central Asian countries is the main factor hindering the formation of a regional legal framework for water relations. Therefore, we so far failed to achieve the convergence of the positions of all stakeholders both on the global Conventions of 1992 and 1997, and in terms of regional draft documents, including:

✓ The overall water allocation strategy, sustainable use and protection of water resources in the Aral Sea basin (World Bank project).

✓ Agreements on the principles of share holding in cost recovery for operation and maintenance of water facilities of the joint interstate use on the 4-lateral basis (KR project).

✓ Treaties between the Republic of Kazakhstan, Kyrgyz Republic, Tajikistan and Uzbekistan on the basic principles of cooperation in the field of water relations (KR project).

To implement its water policy, the KR should undertake and implement a number of measures and activities, among which the decisive place should take the following international legal initiatives:

1) To continue to initiate the development and adoption of multilateral regional document on water relations.

2) To continue to promote the idea of IWRM for all coastal states, in cooperation with Tajikistan, which offered to conduct a comprehensive examination of the entire system of water use in Central Asia under the auspices of the UN, including consideration of the issues of effectiveness and efficiency of the functioning of all the existing reservoirs and complex examination of the environmental situation in the region.

3) It should initiate the adoption of new water allocation schemes on small transboundary rivers, flowing down the slopes of mountain frame of the Fergana valley.

4) To abandon the Almaty Agreement of 1992, that just fixed the scheme which existed in Soviet times, and to negotiate about the revision of the terms or on a new agreement.

5) To seek payment (in money terms) for the storage of water, for the maintenance of water infrastructure, flood prevention, as well as compensations for unreceived energy. Arguments should be based on competent calculations and be put to discussion at the highest political level.

6) To systematically conduct analysis and research, enabling to develop and propose various alternatives of institutional mechanisms of the transboundary RES management to the countries in the region.

7) It is necessary to prepare professional personnel on water issues. It is necessary to pay more attention to the development of art of negotiations, mediation and arbitration.

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WATER RESOURCES OF RIVER RUNOFF OF THE SOUTHERN REGIONS OF KAZAKHSTAN: RETROSPECTIVE STATE, PATTERNS OF DISTRIBUTION

Қазақстанның оңтүстік және оңтүстік-шығыс аймақатары өзен ағындысының аумақтық үлестірімінің заңдылықтары қарастырылды, Арал-Сырдария, Шу-Талас және Балқаш-Алакөл сушаруашылық алаптарының су ресурстары 1960-2012 жж. кезеңінде сушаруашылық телімдері бойынша анықталды. Сонымен қатар әрбір жеке су шаруашылық телім үшін онда қалыптасатын, телімге келетін және шығатын су ресурстары және су шаруашылық алаптары үшін су ресурстары анықталды.

The patterns of the territorial distribution of river runoff resources of the southern regions of Kazakhstan are considered, water resources for the period from 1960 to 2012 were assessed in the context of water management areas of the Aral-Syrdariya, Shu-Talas and Balkash-Alakol water management basins. Water resources formed within each water management area, the inflow and outflow of water from them were also separately calculated, and water resources of water management basins were assessed.

Introduction. Sustainable development of society is possible provided that it has reliable water supply now and in the future. Planning and implementation of water management measures for the sustainable development of any country, i.e. ensuring the water security of the country is possible only if there is an awareness (assessment) of the occurring and possible in the future changes in water resources and water regime of rivers under the influence of natural and anthropogenic factors. There is an acute shortage of water resources in the Republic of Kazakhstan, there is no human activity without them, and they cannot be replaced by anything. The extremely high territorial-temporal variability of river runoff and the significance of its transboundary component ten times exacerbate the problem of water supply in the country. In these conditions, the need comes, first of all, to justify the geographical bases of water security of the country, for the sustainable development of society is ensured by the awareness and management of changing water resources. Southern and South-Eastern region of Kazakhstan is of great economic, social and environmental importance for the country. One of the most important agro-industrial complexes of the country has been formed here due to favorable climatic conditions, availability of the necessary land, water resources, raw materials and labor resources.

Problem statement. The implementation of the economic development plans in Kazakhstan for the future period of 2030-2050 in current circumstances requires very serious efforts. First of all, it is necessary to have a clear idea of the available water resources of the country. 85% of consumed water resources in Kazakhstan are the surface river runoff. The problem is aggravated by water scarcity, the uneven distribution of water resources over the territory of the Republic of Kazakhstan. Thus, though the southern region is relatively well supplied with water, at the same time it is the main consumer (70-80%) in irrigated agriculture, which is historically formed here. The overall development of socio-economic state and the improvement of the Food Program of the RK for the future as a result, depend on the availability of water for agriculture.

The multilateral assessment of water resources of the country in the context of water management basins (WMBs) is given in the major research of 2009-2011, fulfilled by a number of organizations [1]. But the results of this tremendous work do not provide their practical narrowly regional use, for example, in the context of water management areas (WMAs). There is a need for considerable detailing of the issue of the territorial distribution of water resources: by WMAs and their parts. A scrupulous detailing of runoff data: volume of inflow to each area and outflow from it, the amount of formed local runoff for each area, is necessary for each area in order to successfully use river water resources and for the secure planning of the use.

Research methodology. The research is based on methods spread in hydrology and based on the territorial patterns of changes in river runoff, such as a comprehensive physical and geographical analysis, taking into account the factors of the formation and change of the runoff.

Patterns of distribution of river runoff in the region under study were analyzed on the basis of mapping average annual runoff for each water management basin. The average annual runoff values of the representative gauging stations (GS) and obtained on the basis of their analysis regional dependences of runoff on the average height of the catchment $h = f\ (H_{aver.})$, were used for the preparation of the maps of the runoff [1, 2].

Average annual runoff (runoff layer h) obtained at gauging stations is assigned to the horizontal line, corresponding to average height of catchment in the mountain areas, in the plain areas – to the geometric center. Then, the lines through the points of equal values of the layer were drawn. Next, the isolines were adjusted based on the features of the relief, orography, the orientation of the mountain slopes with respect to moisture-bearing masses moving into these regions.

Assessment of the indicators of river runoff by water management areas of the basins of south-eastern and southern regions of Kazakhstan was carried out during the accounting period from 1960 to 2012. The methods of statistical analysis of hydrological data, hydrological and water management calculations, complex hydrological and geographical analysis were used. Differentiation of local and transit runoff (inflow) was carried out.

The local runoff of the WMA was estimated as the sum of the runoff of the studied areas (covered by the observations in the alignments of gauging stations (GS) of the rivers) and the runoff of unstudied areas (not covered by the actual observations on the rivers).

Calculations of the runoff by the studied areas were made by summing the river runoff in the alignments of GSs, closing the zone of runoff formation. Selection of GSs was carried out on the basis of the analysis of the channel water balance of specific river or river basin (when there were GSs at several tributaries) and the comparison of their runoff values. The GSs with the greatest average annual water discharges relative to other GSs along the river (if available) or in the basin of a particular river, below which the areas were referred to unstudied, in spite of the GSs available here, were taken into account. This is due to the fact that the latter are sometimes located below areas with certain natural runoff losses.

Calculation of runoff on the unstudied areas was carried out on the basis of regional curves $h = f\ (H_{aver.})$, as well as based on the map of runoff that previously was considered in the paper [2].

Local runoff of the WMB was determined by the sum of the similar values for the WMB within a particular basin.

The resources flowing into this area from other areas – *inflow to WMA/WMB,* were identified for each WMA and WMB.

The sum of inflow and local (formed in the territory of this WMA within the RK) resources gives *total resources of the WMA/WMB.*

The extensive archive and stock material of the RSE "Kazhydromet" (UGKS of the Kazakh SSR), reference and catalog data of the state water cadastre, the monograph " Resources of surface water of the USSR" were used in the work as a source information [3-5].

Results of studies and their discussion. River basins of the Southern and South-Eastern Kazakhstan are relatively well studied in the hydrological context. Detailed studies of the river runoff of the southern region of Kazakhstan were fulfilled by V.L. Schultz [6] and B.D.

Zaikov [7], they were considered in more detail by the 70-ies of the last century [3-5, 8-12]; the more recent works include the study of the Institute of Geography [1]. The patterns of runoff formation in the region were studied in the study. Features of the territorial distributions of river runoff mainly depend on the orographic and climatic conditions of a particular basin.

In order to visualize the territorial distribution of annual runoff in the water management basins of the Republic of Kazakhstan, the average annual runoff maps were created based on the use of the identified regional dependencies of the runoff on physical and geographical characteristics of the basins for the all three water management basins (Figures 1-3).

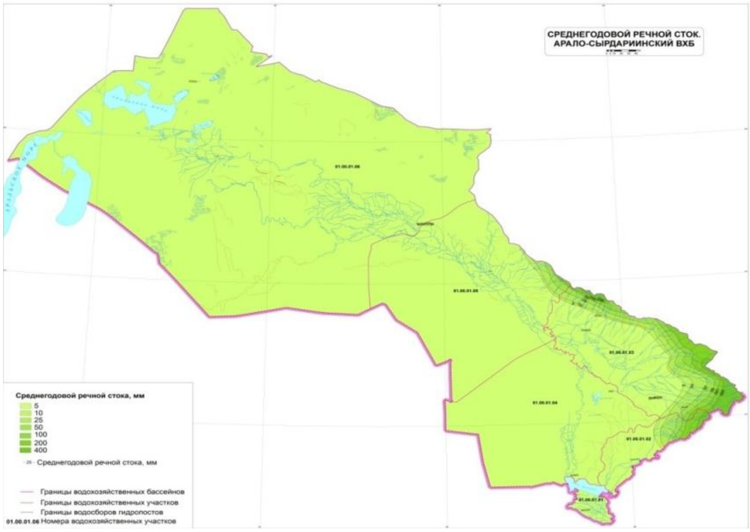

Figure 1 – Map of runoff (average annual layer) of the Aral-Syrdariya WMB

All hydrological regions of *the Aral-Syrdariya WMB* are characterized by a gradual increase in the river runoff according to the altitude of the terrain, at maximum altitude there are the most favorable conditions for the formation of runoff. River runoff of the region naturally decreases from east to west at the Karatau ridge. The average altitudes of catchment areas vary from 600 to 1200 m, layer of runoff is greater than 400 mm in the river basins of the western part of the south-western slopes of the Karatau ridge: Ikansu, Shert, Karashyk, Aktobe, Tastaksai, etc. The layer of runoff reaches a maximum value of 564 mm in the river basins of the southern part of the south-western slopes of the Karatau ridge: Bogen, Balabogen, Aktas and other rivers, where the absolute altitude is equal to 520-900 m above sea level. River basins of the south-western slopes of the Boraldaitau ridge, which include Boraldai, Kokbulak, Karagashty, Koshkarata and other rivers, are characterized by altitudes of catchment areas from 700 to 1100 m, maximum runoff layer reaches 435 mm. The depth of runoff reaches the maximum value (717 mm) over the entire catchment basin of the Aral-Syrdariya WMB in the river basins of the north-western slopes of the Karzhantau ridge, with an interval of altitudes from 1100 to 2500 m. Zhabagylysu, Mashat, Aksu, Badam, Sairam and other small rivers flow in this area.

The Shu-Talas WMB. The nature of the distribution of the average runoff is different for the left-bank (main) and right-bank tributaries of Shu river in the Shu valley. (Figure 2). The northern slopes of the Kyrgyz Alatau are well accessible to wet air flows coming from the west and north-west, so the water contents of the rivers of these slopes are significantly higher than of the upper reaches of Shu river. Thus, the rivers of the extreme western spurs of the Kyrgyz Alatau have runoff layer of 79-306 mm with average altitudes equal to 2090-2370 m. The layer of river runoff corresponds to the value of about 38-151 mm with average altitudes of catchment areas equal to 960-2530 m. Most of the rivers of the northern slopes of the Talas Alatau have a layer of runoff of 38-186 mm with average altitudes of catchment areas equal to 580-1080 m.

Figure 2 – Map of the runoff (average annual layer) of the Shu-Talas WMB

Features of the territorial distributions of the river runoff of *the Balkash-Alakol WMB* are mainly due to orographic and climatic conditions of the basin (Figure 3).

The main part of the river runoff is formed in the mountain area, which differ for a variety of landscapes from the plains in the relatively small stretches of spaces, even within one and the same altitude, the same mountain slope. Western and northern slopes of Zhetysu Alatau and the central part of the northern slope of Ile Alatau have the most specific water content - the average annual runoff layer here reaches 800-1000 mm. In the intra-mountain and less moistened areas of the Balkash-Alakol WMB (basins of Sharyn and Shelek rivers, the southern slope of Zhetysu Alatau), the average annual runoff layer hardly reaches 400 mm. The runoff usually dissipates in the plains of the Balkash-Alakol WMB. The rivers of the North Balkash lake region have the lowest specific water content, the runoff ranges from 5 to 50 mm. Water content decreases from north to south in the river basins of Alakol lake, according to the patterns of geographical zonality, as well as from the west to the east, depending on the accessibility of moisture-bearing western air masses. The most water-bearing areas are the south-western slopes of the Tarbagatai ridge (basin of Urzhar, Karakol rivers), where the depth of runoff reaches 600 (sometimes even 800) mm. The lowest water content - a maximum of 400 mm, is characteristic to the north-eastern slopes of the Zhetysu Alatau ridge. Water content of relatively latitudinally located ranges (ranges of Tarbagatai, Zhetisu Alatau) clearly decreases to the east. Thus, both the latitudinal pattern of distribution of river runoff and its longitudinal and high-altitude differentiations are traced in the basin of the rivers of the lake Alakol.

Water management and administrative division is the basis of addressing the water management challenges, the issues of protection and rational use of water resources, long-term water supply for the population, industry and agriculture, the development of measures to protect the environment, ensuring the effective management of the river basins of Kazakhstan. Further, there was the assessment of water resources of the Aral-Syrdariya, Shu-Talas and Balkash-Alakol water management basins, which are divided into relevant water management areas (Figure 4). The basis of the water management regionalization of the territory of water management basins under consideration is formed by the Resolution of the Republic of Kazakhstan "On approval of the General Scheme of complex use and protection of water resources" from April 8, 2016, №200 [13].

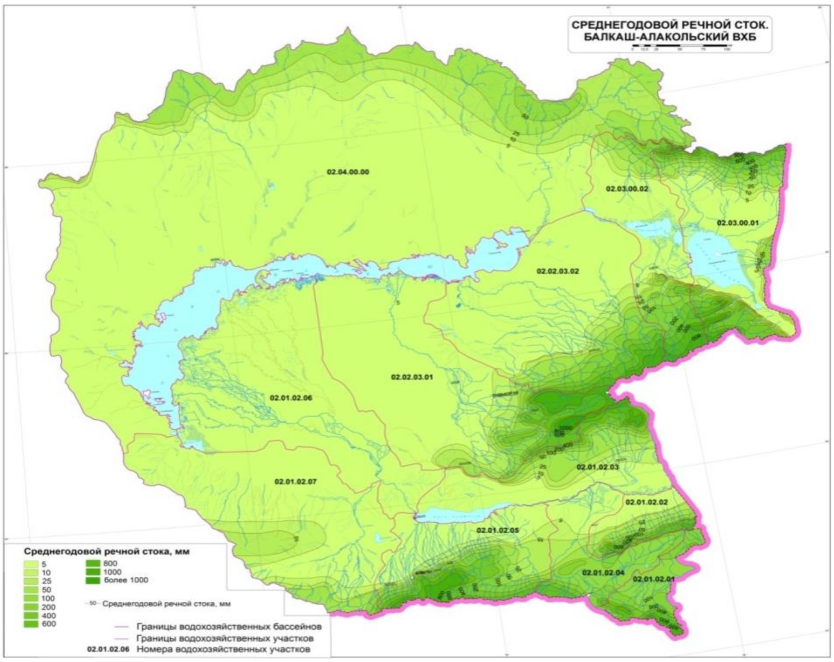

Figure 3 - Map of the runoff (average annual layer) of the Balkash-Alakol WMB

Figure 4 shows the numerical values of the inflow, the local and total water resources of the WMBs under consideration in the context of WMAs.

The Aral-Syrdariya water management basin consists of six water management areas. The results of calculations are presented in Table 1.

WMA 01.01.00.01. Total water resources of the area are estimated by summing the inflow to the Republic of Kazakhstan from the neighboring territory of Uzbekistan through Syrdariya river according to the GS of Syrdariya river - above the mouth of the river Keles, the inflow from WMA 01.01.00.02 and local runoff, forming within this area: W=27,4+0,48+0,007=27,9 km^3.

WMA 01.01.00.02 includes the Keles river basin. Total water resources of the area under consideration are estimated based on the runoff of Keles river and runoff of the rivers of the unstudied areas: W=0,35+0,13=0,48 km3.

WMA 01.01.00.03 includes rivers that originate from the Boraldaitau ridge and south-eastern slopes of the Karatau ridge (Arys, Shayan, Bayaldyr, Shylbyr, Khantagy, Koksu, Aktobe). Total water resources of the water management area are estimated based on the resources of the studied and unstudied rivers: W=2,23+0,32=2,55 km^3.

WMA 01.01.00.04. Total water resources of the area under consideration are estimated by summing inflows from neighboring areas and local runoff. The inflow for this area is the coming runoff of Syrdariya river – intake basin below the Shardariya reservoir and runoff on Arys river - Shauldir village: W=25,9+1,28+0,094=27,3 km^3.

WMA 01.01.00.05. Total water resources of this area are estimated by the inflowing runoff in Syrdariya river - Koktobe village and local runoff, formed on the territory of the water management area: W=24,6+0,18=24,8 km^3.

WMA 01.01.00.06. Total water resources of this area are estimated by the inflowing runoff in Syrdariya river - Kergelmes passing track and local runoff, formed on the territory of the water management area: W=21,8+0,17=22,0 km^3.

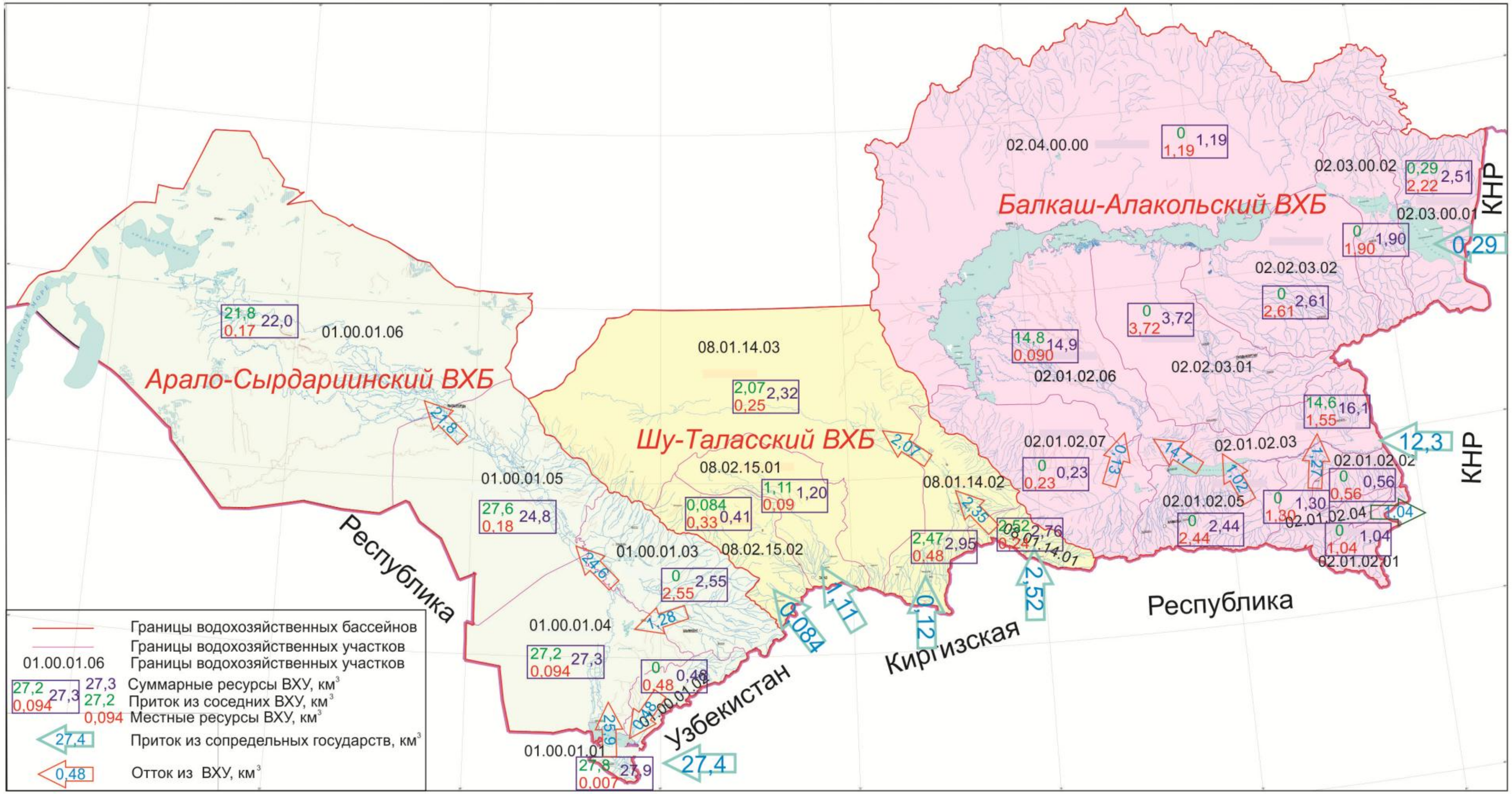

Figure 4 - Water resources of the southern and south-eastern regions of Kazakhstan

Table 1 – Average long-term values of runoff based on water management areas and on water management basin of the Aral-Syrdariya WMB

WMA	Inflow, km^3	Local resources, km^3	Total resources, km^3
01.00.01.01	27,8*	0,007	27,9
01.00.01.02	-	0,48	0,48
01.00.01.03	-	2,55	2,55
01.00.01.04	27,2	0,094	27,3
01.00.01.05	24,6	0,18	24,8
01.00.01.06	21,8	0,17	22,0
Aral-Syrdariya WMB	27,4	3,48	30,9
Note * - inflow to the WMA 01.00.01.01 takes into account not only the inflow from the territory of Uzbekistan, but also the inflow from the WMA 01.00.01.02			

Total resources of the entire *Aral-Syrdariya WMB* are estimated by the inflowing runoff in Syrdariya river from Uzbekistan and local runoff, formed within the Republic of Kazakhstan: W=27,4+3,48=30,9 km^3.

The Shu-Talas water management basin consists of five water management areas. Results of water resources assessment are presented in Table 2.

Table 2 – Average long-term values of runoff based on the water management areas and on the water management basin of the Shu-Talas WMB

WMA	Inflow, km^3	Local resources, km^3	Total resources, km^3
08.01.14.01	2,52	0,24	2,76
08.01.14.02	2,47	0,48	2,95
08.01.14.03	2,07	0,25	2,32
08.02.15.01	1,11	0,09	1,20
08.02.15.02	0,084	0,33	0,41
Shu-Talas WMB	3,72	1,38	5,10

WMA 08.01.14.01. The local water resources of this WMA consist of the runoff of rivers of the western slope of the Ile Alatau ridge (rivers of Kastek, Karakonys, Yrgaity, Zhansai, Karasu and others), which were estimated in the amount of 0,24 km^3, the resources of the studied areas of them are 0,18 km^3, unstudied – 0,06 km^3. Water comes to this area from the territory of the Kyrgyz Republic in the amount of 2,52 km^3. Total water resources amount to: W=0,24+2,52=2,76 km^3. The outflow from this area to the WMA 08.01.14.02. is estimated based on GS of Shu river – Tasotkel aul and amounts to 2,35 km^3.

WMA 08.01.14.02. The local runoff is formed in the rivers flowing from the western slope of the mountains of Aitau and Kindiktas (Ungirli, Terekty, Shokpar rivers), as well as from the northern slopes of the Kyrgyz ridge (Aspara, Merki, Karakystak and other rivers) and amounts to 0,48 km^3, the resources of the studied areas of them amount to 0,31 km^3, unstudied – 0,17 km^3. The inflow to this WMA comes from the WMA 08.01.14.01 through Shu river (GS of Shu river – Tasotkel aul) in the volume of 2,35 km^3 and from the territory of the Kyrgyz Republic in the volume of 0,12 km^3, totaling in 2,47 km^3. Total water resources are estimated in the volume of 2,95 km^3. The outflow from the WMA is done through Shu river to the WMA 08.01.14.03 in the volume of 2,07 km^3.

WMA 08.01.14.03. includes the rivers flowing down from the northern slopes of the Kyrgyz ridge (Shalsu, Taldysu, Zharlysu and other rivers), as well as from the northern slopes of the Karatau mountains (Darbut, Koshkarata, Rang, Arpaozen and other rivers), which form local resources of the WMA in the volume of 0,25 km^3. Of them, the resources of the studied areas are 0,06 km^3, unstudied – 0,19 km^3. The inflow comes from the WMA 08.01.14.01 through Shu river (GS of Shu river – Moyynkum aul) in the volume of 2,07 km^3. Total water resources amount to 2,32 km^3. There is no outflow to other WMAs.

WMA 08.02.15.01. Local resources are formed by total runoff of small rivers and streams flowing down from the northern slopes of the Talas mountain range in the volume of 0,09 km^3. The runoff with the volume of 1,11 km^3 flows from the territory of the Kyrgyz Republic through Talas river. Total water resources of the WMA amount to: W=0,09+1,11=1,20 km^3. There is no outflow from this WMA to others.

WMA 08.02.15.02. includes the rivers of the northern and south-eastern slope of the Karatau mountains (Teris, Akzhar, Tamdy, Koktal, Shabakty rivers). Local runoff amounts to 0,33 km^3. The inflow comes from the territory of the Kyrgyz Republic in the volume of 0,084 km3. Thus, total water resources of the WMA amount to 0,41 km^3. There is no outflow to other WMAs.

Water resources formed within the Shu-Talas WMB are estimated at 1,38 km^3. The runoff with the volume of 3,72 km^3 flows from the territory of the Kyrgyz Republic. Total resources amount to: W=1,38+3,72=5,10 km^3.

The Balkash-Alakol water management basin consists of 12 water management areas. The resources flowing to this area from other areas (inflow to the WMA/WMB), local resources (formed on the territory of this WMA/WMB within the RK), total resources (sum of inflow and local resources) were defined for each WMA and WMB in general. The results are presented in Table 3.

WMA 02.01.02.01. includes the basin of Tekes river. Runoff from other areas does not enter this WMA. Local resources in the volume of 1,04 km3, which were estimated at the sum of the runoff of the studied (0,29 km3) and unstudied (0,75 km3) parts, consist of water resources formed on the territory. All water resources in the amount of 1,04 km3, formed in this WMA, flow to the territory of the People's Republic of China (PRC) though Tekes river.

WMA 02.01.02.02. There is no inflow to this area. Local resources consist of total runoff of numerous small rivers and streams flowing from the Uzynkara mountain ridge. The studied runoff make up 0,10 km3, runoff from the unstudied areas – 0,46 km3, total runoff of the water management area – 0,56 km3. Local water resources are used for irrigation on the alluvial cone of the rivers, and then are lost; there is no outflow from the WMA, accordingly.

WMA 02.01.02.03 includes rivers flowing down from the southern slope of Zhetysu Alatau (Osek, Khorgos) that make up the local resources of the WMA, as well as Ile river from the state border of the RK with the PRC to the Kapshagai tract (including the Kapshagai reservoir). Local water resources are estimated at 1,55 km3, the resources of the studied areas make up 0,66 km3, of the unstudied – 0,89 km3. Inflow to this area comes from the PRC (estimated on the GS of Ile river - Kayyrylgan tract), from the WMA 02.01.02.04 through Sharyn river, from the WMA 02.01.02.05 through the rivers flowing into the river Ile (Kapshagai reservoir). The total inflow is 14,6 km3. The outflow from the area is estimated on the GS of Ile river – Kapshagai tract and amounts to 14,7 km3.

WMA 02.01.02.04 includes the Sharyn river basin, the resources of which amount to 1,30 km^3, of them, for the studied areas - 1,27 km^3, for the unstudied – 0,030 km^3. Runoff from other areas does not enter this WMA. Water formed in the volume of 1,27 km^3 flows off in the WMA 02.01.02.03.

WMA 02.01.02.05. Water resources of the WMA are made up by the river runoff of northern slope of Ile Alatau mountain ridge (Kaskelen, Shamalgan, Ulken and Kishi Almaty, Talgar, Turgen, Yesik and other rivers). There is no inflow to this area. Local resources are estimated at 2,44 km^3, of which the runoff of the studied rivers is 1,23 km^3, of the unstudied – 1,21 km^3. Outflow is carried out through the rivers flowing into Ile river (Kapshagai reservoir), and makes up 1,02 km^3.

Table 3 – Average long-term values of runoff based on the water management areas and on the water management basin of the Balkash-Alakol WMB

WMA	Inflow, km^3	Local resources, km^3	Total resources, km^3
02.01.02.01	-	1,04	1,04
02.01.02.02	-	0,56	0,56
02.01.02.03	14,6	1,55	16,1
02.01.02.04	-	1,30	1,30
02.01.02.05	-	2,44	2,44
02.01.02.06	14,8	0,090	14,9
02.01.02.07	-	0,23	0,23
02.02.03.01	-	3,72	3,72
02.02.03.02	-	2,61	2,61
02.04.00.00	-	1,19	1,19
02.03.00.01	0,29	2,22	2,51
02.03.00.02	-	1,90	1,90
Balkash-Alakol WMB	12,6	18,8	30,4*
Note* - the resources of the WMA 02.01.02.01 were deducted from the total resources in order to avoid double counting, since they are formed in the territory of the RK, and then flow into the territory of China, and then are recorded as the inflow to WMB			

WMA 02.01.02.06 includes the area of Ile river from the Kapshagai reservoir (Kapshagai tracts) before falling into the lake Balkash. It is the zone of the runoff dispersion. Small streams, the runoff of which is estimated at 0,090 km^3, are formed only in the beginning of the area. The inflow to the area is carried out through the river Ile (GS of Ile river – Kapshagai tract) from the WMA 02.01.02.03 and through Kurty river from the WMA 02.01.02.07. The total inflow to the area is 14,8 km^3. There is no outflow to other WMAs. Ile river flows into the lake Balkash, forming a vast delta.

WMA 02.01.02.07 includes the Kurty river basin. Water from other WMAs does not come here. Local resources are estimated at 0,23 km^3, the resources of the studied areas are equal to 0,13 km^3, of the unstudied – 0,096 km3. The outflow is done though Kurty river to the WMA 02.01.02.06 and amounts to 0,13 km^3.

WMA 02.01.03.01 is the Karatal river basin. There are no inflow from other and outflow to other WMAs. Local resources are estimated at 3,72 km^3: for the studied areas - 3,44 km^3, for the unstudied – 0,28 km^3. Karatal river falls into Balkash lake forming a small delta.

WMA 02.01.03.02 includes the rivers Lepsy, Aksu, Biyen, Sarkand. Local resources are estimated at 2,61 km^3: for the studied areas - 2,00 km^3, for the unstudied – 0,61 km^3. There are no inflow from other and outflow to other WMAs. The rivers Lepsy and Aksu fall into the lake Balkash.

WMA 02.04.00.00 – The North Balkash lake region, includes the rivers Ayagoz, Bakanas, Moyynty, Tokrau. Local resources are estimated at 1,19 km^3: for the studied areas - 0,56 km^3, for the unstudied – 0,62 km^3. There are no inflow from other and outflow to other WMAs. Ayagoz river falls into Balkash lake.

WMA 02.03.00.01 includes Urzhar, Katynsu, Ai rivers, as well as Yemel river bringing its water from China. Alakol lake is the part of the WMA. The inflow to this WMA is carried out from China through Yemel river – Akshi aul and amounts to 0,29 km^3. Local resources are estimated at 2,22 km^3: for the studied areas - 0,63 km^3, for the unstudied – 1,59 km^3. There is no outflow to other WMAs.

WMA 02.03.00.02 includes Tentek, Shynzhaly, Karakol rivers. Sasykkol lake is part of the WMA. Local resources are estimated at 1,90 km^3: for the studied areas - 1,77 km^3, for the unstudied – 0,13 km^3. There are no inflow from other and outflow to other WMAs.

The Balkash-Alakol WMB. Water resources formed within the WMB are estimated at 18,8 km^3. Of them, the resources of the Ile-Balkash basin make up 14,7 km^3, the resources of the Alakol lake basin – 4,11 km^3. The inflow to the Balkash-Alakol WMB is formed by the resources flowing from China: through Ile river (GS of Ile river – Kayyrylgan tract) – 14,6 km^3, through Yemel river (GS of Yemel river – Akshi aul) – 0,29 km^3. And the outflow from the Balkash-Alakol WMB are made up by the resources of the WMA 02.01.02.01 (Tekes river basin) in the volume of 1,04 km^3, which flow to China, fall into Ile river (on the territory of China) and are recorded at the GS of Ile river – Kayyrylgan tract.

Conclusions. The present research has analyzed the spatial distribution patterns of river runoff, based on the maps of the average long-term runoff layer (in mm) for the Aral-Syrdariya, Shu-Talas and Balkash-Alakol water management basins. In general, the water content in the region is reduced from north to south, according to the pattern of geographical zonality, as well as from west to east, depending on the reach of moisture-bearing western air masses. At the same time, the high-altitude, typical of mountain areas, zoning, or the so-called high-altitude zonality, is fully manifested.

The assessment of water resources for the period from 1960 to 2012 obtained in the research in the context of water management areas of the south-eastern and southern regions of Kazakhstan is made the first time. There were also separately calculated water resources formed within each WMA, the inflow and outflow of water from them. The total surface water resources of the South and South-East Kazakhstan make up 69,7 km^3, of which 26,0 km^3 are formed on the territory of the Republic of Kazakhstan and 47,4 km^3 of water comes from the neighboring countries.

The research results can be directly used by specialists of water management for practical purposes, including the development of various scenarios of water consumption, when planning various water management activities in the near future.

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MODERN WATER REGIME OF RIVERS OF THE ILE-BALKASH BASIN IN VIEW OF CLIMATE CHANGE

В данной работе рассмотрены вопросы влияния изменения климата на внутригодовое распределение, а также на характерные периоды режима стока рек Иле-Балкашского бассейна.

Бұл мақалада Іле-Балқаш алабы өзендерінде климат өзгеруінің ағынды режимінің жылдық үлестіріміне және ұқсас кезеңдеріне әсерінің мәселелері қарастырылған.

The influence of climate change on annual spreading and on specific periods of Ile-Balkash basin rivers drain regime questions are viewed in this statement.

Introduction. The second half of the XX and the beginning of the XXI centuries are characterized by targeted climatic changes. This is reflected on the factors of formation of river runoff and on their hydrological regime.

The changes in the hydrological regime of rivers, in particular the rivers of Kazakhstan, have not gone unnoticed over the recent decades, when the problem of global climate change and its consequences is being analyzed in detail by scientists. The hydrological regime of rivers is quite sensitive to climatic variations, therefore the study of the characteristics of the hydrological regime as well as their changes are of great importance for basic science, in addition to the practical interest of the various sectors of the economy that are related to the use of the rivers.

Sources of information. The extensive archive and stock material of the RSE "Kazhydromet" (DHCS of the Kazakh SSR), reference and catalog data of the state water cadastre, monographs of the "Surface water resources of the USSR" [3] were used in the paper as a source information.

Problem statement. The majority of modern scientific researches in the area of changes in water resources and river runoff pay attention to the nature of inter-annual variability and cyclicity of the annual variation of river runoff of a particular region in the context of climate change and anthropogenic impact. Often, the annual indicators of runoff average the changes that take place within a year in the runoff distribution and do not reflect the real situation with the change in the water regime of rivers, both in the water management basin in general and at the regional level, whereas exactly the intra-annual runoff distribution (hereinafter the IARD) has practical nature directly for water users. The knowledge of hydrological regime, runoff distribution by seasons and month is of particular importance under the conditions of aridity of the study area and the scarcity of water resources, as the main source of water supply here are the rivers that define the specificity in the problem of water management in the region, where irrigated agriculture is a water-intensive consumer [1].

Research methodology. Scientific research is based on the methods of statistical and hydrological calculations, spatial-temporal analysis. Hydrological and meteorological calculations are made using the generally accepted classical methods. Thus, a graphical-analytical method, as well as the method of linear trend are used to assess the relationship of river runoff and meteorological elements: the trends of change for the entire period of observations are defined, indicating the annual values of distribution of water discharge in the year for the average water content year, at the main gauging stations within each water management basin (hereinafter – the WMB), as well as the data on air temperature and atmospheric precipitation at the nearest weather station. In addition, the characteristics of flood such as the date of the beginning of the onset, the maximum value, the duration and the end date of the flood, are evaluated, when there is the highest runoff in the river (from April to September), which will allow a more detailed assessment of trends of change in the hydrological regime and its relationship with climatic parameters.

Research results and their discussion. Long-term dynamics of the river runoff, temperature and atmospheric precipitation for the period from the beginning of observations to 2012 for the Ile-Balkash basin were considered by us in this paper. The analysis of the linear trend of the annual river runoff, atmospheric precipitation and air temperature was made to assess the intensity of the ongoing changes. The relationship of climatic changes with water content of the rivers of the basin was estimated based on the results of parallel observation periods according to precipitation and air temperature at weather stations, which are located near river under consideration. The changes in the IARD for two periods from the beginning of observations to 1965 and 1960-2012 were studied; also, the relationship of the changes in the terms of floods with the changes in climatic characteristics was evaluated.

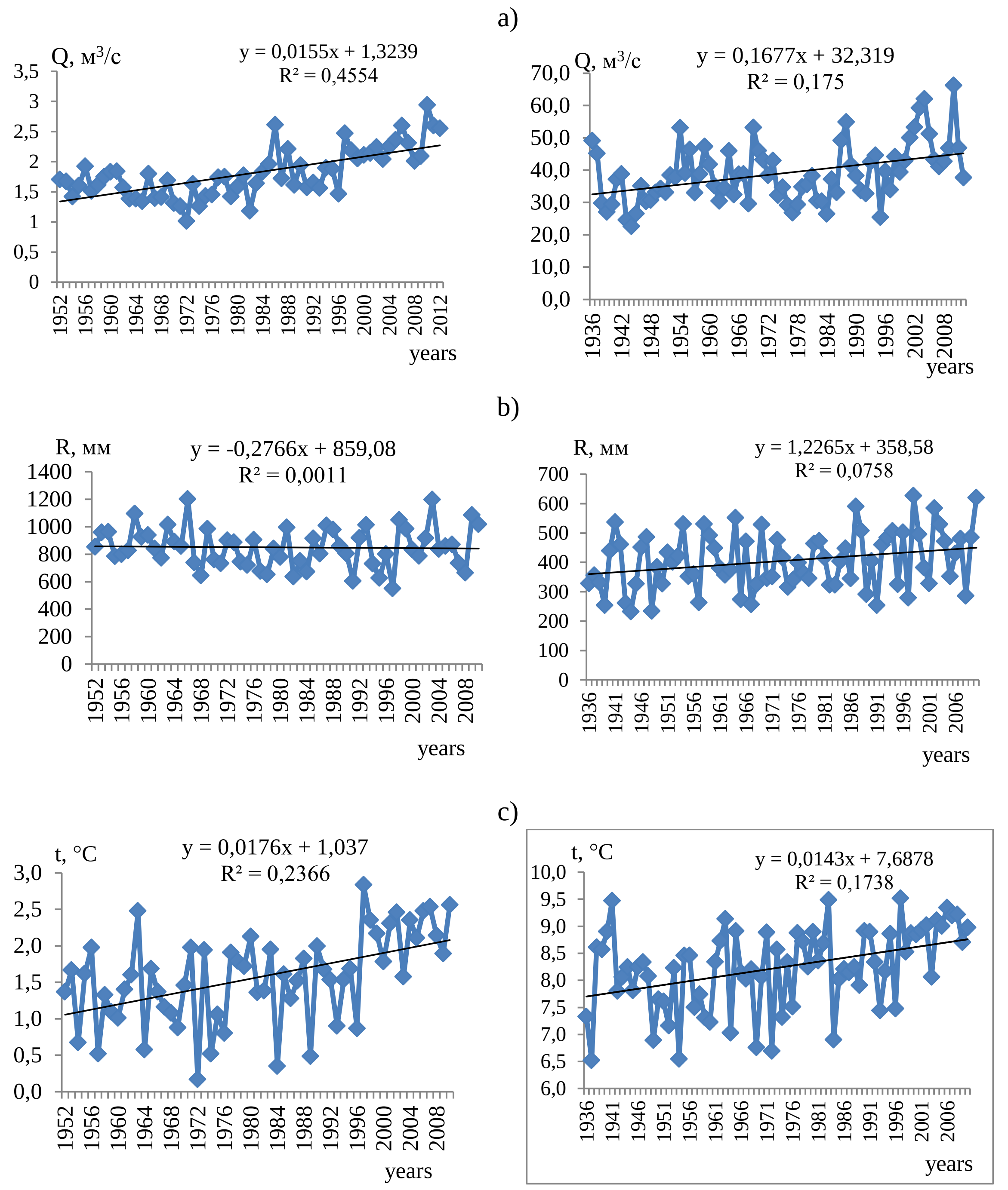
The results of studies of the relationship of long-term variation of the runoff, atmospheric precipitation and air temperature as an example of a graphic demonstration on two rivers of the Ile-Balkash basin, are shown in Figure 1.

Analysis of the dynamics of water content of Ulken Almaty river with the variation of atmospheric precipitation and air temperature at the Ulken Almaty WS (Figure 1) for the period of 1952-2010 shows that the water discharge and air temperature have a positive trend, and the line of atmospheric precipitation is going to decline. An increase in the water content against the decrease in the amount of precipitation is recorded, probably this is due to the fact that when the air temperature increases and the amount of precipitation decreases, the stability of water resources is maintained by increasing glacial melting, as the most important role is played by glacial component in annual runoff (more than 40% of annual runoff) of Ulken Almaty river.

Comparative analysis of the graphs of fluctuations of annual river runoff with the annual amount of precipitation and average annual air temperature for the station of Sharyn river – Sarytogai tract shows that fluctuations of the mentioned variables have a positive trend (Figure 1). Water regime of Sharyn river is caused by snow and glacial feeding, and therefore there is an increase in water resources with a slight increase in the amount of precipitation and in air temperature.

In the rivers of the north-western and north-eastern part of slopes of the Zhetysu Alatau mountain ridge (Lepsy river – Lepsy aul, Byzhy river – Krasnogorovka village and others), there is a tendency of the increase in runoff and hardly noticeable positive trend in precipitation, and air temperature has a marked tendency of growth, where the air temperature increases by 0,3 °C each decade. There is an increase in the water content against a significant increase in air temperature, whereas precipitation remains relatively stable over the entire observation period of 1933-2012, this pattern may be associated with the fact that the regime of feeding of water resources of Lepsy river is mainly due to mixed snow and glacier component. The same pattern of an upward tendency of runoff is observed at Byzhy river – Krasnogorovka village, but since Byzhy river originates slightly below Lepsy river at an altitude of 2000 m on the north-western slope of the Altynemel ridge, therefore the increase in runoff is due to an increase in air temperature, rather than an increase in precipitation that occurs due to the melting of snow in spring and summer period.

There is a trend toward an increase in air temperature in the area of the Alakol lake basin and in the Ayagoz river basin; the amount of precipitation at the station of Tentek river – Tonkeris aul has not changed; a decrease is observed in Ayagoz river. The river runoff in these basins is almost stable; there is a noticeable decrease on average in Ayagoz river for the entire period of observations of precipitation by 50 mm with an air temperature increase of almost 1,5^{0}C; there is a flat area here and the feeding is mainly with snow and rain. The water content remains unchanged in Tentek river also, but the amount of precipitation is more stable than in Ayagoz river with increasing temperature, as Tentek river originates on the northern slope of Zhetysu Alatau at an altitude of 4000 m, where glacial feeding dominates.



Ulken Almaty river –2 km above Ulken Almaty lake

Sharyn river – Sarytogai tract

Figure 1 – Comparison of variability of water runoff (a), atmospheric precipitation (b) and air temperature (c) on the territory of the Ile-Balkash basin

IARD is sensitive to changes in both precipitation and air temperature. At that, important is not only to the magnitude of these changes, but also seasons (months) of their manifestations. A decisive role can be played by both precipitation and air temperature.

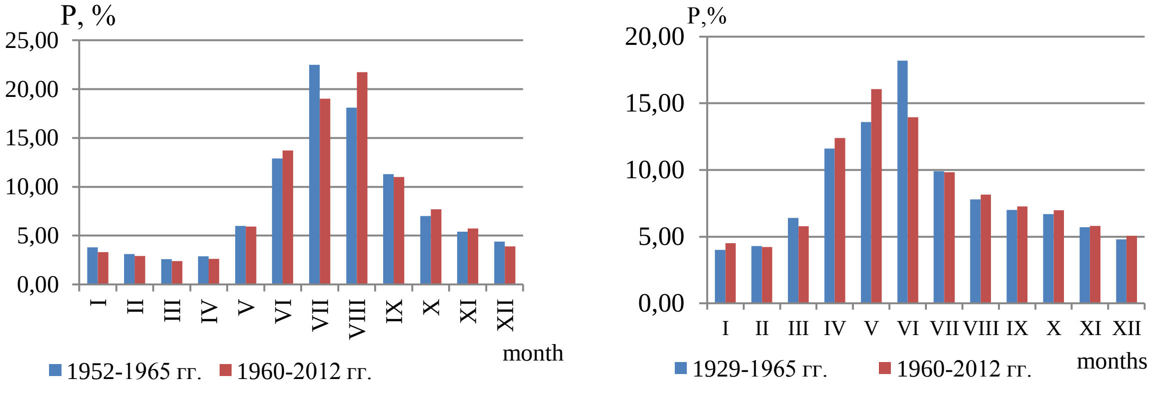
Spring flood is the main phase of the hydrological regime of rivers, which accounts for a major amount of annual runoff and, as a rule, the maximum water discharges. Runoff variations during the flood are determined mainly by snowmelt. The main elements of the spring floods are start and end dates of floods, its duration, maximum (fixed-term and daily average) discharge and the level and date of onset, duration of rise and fall, the volume and depth of runoff [2].

The maximum discharges of water in the rivers of the Balkash lake basin are formed by the melting of snow and glaciers. However, floods are superimposed by flood rains in some areas (the rivers of the middle mountains of the Ile (Zailiyskiy), Zhetysu Alatau and Tarbagatay ridge, the maximum discharges in which in some years are several times higher than the formation by melt water [3].

The maximum discharges of snow-glacial origin for the rivers from the northern slopes of the Ile (Zailiyskiy) Alatau are observed in the rivers of the alpine zone with the average altitudes of catchment areas of over 3200 m. The cases of mixed floods on these rivers are very rare. Share of sub-soil seasonally snow and rain components in the annual runoff with the increase in the average height of the catchment areas reduces [3, 4].

The Ulken Almaty river basin is located in the mountainous, plain and foothill areas. The mountain area (46% of the basin's territory) is runoff-forming; it consists of cliffs, glaciers and eternal snows. The glacial character of feeding defines the inter-annual runoff distribution. The share of high-water period (May-September) is about 70% of annual runoff.

Let us consider in more detail the change in the IARD of the two periods of 1952-1965 and 1960-2012: there is an alteration of the month of the onset of the peak of flood from July to August in the modern period, while the month of the beginning of flood remains as May, and the end of the flood is observed in September; there is a noticeable increase in the volumes of runoff in June by 6%, in August – by 20%, and a decrease in July by 15% over the modern period of 1960-2012. A decrease in runoff by 5-15% can be observed for the modern period (1960-2012) from December to April (Figure 2 a).



a b

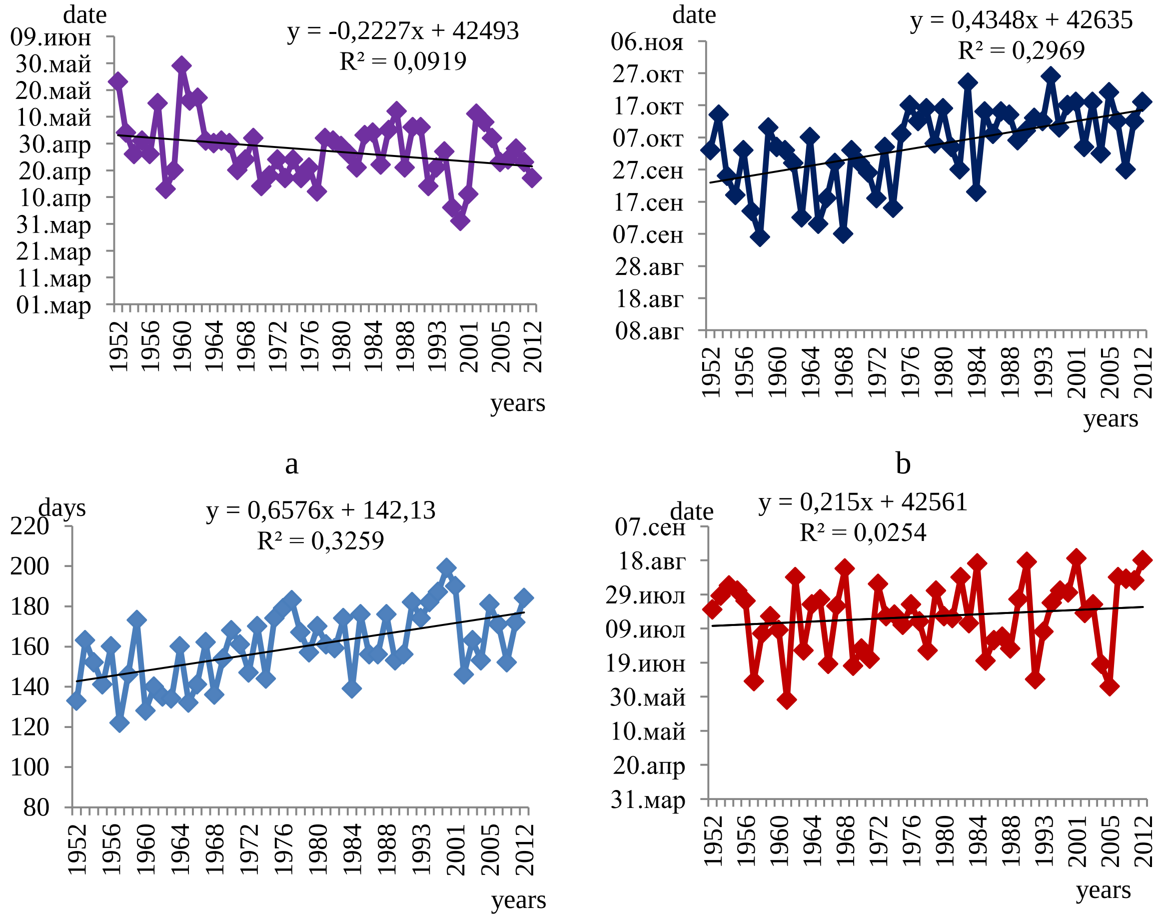
Figure 2 – Intra-annual runoff distribution at Ulken Almaty river - 2 km above Ulken Almaty lake (a) and Sharyn river – Sarytogai tract (b)

The rivers of the basins of Tekes and Sharyn are characterized by lower runoff of the limiting period accounting for 27% of annual runoff (Sharyn river - Sarytogai tract). The sources of Sharyn river are located above the snow line, on the southern slope of the ridge

Ketmen [3, 4]. The river is abounding in water with pronounced spring and summer floods (March-September), when more than 70% of the total annual runoff is discharged. The main discharges fall to the period of maximum rainfall, that is May - June. The distinguishing feature of the river regime is the uniform distribution of the runoff inside the cold period.

Comparison of the data for the period of 1929-1965 with our data for the period of 1960-2012 showed that for the period of 1960-2012 there was a significant increase in runoff in April and May (7% and 18%, respectively) and a decrease in June by 23 %. There were no significant changes observed in the limiting seasons in autumn and winter (Figure 2 b).

Figure 3 shows the graphs of the start and end dates of flood, the duration and dates of peak of flood in the river Ulken Almaty. Flood usually occurs in two phases. The first is caused by the melting of snow in the foothill zone, and the second – by the melting of glaciers and snowfields in the mountains. The graph presents the tendency of the dates of the beginning and the peak of floods towards earlier dates: the date of the beginning of floods, on average, by 2,2 days for 10 years, the dates of peaks of floods – by 2,1 days for 10 years; the end dates of floods are shown towards late dates: by 4,3 days for 10 years. Accordingly, the average duration of floods has increased by 6,5 days for 10 years (Figure 3).



a b

c d

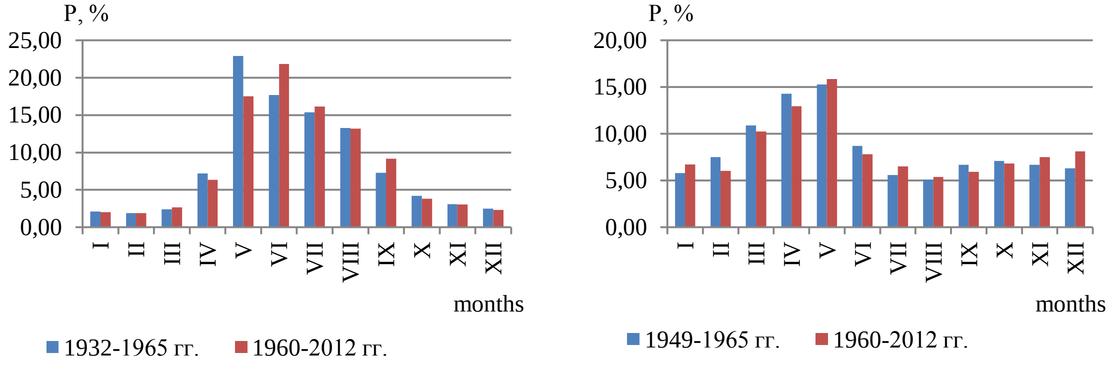
Figure 3 - Changes in characteristic parameters of floods at Ulken Almaty river - 2 km above Ulken Almaty lake a – the dates of the beginning of floods, b – the dates of the end of floods, c – the durations of floods, d – the dates of peaks of floods

A shift in terms towards the earlier dates is observed for Sharyn river in all the considered parameters of the spring flood. A significant decrease in the linear trend is observed especially in the endings dates of floods (3,4 days for 10 years). The effect of the alteration of the start and end dates of floods to the earlier periods leads to the fact that the duration of floods decreased with a statistically significant trend.

The rivers of the north-eastern part of the Zhetysu Alatau ridge, the sources of the rivers originate under the glaciers of northern slope of Zhetysu Alatau at an altitude of more than 3000 meters above sea level. The rivers of the high-mountain zone (at an altitude of more than 2800-3000 m) are characterized by the fact that meltwater of alpine snows and glaciers plays an important role in the formation of the maximum discharges. Liquid precipitation can only slightly increase them in some years [3, 4].

There are the discharges of the mixed (snow and rain) origin in the small rivers of the mid-mountain zone. The maximum discharges in the rivers of the lowland-foothill zone (at an altitude of below 1000 m) are formed by melting of seasonal snows.

Feeding of Lepsy river is mixed snow and glacial. The first phase of snow floods takes place from mid-March until the second half of April, it is caused by snowmelt. Since the second half of May to mid-June, there is a new, higher phase caused by the melting of snow reserves of the mountainous part of the basin. The share of flooding (spring-summer) in the rivers of the area is an average of about 80%, and the share of the limiting winter season is about 20% of the runoff (Lepsy river – Lepsy aul). Further, the changes in the IARD for 1960-2012 are analyzed in comparison with the period of 1935-1965. During the period of 1960-2012, there was a substantial decrease of runoff in April, May (12% and 23%, respectively) and in October (9%) compared to the period of 1932-1965 (Figure 4 a).



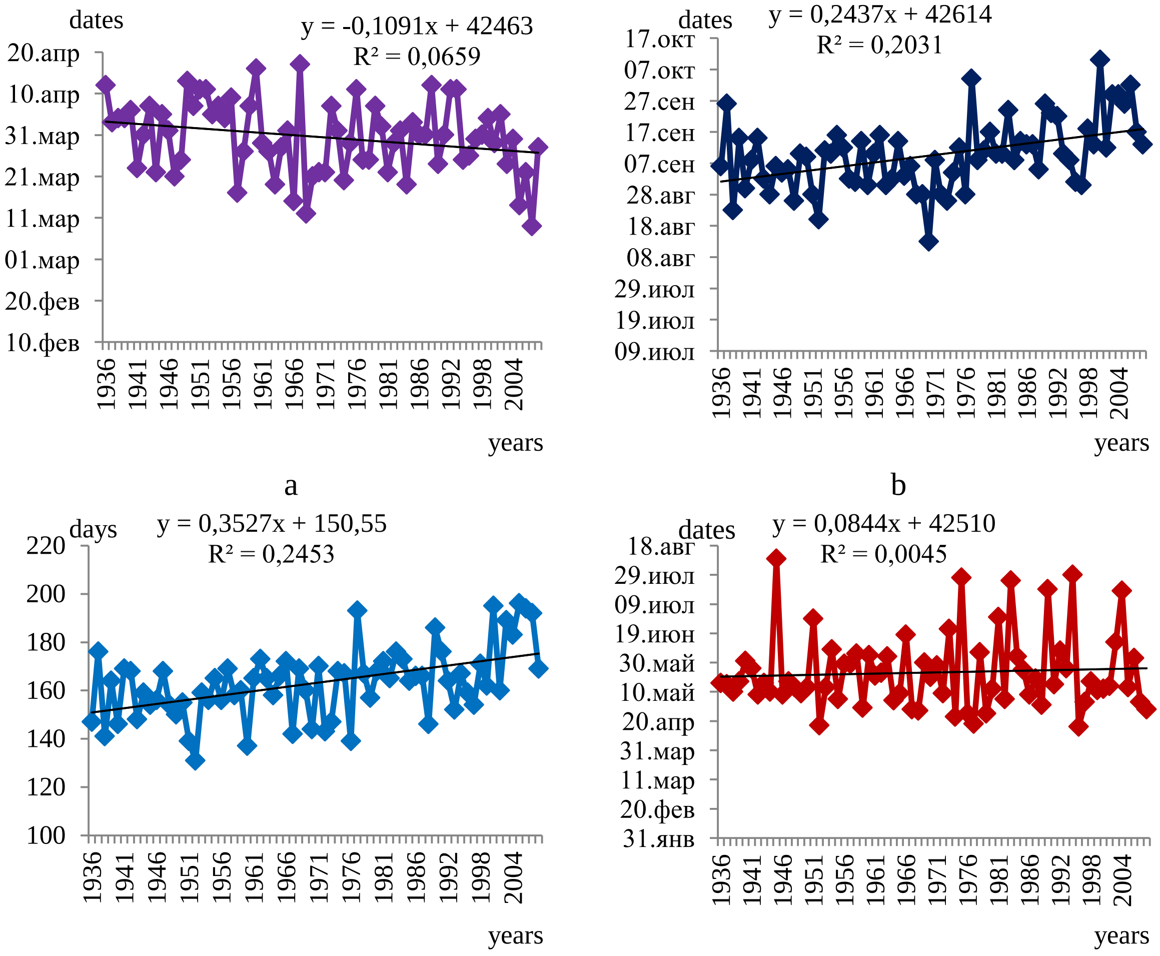
a b

Figure 4 – Intra-annual runoff distribution of Lepsy river – Lepsy aul (a) and Byzhy river – Krasnogorovka village (b)

A significant increase was observed in June, September and March (23%, 26%, 11%), as well as a slight increase in July. During the modern period, the highest monthly runoff for this area is observed in June, which happens a month later than in 1932-1965.

The IARD of the Byzhy river - Krasnogorovka village with a height of water intake of 1490 meters is significantly different from the variation of the IARD of other rivers of the area. The period of flood takes place in spring (March-May) and is about 40% of the annual runoff, further there is a decrease in runoff in the summer months (June-August) and is 20 %. There is a slightly increased runoff (40%) from October to January compared to the previous months (August-September). The increased autumn and winter runoff is caused by the variation of precipitation that falls in large quantities in the same months. Significant differences in all seasons were found when comparing the values of the IARD obtained in this study with the previously made calculations (1949-1965) [3]. Thus, the decrease ranges from 6 to 19% from February to April in the period of 1960-2012, and in the winter limiting season - in December and January – there is an increase from 12 to 30% (Figure 4 b).

Floods in the rivers of the north-eastern part of the Zhetysu Alatau ridge begins in early April and ends in mid-September. Figure 3.6 shows the graphs of the beginning and ending dates of floods, the duration and dates of peak of flood in Lepsy river – Lepsy aul. The tendency of the date of the beginning towards earlier dates: the date of the beginning of floods, on average, by 1,1 days for 10 years, and the ending dates of floods towards later dates: by 2,4 days for 10 years. Accordingly, the average duration of floods has increased by 3,5 days for 10 years (Figure 5).



a b

c d

Figure 5– Changes in characteristic parameters of floods of Lepsy river – Lepsy aul.
a – the dates of the beginning of floods, b – the ending dates of floods, c – the duration of floods, d – the dates of the peaks of floods

The alteration of the terms towards earlier dates is observed for the station of Byzhy river – Krasnogorovka village in all the considered parameters of the spring flood. A significant change of the linear trend is observed especially in the endings dates of flood towards earlier dates, on average, by 6,8 days for 10 years.

The periods of the beginning and end of floods have a conventional meaning, as defining the beginning of floods is quite a complicated issue. With some degree of conditionality we can talk about the fact that there is a statistically significant trend of alteration of the date of the beginning of flood towards an earlier date at the present time at the considered stations. The dates of the alterations of the beginning, the end, the peak of spring floods have a close connection with the change of the air temperature in the year, and this indicator was considered as a conditionally objective characteristic of flood. The issue of climate change began to be increasingly discussed since the early 70-ies of the XX century in the world's scientific literature. According to data of numerous scientific researches, a significant change of air temperature began to occur exactly in the last 100 years (1901-2000), the global surface air temperature of the northern hemisphere increased by 0,6 ± 0,2 °C. And according to recent data of the IPCC, the air temperature around the globe has increased by 0,7 °C over the past 100 years. Since 1970, the rate of change is about three times higher than those in the past 100 years as a whole [5, 6]. Therefore, the coefficients of the linear trend over the two periods of before and after 1970 were calculated to assess the tendencies of the change in intra-annual air temperature: in the period from the beginning of the observations to 1969 and 1970 - 2011. The data of these calculations are shown in Table 1.

Table 1 - The value of the linear trend for the average annual and monthly air temperatures (˚C for 10 years) over the territory of the Ile-Balkash WMB in the period of 1932-1969 and 1970-2011

Period, years	Months												
	1	2	3	4	5	6	7	8	9	10	11	12	year
WS Ulken Almaty lake													
1932-1969	0,73	-0,09	0,51	0,01	-0,15	0,05	0,07	0,21	0,19	-0,38	0,27	0,78	0,23
1970-2011	0,13	0,71	0,84	0,03	0,22	0,23	-0,02	0,20	0,23	0,19	0,33	0,13	0,29
WS Kyrgyzsai													
1936-1969	0,14	-0,10	0,58	-0,11	-0,28	-0,05	-0,45	-0,35	-0,17	-0,55	0,39	0,44	-0,04
1970-2011	0,09	0,67	0,71	0,08	0,13	0,27	-0,07	0,11	0,25	0,23	0,28	-0,08	0,22
WS Lepsy													
1933-1969	0,54	-0,27	1,10	-0,01	-0,13	-0,21	-0,11	-0,26	0,12	-0,27	0,66	0,73	0,16
1970-2011	0,25	1,08	0,71	0,10	0,13	0,26	0,16	0,17	0,16	0,30	0,66	0,28	0,36

Modern changes in the average annual air temperature at weather stations in the territory of the Ile-Balkash WMB (Ulken Almaty lake, Kyrgyzsai, Lepsy) are higher compared to the period before 1969 and is approximately 0,2-0,4˚C for 10 years. Changes in average temperature by months are non-uniform and are most pronounced in February and March for the period of 1970-2011. The maximum temperature rises at the weather stations of Ulken Almaty lake and Kyrgyzsai for the period of 1970-2011 are observed in March and are 0,84 and 0,71 ºC /10 years, respectively. The intensity of warming at the WS Lepsy is maximal in February and the value of the coefficient of the linear trend is 1,08 ˚C for 10 years.

Conclusions. Depending on the nature of feeding of a river and the location of gauging stations and weather stations, there is a tendency to increase the runoff against hardly noticeable positive trend of precipitation, and air temperature has a pronounced upward trend, mainly due to mixed snow and glacial component, on flat territory. In the mountains, an increase in the water content against the decrease in the amount of precipitation is recorded, probably this is due to the fact that when the air temperature increases and the amount of precipitation decreases, the stability of water resources is maintained by increasing glacial melting, as the most important role is played by glacial component in annual runoff.

According to data obtained from the assessment of the linear trend of the date of the beginning, the end and the peak of floods, shown in Figures 3, 5 and the air temperature in Table 1, it can be concluded that the increase in air temperature in February and in March, for the period from 1970 to 2011 by +0,7...+1,08°C on average for 10 years, compared to the period before 1969, had an impact on the dates of the beginning of floods by moving them towards the earlier. The dates of the beginning of floods on the rivers under consideration started to be recorded 1,1-2,2 days earlier, on average, for 10 years. End date of flood is also a quite difficultly definable characteristic. Nevertheless, the general trend for the modern period is mainly a "lag" of the end dates of floods. But depending on the feeding of the rivers, the end dates of floods may occur at different times. On the rivers of Ulken Almaty and Lepsy, where the most significant role is played by glacial component in the annual runoff, the end date of flood is observed 4,3-2,4 days later for 10 years and, accordingly, the average duration of flood has increased with a significant trend (6,4 days for 10 years); and for the station of Sharyn river – Sarytogai tract and Byzhy river - Krasnogorovka village, where an important role is played by snow feeding, the end of flood has shifted to earlier dates.

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PERSISTENT ORGANIC POLLUTANTS IN THE WATER OF TRANSBOUNDARY BASINS OF KAZAKHSTAN

Представлены результаты исследования уровня аккумулирования стойких органических загрязнителей, а именно наиболее токсичных полихлорированных бифенилов (ПХБ) в водных ресурсах трансграничных бассейнов Казахстана. Установлена загрязненность ПХБ воды нижнего течения рек Жайык, Сырдарья, а также водоемов и водотоков Иле-Балкашского бассейна. В водных ресурсах этих бассейнов регистрируются строго контролируемые «маркерные» и высоко токсичные диоксиноподобные конгенеры ПХБ. Обозначены основные источники загрязнения ПХБ водных ресурсов изученных бассейнов.

Жұмыста Қазақстанның трансшекаралық алаптарының су ресурстарындағы тұрақты органикалық ластағыштар, соныңішіндееңулы полихлорлыбифенилдердің (ПХБ) жинақталудеңгейін зерттеу нәтижелерікөрсетілген. Жайық, Сырдария өзендерінің төменгіағысы, сонымеңқатар Іле-Балқаш алабының су ағындары мен су айдындарысуларының ПХБ-мен ластанғанынанықталды. Осы алаптардың су ресурстарында қатаңбақылаудағы «маркерлік» және улылығы жоғары ПХБ диоксинтәрізді конгенерлер тіркелген. Зерттеліп отырғаналаптардың су ресурстарын ластау шынегізгі көздер көрсетілген.

Results of studying the level of accumulation of persistent organic pollutants, namely polychlorinated biphenyls (PCBs) in water resources of the transboundary water basins of Kazakhstan are represented. Water pollution by PCBs found downstream of Zhayik and Sirdarya rivers and water bodies of Ili-Balkhash basin also. In water of these water basins strictly controlled “marker” and highly toxic dioxin like PCBs congeners are registered. The main sources of water resources contamination by PCBs are designated.

Introduction. In the recent 30-40 years, an increased attention was paid to the control of the spread and the study of the group of persistent organic pollutants (POPs), which impact on the environment at a very low level of concentration.

Persistent organic pollutants (POPs) are industrially produced chemicals. They are also formed as by-products of anthropogenic activities. The international community recognizes POPs as substances, which pose a great danger to human health and the environment.

In order to take human health and the environment protection measures, a global international agreement - the Stockholm Convention on POPs, was adopted in 2001. It entered into force in 2004, the Convention has been ratified by 170 countries by the present time; Kazakhstan ratified in 2007.

Currently, UNEP (United Nations Environmental Project) highlights a group of 12 compounds and groups of compounds, to which priority attention should be paid in ecological studies. This so-called "dirty dozen" includes the following substances: polychlorinated biphenyls (PCBs), polychlorinated dibenso-p-dioxins (PCDDs), polychlorinated dibenzofurans (PCDF), aldrin, dieldrin, dichloro-diphenyl-trichloroethane (DDT), endrin, chlordane, hexachlorobenzene (HCB), mirex, toxaphene and heptachlor.

One of the most toxic and globally widespread representatives of POPs are polychlorinated biphenyls (PCBs). The sources of PCBs entering the environment are leaks from transformers, condensers, heat exchangers, evaporation from different technical systems, where they were used as dielectrics, hydraulic fluids, liquid industrial waste.

PCBs are currently globally spread. This is contributed by their high stability (they are the most stable chemical compounds), hydrophobicity (they are slightly washed out by precipitation), resistance to biodegradation, bioaccumulation potential and a considerable amount of applications. These chemical compounds are the objects of transboundary transport through air, water and migratory species, and are deposited far from the source of their emitting, accumulating in terrestrial ecosystems and ecosystems of water bodies for a long time.

In relation to PCB, the Stockholm Convention sets three main objectives:

- immediate termination of PCB production;
- decommissioning of equipment containing PCBs by 2025;
- the soonest, no later than 2028, destruction of PCB wastes.

Danger of PCBs is explained by their high persistence, the ability to penetrate through the skin and mucous membranes, digestive system bodies with food and, accumulating, lead to chronic poisoning. In contrast to the poisons that affect specific organs, PCBs damage the system of internal regulation, violate normal biological functions. They are risk factors for the development of malignant tumors, reproductive disorders, endocrine and immune status of people and therefore are called endocrine disrupters. It was calculated that PCBs, which entered into the peoples' bodies, may be withdrawn only after 7-8 years. Children are particularly exposed to these toxicants, due to their underdeveloped immune system.

According to the World Health Organization, content of PCBs in clean water must not exceed 0,5 ng/l. In the United States, the adopted standard for fishery water bodies is 0,079 ng/l. In Russia, the MPC values for PCBs are as follows: water (water bodies of the economic and cultural-domestic water use) - 1 mkg/l, the soil - 0,1 mg/kg, fish - 5 mg/kg, drinking water - 1mkg/l, and their presence in the water of fishery reservoirs is not permitted [1,2].

According to the results of the preliminary inventory, there are eight "hotspot" areas contaminated by PCBs in the country. The main contaminated area is the territory of Ust-Kamenogorsk city, where the wastes of the Condenser Plant were buried in the storage pond. Other PCB-contaminated areas are the territories of the Zhangiz-Toby and Derzhavin polygons of destruction of military equipment, Saryshagan landfill, the areas of northern and western coasts of Balkash lake, the territories of the Yekibastuz and Kostanai substations, as well as the substations at the mine named after Kostenko in Karaganda. The total area of contamination is 2500 hectares [3,4].

There are PCB-containing equipment in the amount of 116 transformers and about 50000 capacitors on the territory of the country. The volume of the contained in them PCBs is roughly estimated at 800 tons. This equipment is a potential danger in the event of depressurization [5].

In 2013, there was an inventory of PCBs and PCB-containing equipment [6]. Totally, the inventory covered about 127 large enterprises of Kazakhstan. It enabled to identify ~2725 transformers and ~ 1775 capacitors with PCBs in Kazakhstan. According to some data, only the transformers contain PCBs of about 256 tons.

PCBs are studied extremely insufficiently in the natural objects and ecosystem of water bodies in Kazakhstan. Observation of these xenobiotics is not conducted by also the network of Kazhydromet and other agencies of nature protection. And the "Concept of Environmental Safety of Kazakhstan for 2004-2015" states about the absence of objective assessment of pollution of the environment with POPs in Kazakhstan.

There is some information available on the levels of accumulation of PCBs in natural objects of Ust-Kamenogorsk district. The content of PCBs in soils of the city reached 643,2 mg/kg, discharge water - from 12 to 46 mg/dm^3, in the water of Irtysh river and fish pond - 44 and 0,015 mkg/dm^3, respectively. In snow – up to 3,24 mkg/dm^3, and in the muscles of pond fish – from 0,009 to 0,093 mg/kg. According to the results of research in 2013, PCBs are identified in all the analyzed samples. The content of trichlorobiphenyls (TCB) was 18,06 and 28,66 mg/dm^3, respectively, in the water of Irtysh river and the pond of the Condenser Plant. The concentration of PCBs in aquatic plants from Irtysh river varied in the range of 0,008-

8,89 mg/kg, and in fish fauna (umber) – from 0,010 to 22,00 mg/kg. In soils of the territory adjacent to the plant, PCBs were recorded at up to 460,57 mg/kg [7].

These data characterize the toxicological state of one of the eight "hot spots" – the areas contaminated with PCBs. And what is the toxic atmosphere on other "spots"? Unfortunately it is not known, there is no information on the pages of the available scientific journals. Obviously, there is no control and monitoring by public authorities on protection of the natural environment, though in the region of these highly hazardous to human health pollutants, there are many settlements and food products are manufactured.

Some data on the level of concentration of PCBs in the water and fishes of some ponds in Kazakhstan were obtained by us in the 90-ies of the last century. In the water of the Bukhtarma reservoir in 1994, their average concentration was 0,609 mg/dm^3 in the mountainous part, in the lake – 0,478 mkg/dm^3 [8], in the water of the Shardara reservoir - up to 8,0 mkg/dm^3 [9], the Kapshagai reservoir - up to 11 mkg/dm^3 [10], they were found at concentrations of up to 2,0 mkg/dm^3 in the water of the Small Aral in 2000, there were up to 7-9 mkg/dm^3 of them in 1992 [11] . The accumulation of PCBs was recorded in the organs and tissues of commercial fishes in a number of water bodies of the country.

Materials and methodology of research. Further, this report describes the results of studies conducted in recent years to assess the level of accumulation of PCBs in the water of a number of water bodies located in the system of transboundary basins of Kazakhstan. Samples in transboundary Zhaiyk (Ural) river were taken in 2012, at the 5 points of the lower reaches of the total length of about 50 km. Water bodies of the downstream of Syrdariya river were investigated in 2013.

In 2013-2015, more detailed research on the level of accumulation and spread of polychlorinated biphenyls in the water bodies and watercourses of the Ile-Balkash basin were carried out (Figure 1).

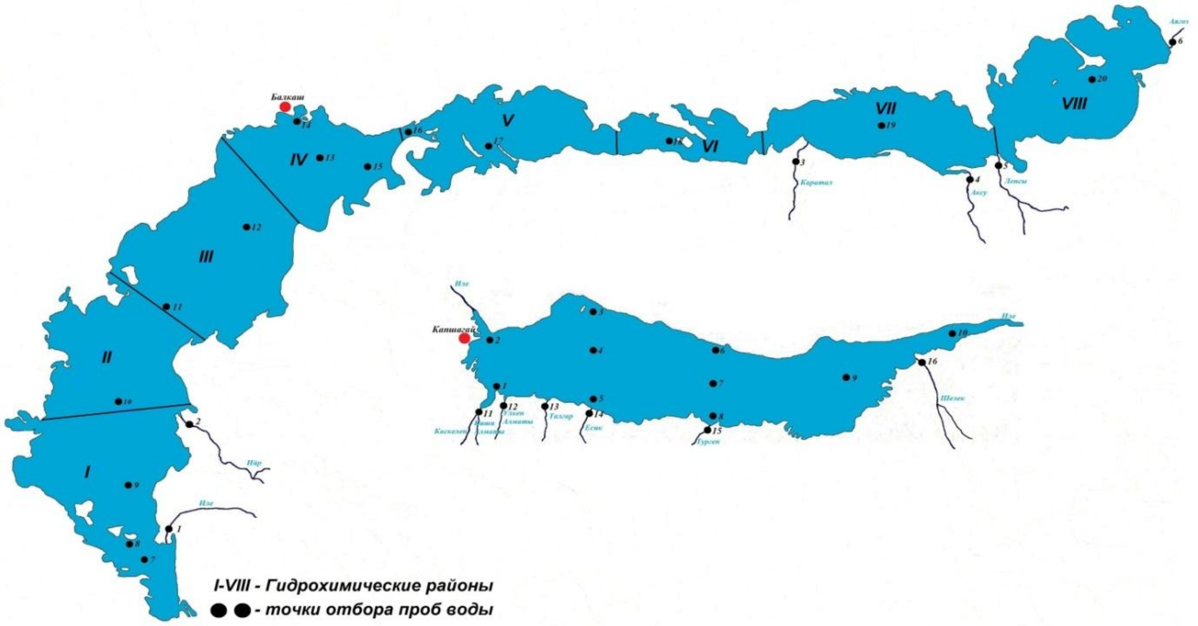

Figure 1 – Schematic maps of Balkash lake and Kapshagai reservoir with water sampling points on the water areas and in flowing rivers

Determination of PCBs in water was conducted according to MI 1792-77 on gas chromatograph "Chromos GC-1000" with software using an electron capture detector.

The discussion of the results.

The following results were obtained on Zhaiyk river. Above Atyrau city (Bugorki village), the concentration of PCBs in the water was 0,93 mg/dm^3, and at the closing station - at the beginning of the Zhaiyk-Caspian channel (ZhCC), it increased to 1,29 mkg/dm^3. A similar pattern in the spread of PCBs along the river flow was recorded also in 2005 (Figure 2).

Such an increase in the number of the toxicant downstream the river is obviously due to the influence of the waste in the form of wastewater and atmospheric emissions of the industrial enterprises located in Atyrau city. Relatively less contaminated is the water in the Pravyy Yaik arm of the delta, through which passes a small part of the river runoff and its shores are less populated. Increase in the level of PCBs in river water in 2012 than in 2005 is clearly observed, namely: it is considerably higher within the city of Atyrau, two times higher near Damba village and significantly increased in the ZhCC.

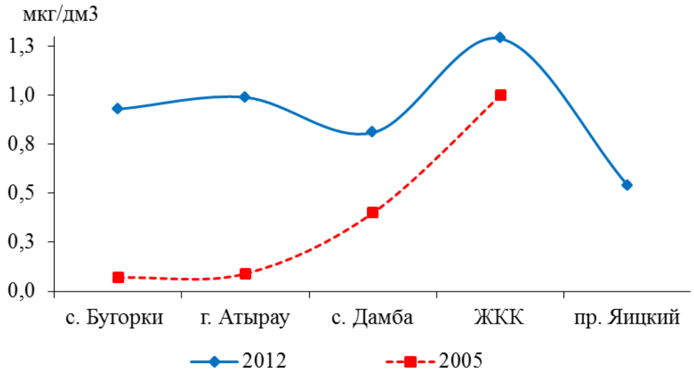

Figure 2 - Changes in concentrations of PCBs downstream Zhaiyk river

Removal of PCBs by river runoff determines the character of the distribution of these toxicants in the water of the pre-mouth sea area. Their greatest content (1,0 mkg/dm^3) was recorded in the square №24, to where river water primarily comes through the ZhCC. As you move away from it, the concentration of PCBs is gradually reduced.

The main cause of pollution of Zhaiyk river with PCBs is, of course, the entering into the river system of wastes of numerous industrial enterprises located mainly in Russia, where vast sources of pollution of the environment are concentrated. According to the inventory [12], in the South-Ural region, adjacent to the river basin, there are 74,5 thousand large PCB-containing equipment (transformers and capacitors). The total amount of PCBs in Orenburg, Chelyabinsk, Sverdlovsk regions and in Bashkortostan is 3354 tons. If we add to this huge contaminated with PCBs areas, especially within the major sources of pollution, it becomes clear about the level of load of PCB-containing waste water and air emissions at the top of Zhaiyk river basin. We do not exclude the possibility of pollution of the river and its tributaries within the cities of Uralsk, Atyrau, as well as Aktobe and Alga (tributary of Yelek river). However, it is difficult to say anything definitely because of the complete lack of information on the content of PCBs both in the transboundary runoff of the river, and in the waters within the Republic of Kazakhstan.

In 2013, the PCB concentration was 0,082 mkg/dm^3 in the water of Syrdariya river, and the level of pollutant accumulation was significantly higher (4,70 and 12,0 mkg/dm^3, respectively) in more flowing lakes of Laikol and Makpal than in the river water. This suggests that the main source of the entering of PCBs to these reservoirs is Syrdariya river (Table 1).

Table 1 – Contents of PCBs in water bodies of downstream of Syrdariya river

Sampling sites	Congeners	PCB, mkg/dm^3
Syrdariya river	52	0,082
Laikol lake	41, 64, 71	4,70
Kamystybas lake	not found	
Makpal lake	44	12,0
Karashalan lake	52	0,124
Tushchy lake	52 40	0,055 2,13 }2,18
Small Aral Sea	not found	
Kokaral dam, d/reach	41, 64, 71 44	0,008 23,11 }23,12

Below the Kokaral dam, currently, there is formed a water body that is connected to the northern border of the Big Aral Sea. This water body does not have connection to Syrdariya river. At the same time, high enough accumulation of PCBs of 23,12 mkg/dm^3 was registered in its water. It is difficult to call the direct sources of pollution of these water areas the studied pollutants. One can only assume about the impact of the so-called "historical" sources, what were military objects that operated for many years in the Soviet Union on "Vozrozhdeniye" island and elsewhere in the region. 6 individual congeners (PCB 40,41,44,52,64,71), which together relate to tetrachlorobiphenyls, were identified in the studied water samples. Higher concentrations are characteristic of "light" congeners: PCB 40 were present in an amount of 2,13 mkg/dm^3, PCB 44-12,0 and 23,1 mkg/dm^3. From the "marker" congeners in samples from two sites, PCB 52 in concentrations of 0,055 mkg/dm^3 and 0,082 mkg/dm^3 were registered. A more diverse composition of congeners is registered in the water of the lower reach of Kokaral dam and drainage lakes.

An important role in the spread of PCBs in the region, apparently, belongs to atmospheric removal of pollutants from the land surface and the dried seabed. It is appropriate to refer to the results of our research in 1992, when the amount of PCBs in the water of the Big Aral Sea reached 26,0 mkg/dm^3. In addition, higher levels of accumulation of PCB were found in flounder specimens caught near "Vozrozhdeniye" island - up to 180 mkg/kg in the muscles, up to 190 mkg/kg - in the liver [11].

Comparison of the results obtained in 2013 with the above data of the earlier conducted research indicates a growing level of concentration of PCBs in the water bodies of the lower reaches of Syrdariya river waters now. All this gives grounds to assume the negative impact on natural objects, including water resources of the region, of the sources of pollution with PCBs of transboundary or regional character.

The scientific results on the contamination of water reservoirs and watercourses of the Ile Balkash basin with PCBs were also obtained for the first time. In the waters of the rivers flowing into Balkash lake, the concentration of PCBs in 2013 ranged from 0,094 to 0,129 mkg/dm^3, on average, 0,109 mkg/dm^3, in 2014 - from 0,011 to 0,096 mkg/dm^3, on average, 0,069 mkg/dm^3, and in 2015 their average content was 0,252 mkg/dm^3, which is 2,3 and 3,6 times higher than in 2013 and 2014, respectively. The increased concentrations were recorded in the waters of Ile and Karatal rivers flowing through the industrial cities and large settlements.

As seen in Figure 3, the PCB 114 congener, which is one of the most hazardous dioxin-like congeners, is registered in the waters of Ile, Karatal and Ayagoz rivers [12].

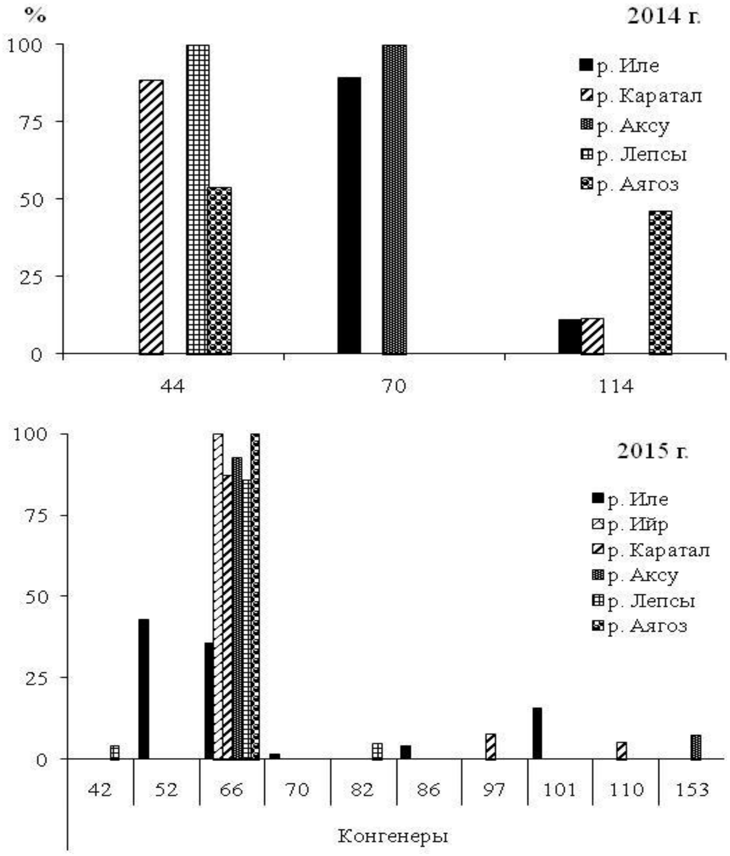

Figure 3 - The relative content of PCB congeners in the water of rivers, flowing into Balkash lake

The relative concentration of this congener in the waters of Ile and Karatal rivers reaches 10%, and in the water of Ayagoz river – 47 %. These data indicate the presence of pollution sources of the listed rivers with highly toxic PCB congeners.

In 2015, 10 individual PCB congeners were found in the river waters. Their greater number with a total concentration of 0,456 mkg/dm^3 was found in the water of Ile river. Among them, there were two strictly controlled in the environment "marker" PCB 52 and PCB 101 congeners, their share in total content of congeners was 43 and 16%, respectively. Among the rivers flowing into the East Balkash in 2015, the "marker" PCB 153 congener in the amount of 0,016 mkg/dm^3 (7,4%) was detected in the water of Aksu river.

In the water of Balkash lake, same as in the rivers flowing into it, the accumulation of PCBs was found. Their concentrations in the lake are undergoing considerable spatial and temporal changes. A higher level of contamination of water resources with PCB is registered in 2015. They were found in water of all the sampling points located throughout the lake area.

The following comparison of the average concentration of PCBs in water (mkg/dm^3) during the years of research shows that the growth of this indicator in 2015 was by 7,7 times for Western Balkash, 2,1 times – for Eastern Balkash compared to the data for 2013 and 2014:

	2013	2014	2015
Western Balkash	0,084	0,073	0,619
Eastern Balkash	0,091	0,093	0,194

In 2015, the congener composition of PCBs was wide enough in lake water; totally it was presented by 16 isomers (Figure 4). Dioxin-like PCB 114 and PCB 118 congeners were recorded in the water of the western water area of the lake; the relative concentration of the first reached 47% in 2014. "Marker" PCB 101, PCB 52 and PCB 153 congeners were recorded in the water in the area of Balkash city. In the water of the eastern part of the lake, the "marker" PCB 52 congener is more spread, the relative share of it amounted to 97% of the amount of congeners identified.

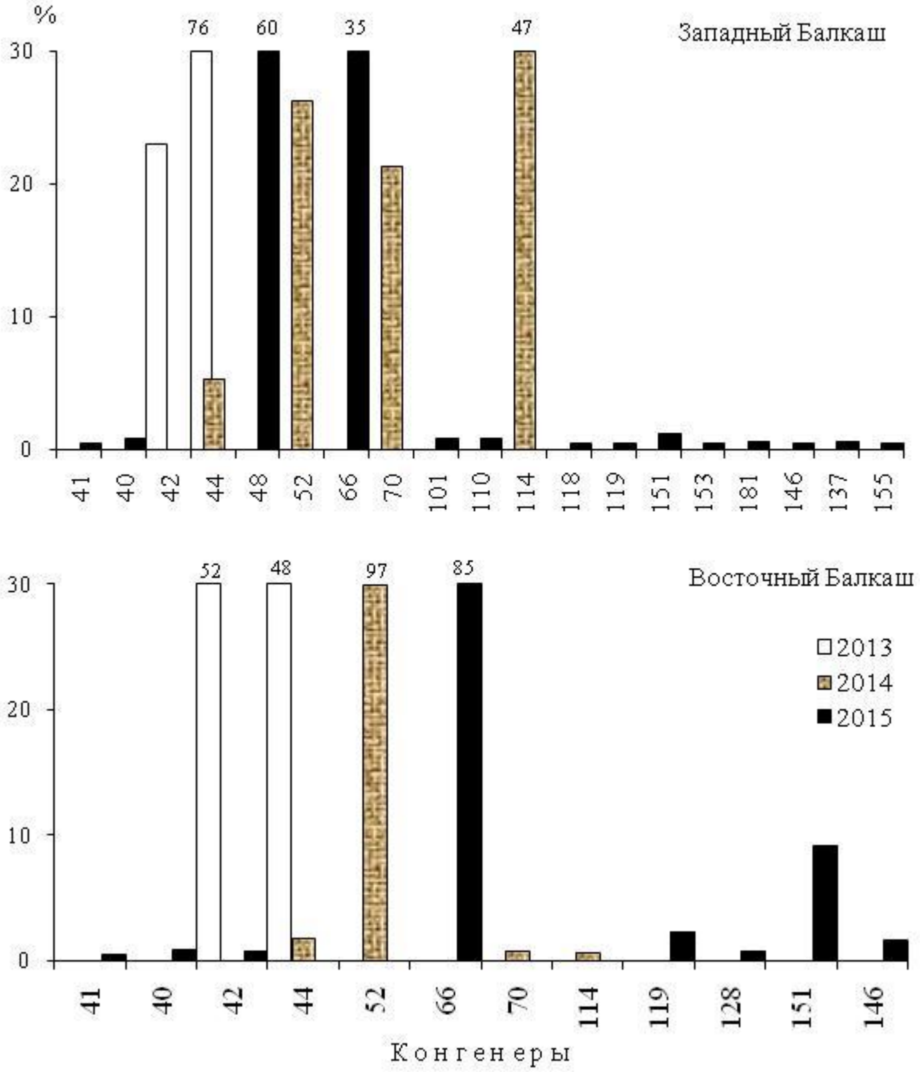

Figure 4 - The relative content of PCB congeners in the water of Balkash lake

All the small rivers that flow into the Kapshagai reservoir originate in the mountains of Trans-Ili Alatau, and flowing through the cities of Almaty, Yesik and Talgar, are polluted by many toxic compounds, including PCBs. The findings suggest about a substantial increase in the level of contamination of river water with PCBs in 2015, compared to the previous. There is not only a significant increase of their content in the water of a number of rivers, but also susceptibility of water resources of all watercourses to contamination by these pollutants. The increased concentrations of PCBs (up to 0,143 mkg/dm^3) were found in 2014 in the water of Ile river, i.e. in the transboundary runoff, and in 2015 - in the waters of the rivers Yesik, Talgar and Kishi Almaty (up to 0,168 mkg/dm^3).

The congener composition of PCBs in river waters is wide enough, there were found 9 individual congeners related to homology groups from tetrachlorobiphenyls (PCB 44, 66) to heptachlorobiphenyls (PCB 171). Among registered isomers, there were PCB 153, 52 and 138 "marker" congeners, as well as the highly toxic dioxin-like PCB 118 - in the water of Kishi Almaty river.

The waters of Kishi Almaty and Talgar rivers are characterized by relatively wide variety of congeners. This is a sign that sources of different origin are involved in the contamination of the watercourse with these toxic compounds. These may be contaminations with a commercial mixture of PCBs, atmospheric transport or it may be of pyrogenic origin caused by processes of combustion of industrial and municipal waste.

Materials on the contamination of the water resources of the Kapshagai reservoir with PCBs were also obtained for the first time (Table 2).

Table 2 - Content of PCBs and their congeners in the water of the Kapshagai reservoir in 2013-2015.

Indicators	Stations									
	1	2	3	4	5	6	7	8	9	10
2013										
Congeners	40;52;87; 118	42	44	not found	118	44	87	40	not found	52
Total PCBs, mkg/dm^3	4,86	4,40	1,02	not found	2,01	0,077	0,903	3,02	not found	0,153
2014										
Congeners	66	66	66	66	66	not found	44	not found	not found	52; 129; 138
Total PCBs, mkg/dm^3	7,80	3,76	1,24	0,96	2,10	not found	0,110	not found	not found	0,143
2015										
Congeners	41;52;66; 74;85;101; 110;119; 155	66;86; 129	44;66;151	66;151;171	41;52; 66;105; 128;151; 153;171	40;44; 52;66; 101; 118;138	66;82;151; 171	66; 171	40;44; 87; 129; 146; 171	44
Total PCBs, mkg/dm^3	0,155	0,130	0,066	0,174	2,22	0,084	0,563	0,353	0,136	0,017

The level of concentration in the water and the spatial distribution of PCBs in the water area of the reservoir in 2013 and 2014 had generally similar character; there is a marked increase in the content of toxicant. In 2015, the presence of PCBs was recorded in the water of all the 10 monitoring stations. Their concentration in the entire water area ranged between 0,017 mkg/dm^3 in the zone of the confluence of Ile river to 2,221 mkg/dm^3. The increased PCB concentrations were observed in the water of the stations № 5, 7, 8, which are located in the zone of the distribution of a number of small rivers as Yesik, Talgar and others, flowing into the reservoir.

The analysis of the congener composition of PCBs is interesting. In 2013, 6 individual congeners were found in the water of the reservoir, in 2014 - 5, and in 2015 - 23. More diverse composition of the PCB congeners were registered in the zones of the reservoir, which are impacted by the runoff of a number of small tributaries, i.e., at stations № 1, 5, 6 and 9. 6 out of 7 adopted by the International community priority "marker" and strictly controlled congeners were recorded in the water of the reservoir (PCBs 52, 101, 105, 118, 138 and 153). Among them, the congeners PCB 105 and 118 are related to the most hazardous dioxin-like congeners [13]. They were found exactly in the water of local areas of the reservoir, which are influenced by the flowing rivers of Yesik, Kaskelen, Talgar and Shengeldy.

The character of distribution of the relative content of PCB congeners, on the example of data for the three stations, in the water of which more diverse isomeric structure is registered, is shown in Figure 5. The biggest specific weight of up to 32 and 38% falls on the share of PCB 66 congeners.

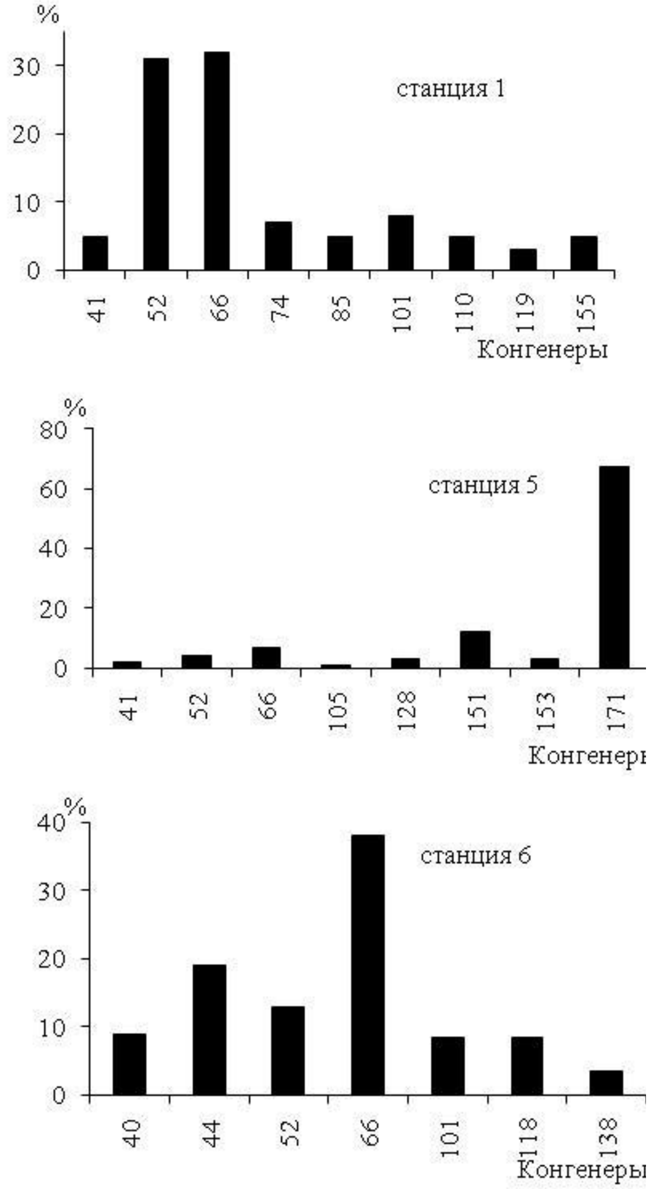

Figure 5 - The relative content of PCB congeners in the water of Kapshagai reservoir

Out of the "marker" congeners, the greater relative content is typical for PCB 52 - 31% (station 1) and 13 % (station 6), PCB 101 of 8 % at the same stations; dioxin-like PCB 118 congener was 8% in the water of station 6. Therefore, the water of the reservoir is characterized by the increased level of toxicity in the presence of various sources of pollution.

Based on the collected information, including from official sources, as well as on the basis of the own observations, there were identified the main sources of pollution of water bodies and watercourses of the Ile-Balkash basin with PCBs. The sources of contamination of the Kapshagai reservoir with PCBs are: the transboundary runoff of Ile river, the runoff of a number of small rivers flowing into it, which, in turn, are polluted, flowing through the city and large settlements.

The most powerful sources are "hot spots" contaminated with PCBs and located in the area of the west and north coasts of Balkash lake, the numerous current and former military facilities of the Russian Federation such as "Daryal-U", "Priozyorsk", "Saryshagan" landfill and other landfills to destroy military equipment (Figure 6). Aggravation of the pernicious influence of such sources on the natural environment of the region can also be expected in connection with the transfer of the "Balkash hub" to Russia and the expansion of the activity of the military bases of the Russian Federation on this vast territory. A significant source of contamination of the region’s environment with PCBs, including Balkash lake, are emissions and wastewater of metallurgical enterprises of the city of Balkash.

Marking: Red – strongly polluted area, yellow – weakly polluted area

Figure 6 - The central part of the territory of "Daryal-U" [14].

The sources of contamination of the rivers Karatal, Ayagoz and others, flowing into the East Balkash, with PCB may be air emissions and waste water of such large industrial cities as Taldykorgan, Tekeli and a number of large settlements.

High contamination of natural objects (soil, bottom lake sediments and pet foods) in the area of the city of Balkash with PCB was recorded in 2013 by the research of the group of experts from the Czech Republic (NGO "Arnika", Prague city). They also noted the presence of several sources of pollution of different origin in the region, including the metallurgical industry, the open combustion of waste and other sources.

Conclusion. The occasional research carried out by us in the nineties of the last century has shown contamination of the aquatic ecosystems of a number of water bodies in Kazakhstan with persistent organic compounds, including PCB.

The results of research in recent years have shown contamination of water resources of Zhaiyk river with these toxicants, and its level increased with the river flow under the influence of the industrial enterprises of Atyrau city. Removal of PCBs by the river runoff determines the presence of these xenobiotics in the water of the pre-estuary area of the Caspian Sea. The main sources of pollution of the river Zhaiyk with PCBs are in the territory of the Russian Federation.

The lake systems of the downstream of Syrdarya river are polluted by the transboundary runoff of the river, PCBs content in the water of flowing lakes reached high values – 4,7 and 12,0 mkg/dm^3. In the large for its area water body formed below the Kokaral dam, the PCB concentration reached 23,1 mkg/dm^3, which is explained by the influence of the "historical" sources - military facilities, which operated on “Vozrozhdeniye” island.

PCBs are studied extremely insufficiently in the natural objects and ecosystems of the water bodies of Kazakhstan. Observation of these xenobiotics is not conducted also by the Kazhydromet network and other agencies of nature protection.

A significant increase in the level of contamination of water resources of the rivers flowing into the Kapshagai reservoir and Balkash lake with PCB was recorded in 2015 compared with previous years. Moreover, the exposure to contamination of the water of all the studied watercourses with these xenobiotics has increased. The "marker" PCB 52, 101, 138 congeners were registered in the river waters, and also highly toxic dioxin-like PCB 114 and 118 congeners were found in the waters of the rivers Kishi Almaty, Ile, Karatal and Ayagoz.

The water throughout the water area of the Kapshagai reservoir is contaminated with PCBs. The increased level of their accumulation of up to 2,22 and 7,85 mkg/dm^3 in 2013-2015, and the presence of the "marker" (PCB 52, 101, 138, 153) and dioxin-like congeners (PCB 105 and 118) in the water were recorded in the zone of the runoff distribution of the rivers Kaskelen, Kishi Almaty, Yesik, Shengeldy and Talgar.

There is an accumulation of PCBs in the water of Balkash lake, same as the rivers flowing into it; their level in 2013-2015 had a clear growth trend and they were recorded in the water throughout the water area of the water body. In 2015, the growth of the concentration of PCBs in the water made up 7,7 times for the Western Balkash (WB), 2,1 times – for the Eastern Balkash (EB), compared to the data of 2013 and 2014. The increased level of contamination with PCBs is characteristic of the water of northwest water area of the lake due to the location of powerful sources of pollution with this xenobiotic in the territory of the Balkash lake region.

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INTRA-ANNUAL VARIATIONS OF RIVER RUNOFF IN SOUTHERN AFRICA

The analysis of six monthly river runoff time series in southern Africa by the method of "periodicities" reveals 12 and 6 month periods in dataset. The repeating successions of mean runoff values for monthly time intervals were then averaged for the periods of 12 months (intra-annual cycle) and 6 months (half-annual cycle). These successions, the revealed sinusoids with the periods of 6 and 12 months and their sum were then used for the computation of training forecasts of river runoff with the lead time of 24 months, the results of which were tested using new independent data. Overall, all of the results from the forecasts computed using schemes presented here are better than forecasts results using the mean value of the time series.

The results of the runoff forecasts through use of the repeating succession of mean monthly values over a half year cycle are somewhat better than by the 6 month sine. Forecasts computed by the 12 month period sine are better than those obtained using the repeating succession of mean monthly runoff values of the half annum cycle. The sum of the harmonics with the periods of 12 and 6 months, in turn, provided better forecast results than those computed using the 12 month sine alone. Overall, however, the best forecast results, from the methods used here, were obtained using the repeating succession of mean monthly values over an annual cycle.

The intra annual cycle of the mean monthly values of runoff has various distinctions compared to the results from the standard harmonics. In particular its peak values are narrow, and stretched, whereas the time interval of low flow values is significantly longer. In contrast, the repeating succession of mean runoff values for monthly intervals over the half annual cycle more closely resembles the results obtained using the standard sine. The values obtained using the difference of both the annual and half annual cycles also more closely resemble the standard sine over a 12 month period.

As such, the annual cycle of mean monthly values of river runoff in southern Africa is composed, in essence, of two harmonics with the periods of 12 and 6 months. Of interest in terms of further research, would be the analysis of the monthly variation of river runoff in Middle Asia and Kazakhstan. Indeed, located as they are in arid and semi-arid zones, as some of the southern African catchments analyzed here, it would be interesting to explore whether or not the half year cycle is present in these time series as well.

Анализ шести месячных серий стока воды в южной Африке по методу «периодичности» показал 12-ти и 6-ти месячные периоды в данных. Повторяющиеся сукцессии средних значений стока для месячных интервалов времени были усреднены за период 12 месяцев (внутригодовой цикл) и 6 месяцев (половина годового цикла). Эти сукцессии, выявленные синусоиды с периодами от 6 до 12 месяцев и их суммы были затем использованы для расчета подготовки прогнозов речного стока с заблаговременностью 24 месяцев, результаты которых были протестированы с использованием новых независимых данных. В целом, все результаты прогнозов, вычисленных с использованием схем представленных здесь лучше прогнозов результатов с использованием среднего значения временного ряда.

Результаты прогнозов стока посредством использования повторяющейся последовательности средних месячных значений полугодового цикла несколько лучше, чем для шестимесячного синуса. Прогнозы, рассчитываемые по 12-месячному периоду синусоиды, лучше, чем полученные с помощью повторяющейся последовательности средних месячных значений стока полугодового цикла. Сумма гармоник с периодами 12 и 6 месяцев, в свою очередь, дает лучшие результаты прогноза, чем вычисленные с использованием 12-месячного синусоида в одиночку. В целом, все результаты используемых здесь схем оказались лучше, чем полученные с использованием повторяющейся последовательности средних месячных значений в течение годового цикла.

Внутригодовой цикл средних месячных значений стока имеет различные показатели по сравнению с результатами стандартных гармоник. В частности, его пиковые значения являются узкими и растянутыми, в то время как временной интервал значений низких потоков значительно длиннее. В противоположность этому, повторяющаяся последовательность средних значений стока с месячными интервалами в течение годового цикла больше напоминает результаты, полученные с использованием стандартного синус. Значения, полученные с использованием разности обоих годовых и половины годовых циклов, более близко напоминают стандартный синус в течение 12-месячного периода.

Таким образом, годовой цикл средних месячных значений речного стока в южной части Африки состоит, по существу, из двух гармоник с периодами 12 и 6 месяцев. Представляет интерес с точки *зрения дальнейших исследований проведение анализ ежемесячного изменения речного стока в Средней Азии и Казахстане. Несомненно, так как они расположены в засушливых и полузасушливых районах, так же как и некоторые из водосборов южной Африки анализируемых в данной работе, было бы интересно выяснить, проявляется также в этих временных рядах половина летнего цикла или нет.*

Introduction. Southern Africa is composed, in large parts, of arid and semi-arid areas, a characteristic of which is regular lack of water. Indeed, water availability is significantly variable in these regions, both from year to year, inter-annually, as well as within the year, intra-annually. The periods of droughts when runoff of small rivers is almost absent combine with rainier seasons, when available water fills the beds of rivers and lakes. According to the forecast of the Intergovernmental Panel on Climate Change (IPCC), by the middle of the 21st century, dry conditions within this region may become even less favorable for local population [5].

Variation of river runoff impacts different branches of the modern economy related to water resources, including agriculture, water transport, tourism, and communal and industrial water consumption [e.g. 4]. For the social and economic development of this region, the structure of variations of its river runoff should be analyzed so as to better understood, enabling a more reliable prediction.

The analysis, using the “periodicities” method, of monthly time series of river runoff in southern Africa permitted to reveal the harmonics with the periods of 12 and 6 months. These sinusoids and their sums were applied for the training forecast computation of the runoff. The forecasts were also computed using the successions of mean runoff values consisting of monthly averages obtained using the time intervals of the revealed annual and half annual cycles. The results of the training forecasts were generalized for all time series and the method which provided the best prediction results was thus determined.

Here, it will be shown that the half annual cycle of runoff in southern Africa computed by using the mean monthly values is similar to the corresponding harmonics, while the annual cycle of mean monthly values is essentially equivalent to the combination of two harmonics – the sinusoids of the half annual cycle and that of the 12 month period.

Formulation of the problem. The aim of the research is to analyze and model six monthly southern African river runoff time series, reveal their hidden harmonics, and use the revealed periodicities for long range prediction. Presently, intra-annual variation of river runoff in southern Africa (and in other regions of the Earth) is considered as a single cycle, running over a 12 month period, and different to the sine function solely as a result of local runoff conditions.

The current research provides some material upon which the hypothesis that intra-annual runoff variation of southern African rivers is, in fact, the result of a combination of two 6 and 12 month period harmonics.

The time series were analyzed up to December 1995, while the following two years, 1996 and 1997 (24 months), were then used for the computation of training forecasts of river runoff using the different schemes, the validation of its results using new independent data, and the generalization of the results. The results of the predictions are evaluated using two main parameters, in accordance with the principles of long range river runoff forecast result evaluation.

Long range river runoff forecasts result evaluation principles. A river runoff forecast is considered to be true if the difference between the predicted and actual values is no greater than the accepted forecast mistake Δ, which is equal to 0,674 times the value of the standard deviation of runoff time series σ [1].The forecast for the given time interval is evaluated through the number of accurate monthly forecasts, as well as through the sum of squared mistakes S_f. The actual mistake of forecast δr, related with the sum of squared mistakes of prediction, may be compared with the values of the runoff time series and its standard deviation

$$\delta r = 0{,}674\sqrt{\frac{S_f}{l}} \quad (1)$$

where l is the length of the training forecast interval (24 months). However, to compare forecasts results of different time series with one another, it is better to compare the relative forecast mistakes – $\delta r/\Delta$, of each forecast. This relation, between the actual error to the acceptable error of the forecast, ranging between 0 and 1, does not have a unit of measurement.

The greater the number of true forecasts, and the lower the relative error, the better a river runoff forecast over a given time interval, will be. Overall, a successful long range river runoff forecast must be no less accurate than the forecast of river runoff using the mean value of the time series in question.

Data and data source. Six continuous monthly river runoff time series in southern Africa were obtained from the Southern African Science Service Center for Climate Change and Adaptive Land Use Information System (SASSCAL-IS; http://leutra.geogr.uni-jena.de/sasscalRBIS). This information system is used as a database for data related to the environment of the southern Africa region, and, combined with other programs from the Integrated Land Management System (ILMS) software package, to which the IS belongs, provides a range of geospatial, statistical, and modeling tools for the analysis, description, and modelling of local environmental processes [7,8].

For this analysis, the longest datasets present in the IS were selected. These data originated from two different basins: the Berg River basin in the Western Cape of South Africa, and the Okavango River basin, a transboundary catchment between Angola, Namibia, and Botswana.

The characteristics of the time series are presented in table 1. The first column of the table lists the index value of each time series. The name of each time series, consisting of the names of the river and observation station, is presented in the second column. The third column demonstrates the identifier of the time series within the SASSCAL-IS.

Table 1 – Monthly time series of river runoff in South Africa

Index	Name of time series	SASSCAL identifier	Analyzed interval	Q_m, m^3/sec	σ, m^3/sec	Δ, m^3/sec
1.	Berg River, Bergriviershoek	G1H004	07.1954 – 12.1995	6,028	8,532	5,750
2.	Cubango River, Mukwe	627599	10.1949 – 12.1995	309,60	178,42	120,26
3.	Franschoek River, Le Mouille	G1H003	03.1957 – 12.1995	0,703	0,914	0,616
4.	Kavango River, Rundu	680180	10.1945 – 12.1995	168,03	156,61	105,56
5.	Little Berg River, Nieuwkloof	G1H066	07.1951 – 12.1995	0,919	1,426	0,961
6.	Voëlvlei Dam Canal, Vogel Vallij	G1H065	11.1951 – 12.1995	0,751	0,824	0,556

The fourth column presents the analyzed time intervals of the time series. The time series were analyzed up to 1995. This was the cut off point for the initial analysis because the time series for the Cubango River, Mukwe, ends earlier than the others, in mid-1998. The 24 month forecast interval comprising years common to all time series was thus that of the 24 months of 1996-1997. As such, the generalization of forecast results for the time series was undertaken upon the same interval.

The last three columns illustrate the mean value of river runoff, the standard deviation, and the accepted mistake of the forecast for the analyzed interval. The largest mean value, standard deviation and accepted mistake of forecast of runoff were computed for the data from the Mukwe station, on the Cubango River. For the data from Rundu, on the Kavango River, the values of these attributes are less than for the Cubango River. The mean runoff value for the Bergriviershoek, Berg River dataset, as well as its standard deviation and accepted forecast error, are all significantly lower than those of the Kavango and Cubango rivers. The values of these characteristics for the Le Mouille, Nieuwkloof, and Vogel Vallij datasets are all lower than for the Bergriviershoek dataset. The smallest mean runoff value was computed for the Franschoek River, and the largest, among these three time series, for the Little Berg River. The standard deviation and accepted mistake of prediction are the smallest for the Voëlvlei Dam Canal and are greatest for the Little Berg River.

Methods of research. Six time series of river runoff in southern Africa were analyzed by the method of “periodicities” [2, 3]. This method is based on the approximation of a time series using successive sine characterized by a unitary period step. The amplitude and phase, as well as an additional constant defining where the approximation sine oscillates, were computed by the method of the least squares [6].

The sum of squared differences of the best approximation sine and values of the time series was calculated for each period. Depending on the period of approximation, the local minima of the sum of squared differences of the time series and the approximation sine could then be evaluated. Some indication of the presence of periodicities could then be confirmed.

Reliable harmonics, those which can be used for the computation of runoff forecasts, are indicated by the combination of their being present in a large number of time series and a high correlation value with said time series. As such, sinusoids were only applied for the training forecasts if they were both revealed in all six time series and if had a high correlation with the time series.

The revealed harmonics are reliable if the correlation of their sum with the time series increases through each additional combination. Similarly, a set of summed harmonics should not be used for forecasting if its correlation with the time series is lower than that of the individual sinusoids used.

In addition to the computation of the forecasts by the sinusoids and their sums, forecasts were also undertaken using repeating successions of mean monthly runoff values, averaged for the cycles revealed by the method of “periodicities”. The succession of mean monthly runoff values averaged for the revealed cycles should reflect more individual characteristics of each dataset than the standard sine alone. Due to this, it is posited that the cycles formed by the succession of mean runoff values should have greater correlation with the time series than the respective harmonics alone, and thus, should provide more accurate forecast results.

Results of time series analysis. Table 2 presents the parameters of the best approximation sine of the runoff time series of the Cubango and Kavango rivers for any fixed period. For each period of approximation T, its additional item Q_0, amplitude of approximation sine $\delta Q/2$, its phase φ_Q, and the sum of squared differences with the values of the time series S_Q, were computed.

Table 2 – Sine approximation of monthly runoff time series of the Cubango and Kavango rivers

T, months	$10^{-2}Q_{02}$, m^3/sec	$\delta Q_2/200$, m^3/sec	φ_{Q2}, radian	$10^{-4}S_{Q2}$, (m^3/sec)^2	$10^{-2}Q_{04}$, m^3/sec	$\delta Q_4/200$, m^3/sec	φ_{Q4}, radian	$10^{-4}S_{Q4}$, (m^3/sec)^2
1	2	3	4	5	6	7	8	9
3,0	3,0960	0,0831	-0,9923	1764,882	1,6803	0,1060	-0,6180	1475,741
4,0	*3,0961*	*0,2059*	*4,4067*	*1755,013*	*1,6802*	*0,1917*	*-1,5543*	*1468,026*
5,0	3,0960	0,0411	2,8569	1766,330	1,6802	0,0546	-0,7829	1478,229
6,0	*3,0959*	*0,4850*	*4,1239*	*1701,520*	*1,6806*	*0,4900*	*4,4117*	*1406,748*
7,0	3,0961	0,0425	4,6149	1766,295	1,6803	0,0404	-0,4781	1478,635
8,0	*3,0963*	*0,1350*	*-1,3495*	*1761,747*	*1,6803*	*0,1374*	*-0,8788*	*1473,446*
9,0	3,0961	0,0460	1,2389	1766,208	1,6803	0,0313	-0,5292	1478,834
10,0	3,0963	0,0579	3,9642	1765,870	*1,6805*	*0,0591*	*4,5918*	*1478,076*
11,0	3,0962	0,0837	2,9875	1764,856	1,6802	0,0040	1,1172	1479,125
12,0	*3,1038*	*1,9316*	*2,6905*	*730,0701*	*1,6853*	*1,5994*	*2,8887*	*707,912*
13,0	3,0951	0,1650	0,5647	1759,264	1,6794	0,1410	1,5787	1473,128
14,0	3,0965	0,1052	1,0963	1763,725	*1,6800*	*0,1728*	*4,5204*	*1470,122*
15,0	*3,0960*	*0,1845*	*0,6579*	*1757,348*	1,6805	0,0663	-0,5804	1477,802
16,0	3,0964	0,0523	-0,6701	1766,040	1,6806	0,0641	-1,1312	1477,891
17,0	3,0961	0,1203	2,5510	1762,763	1,6805	0,1244	3,1749	1474,466
18,0	*3,0960*	*0,2638*	*3,4753*	*1747,401*	*1,6824*	*0,2564*	*-0,6375*	*1459,313*
19,0	3,0964	0,1558	-0,9436	1760,089	1,6792	0,1574	2,1800	1471,687
20,0	*3,0972*	*0,1692*	*2,0768*	*1758,880*	1,6802	0,0889	-0,1318	1476,757
21,0	3,0970	0,0964	0,0210	1764,214	*1,6815*	*0,1630*	*4,5759*	*1471,148*
22,0	3,0960	0,0464	-0,3084	1766,204	1,6802	0,0738	-0,9047	1477,493
23,0	*3,0958*	*0,1821*	*3,2019*	*1757,632*	*1,6802*	*0,1272*	*2,8370*	*1474,279*
24,0	3,0954	0,1265	2,7914	1762,352	1,6799	0,0788	3,5098	1477,250
25,0	3,0965	0,0727	3,7010	1765,326	1,6806	0,0706	3,9923	1477,624
26,0	3,0967	0,0595	0,3189	1765,814	1,6810	0,1117	0,7011	1475,360
27,0	3,0947	0,1835	0,8251	1757,435	1,6812	0,2124	2,3623	1465,589
	T, months			η	*T*, months			η
	12,0			0,7660	12,0			0,7221
	6,0			0,1922	6,0			0,2212
	18,0			0,1048	18,0			0,1157
	4,0			0,0817	4,0			0,0866
	15,0			0,0731	14,0			0,0780
	23,0			0,0720	21,0			0,0735
	20,0			0,0669	8,0			0,0620
	8,0			0,0535	23,0			0,0573
					10,0			0,0267

The characteristics of the approximation sinusoids of the Cubango River runoff time series are presented in columns 2-5, while the same characteristics for the Kavango River are shown in columns 6-9. They are specified by the indexes listed in table 1.

Due to the high runoff of these rivers, and the limited available memory of the software used, the values of the time series were divided by 100 during the computation process. As a consequence, the values of the amplitude and additional item of approximation are 100 times smaller than the corresponding parameters of the sinusoids of approximation of the real time series, and the values of the sum of squared differences of the approximation sine and time series are smaller than this real characteristic by a factor of 10^4.

Depending on the period of approximation, there are some local minima of the sums of squared differences of the approximation sinusoids and the river runoff time series. These local minima are shown in italic. The periods with the minima of the sums of squared differences S_Q are shown in the bottom lines of table 2, listed in descending order of their correlation value with the time series η.

The minima of the sums of squared differences of the Cubango and Kavango river runoff time series and the approximation sinusoids occur for both time series for the periods of 4, 6, 8, 12, 18, and 23 months. Additionally, the periods of 15 and 20 months were also revealed in the Cubango River time series, whereas periods of 10, 14, and 21 months were revealed in the runoff time series of the Kavango River. For both rivers, the highest correlation between time series and sinusoids was with for the 6 and 12 month periods.

The above computations were also undertaken for the other four river runoff time series. For all datasets, the periods with the local minima of the sum of squared differences of the time series and their sine approximation are presented in table 3. The first line shows the periods of approximation, and the first column – the indexes specifying the river runoff time series, as listed in table 1.

The periods at which the values of the sums of squared differences of each time series and their sine approximation present the local minima are indicated by the plus sign. The final line of the table presents the total number of each periods' presence in all time series. It is clear that not every period revealed was revealed in all datasets. Indeed, some periods revealed greater numbers of hidden harmonics than others.

Table 3 – Periods revealed in southern African river runoff time series

Index	3	4	6	8	9	10	12	14	15	16	17	18	20	21	22	23	24	25	26	27
1.	+		+				+	+		+				+		+		+		
2.		+	+	+			+		+			+					+			
3.		+	+		+		+				+		+		+		+			+
4.		+	+	+		+	+	+				+		+		+				
5.			+				+			+		+		+		+			+	
6.		+	+				+				+				+			+		+
Totally	1	4	6	2	1	1	6	2	1	2	2	3	1	3	2	3	2	2	1	2

Table 3 shows that only the 6 and 12 month periods were revealed in each time series. The period of 4 months was revealed four times, and the 18, 21, and 23 month periods – three times. The periods with the length of 8, 14, 16, 17, 22, 24, 25, and 27 months were present in a total of two of the selected river runoff time series, while the 3, 10, 15, 20, and 26 month periods were each revealed only once. The periods with the length of 5, 7, 11, 13, and 19 months were not revealed in any dataset, and were as such not presented in table 3.

As stated, only the periods of 6 and 12 months were revealed in all six time series. Furthermore, the correlation of their sinusoids with the respective time series is higher than the correlation of sinusoids from any other revealed periods (see final section of table 2). As such, the 6 and 12 month period sinusoids were selected for application to the training forecast of these time series.

Results of training forecasts. The numbers of true forecasts of river runoff in southern Africa, as well as the relative mistakes of prediction resulting from each forecast schema applied to a 24 month interval, are presented in tables 4 and 5 respectively. The first column of these tables demonstrates the identifier of each time series, as presented in table 1. The remaining columns represent the different forecast schemas used: column I presents the results from the forecast using the mean values of each time series; column II, the forecast results stemming from the use of the 6 month period sinusoid; column III, the 12 month period sine forecast; column IV, the forecast results obtained using the sum of the 6 and 12 month harmonics. The results of forecasts undertaken using the succession of mean monthly runoff values averaged for the half annual and annual cycles are presented in the columns V and VI, respectively.

In the penultimate and final rows of both tables, the sums and percentages of the true forecasts and sums and mean values of relative forecast mistakes for each forecast schema and all time series combined, respectively, are presented. We see that forecast results from scheme I to scheme IV become successively better: from each scheme from scheme I to scheme IV, the number of true forecasts increases, while their mean relative mistake decreases. The forecast results computed by the sinusoids with the period of 6 months are better than by the mean values of the time series. The forecasts results using sinusoids with a period of 12 months are better than by the sinusoids with 6 month period, those obtained using the sums of the harmonics of the 6 and 12 month periods are better than those obtained using solely either of the individual sinusoids.

The runoff forecast computed using the successions of monthly mean values over the half year cycle is better than that obtained using the sinusoids of the 6 month period. Indeed, the best performing forecasts were those obtained using the successions of mean monthly values of the intra-annual cycle.

As undertaken with the 6 and 12 month period sinusoids, the successions of mean runoff values averaged for the year and half year were also summed. Here, however, the correlation of each time series with the respective sum of these successions is lower than that of the succession of mean monthly values over the intra annual (12 month) cycle. The forecast results using the sum of 6 and 12 months successions of monthly mean values, in general, are worse than the values obtained using the mean monthly runoff succession of the intra-annual cycle alone.

Table 4 – Number of true forecasts of river runoff in southern Africa

Index	I	II	III	IV	V	VI
1.	22	20	20	21	22	21
2.	9	13	11	14	13	15
3.	13	14	18	18	14	21
4.	13	16	16	18	16	17
5.	20	16	17	19	16	19
6.	19	18	20	19	19	18
Totally	96	97	102	109	100	111
	0,667	0,674	0,708	0,757	0,694	0,771

Table 5 – Relative mistake of forecasts of river runoff in southern Africa

Index	I	II	III	IV	V	VI
1.	0,4705	0,4533	0,4621	0,4446	0,4448	0,4260
2.	0,8436	0,8284	0,7725	0,7560	0,8272	0,7499
3.	0,8130	0,7935	0,5182	0,4872	0,7880	0,4631
4.	0,6618	0,6464	0,6016	0,5846	0,6437	0,5757
5.	0,7910	0,7291	0,6061	0,5228	0,7291	0,5147
6.	0,7379	0,7361	0,6594	0,6575	0,7229	0,6743
Totally	4,318	4,187	3,620	3,453	4,156	3,404
	0,7203	0,6978	0,6033	0,5755	0,6926	0,5673

The final fragment of the time series of the runoff of the Cubango River, successions of mean monthly values for both the annual and half annual cycles, and the difference of these successions, are presented in figure. The temporal variation of the repeating succession of mean monthly values of the intra annual runoff cycle is clear from its title. The correlation of the time series and repeating succession of mean monthly values for the annual cycle is 0,795. The correlation of the mean monthly runoff values for the half year cycle and the time series is equal to 0,195, while the correlation of the difference of these successions with the time series is 0,771.

We see that the half annual cycle of mean monthly runoff values visually resembles the sine. The difference of the repeating successions of mean monthly runoff values averaged for annual and half annual cycles also resembles a sine harmonic. The correlation of the repeating succession of mean values of runoff for monthly time intervals over the half annum cycle and the best sine of its approximation is 0,985. Finally, correlation between the difference of these successions and the best sine of its approximation is equal to 0,994.

Discussion. Intra-annual variation of river runoff in southern Africa has been represented using a combination of 6 and 12 month harmonics. These harmonics were revealed through time series analysis using the “periodicities” method, as well as through application of a repeating succession of mean monthly values averaged over half a year. Further, the difference between the annual and half-year repeating successive mean monthly values strongly resembles a harmonic structure.

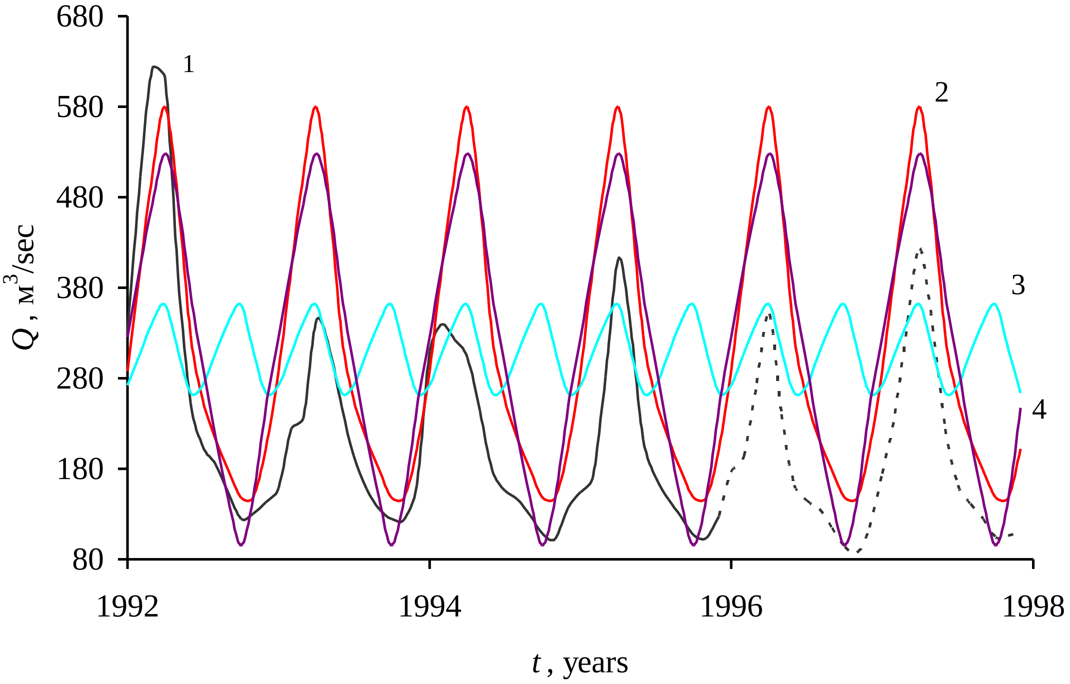

Figure – Monthly variation of the runoff of Cubango River, Mukwe, 1 – time series values (dotted line – training forecast interval of 1996 – 1997), 2 – mean month runoff values of its annual cycle, 3 – mean runoff values for month time interval of 6 month cycle, 4 – difference of the curves 2 and 3/

However, despite high correlation with the standard sine function, the difference of the repeating successions of mean monthly runoff values does not completely resemble harmonics. Rather, these values better reflect the individual spatio-temporal peculiarities of the time series, and, as such the correlation of the difference of these successions with the time series is higher than the correlation with the time series of the sine function.

The timing of the maxima of the 12 month and 6 month sinusoids is almost the same (that the 6 month harmonics precedes that of the 12 month sine by only a few days) and the minima of the 12 month sinusoid coincides with the subsequent maxima of the 6 month harmonics. The sums of the maxima of these sinusoids reflect the peculiarity of the time series, namely, the rapidly rising, narrow peaks, while the sums of maxima of 6 month harmonics and minima of 12 month sine relatively accurately reproduce the timing of the broad time interval of the low runoff values. Indeed, since the maxima of the 6 month sine occurs slightly before the minima of the 12 month sinusoid, the combination of these sinusoids results in a slower reduction in runoff from July to October (for the Cubango and Kavango rivers) than the more rapid increase during the intervening months.

Overall, it is clear that the runoff forecast results computed by the 6 and 12 month sinusoids, their sum, and the values obtained using the repeating successions of mean monthly values for these periods, all provided better results than simply using the mean value of the time series as a forecast method. The best forecast results of all the considered schemes, for all time series, were those computed using the succession of mean monthly values over the intra-annual cycle. Analogically the forecast results by the succession of mean monthly values for month time averaged over the half annual cycle are better than by the best approximation sine over the same period, since the former forecasting method better reproduces some of the local characteristics of a given watershed time series than does the standard sine.

So, intra annual variation of runoff in southern Africa can be reasonably reproduced using harmonics with the periods of 6 and 12 months. The 12 month cycle corresponds to the harmonic calendar period of astronomy. The cycle with the length of 6 months could hypothetically be related with the seasonal shifting of high and low belts of atmospheric pressure. In this case, the belts of low pressure, initiating the rains, shift to the southern African region during the winter and the summer from the equator and the regions of moderate climate respectively. Since the movement and dynamics of atmospheric pressure belts is largely global, it is possible to expect that the 6 month cycle will be revealed in numerous other river runoff time series located around the globe.

Another possibility, however, could be that the precipitation in this region is related with the motion of only one belt of low pressure, a determining factor of which could be a fraction including the 12 month period sine function in the denominator. If this were the case, precipitation should be greater if the pressure belt is closer, and the calculation using such a formula should provide narrow stretched peaks of wet conditions, and lengthier periods of low values. Such results would then, as seen above, reliably describe runoff timing, and, to some degree, would thus strongly resemble the results obtained through the use of the combination of the 12 and 6 month harmonics.

Conclusion. The analysis of six month time series of river runoff in southern Africa revealed harmonics with the periods of 12 and 6 months. The near coincidence of the timing of the maxima of these sinusoids accurately reproduced the narrow, stretched peaks of river runoff, while similar near coincidence of the 12 month minima and the 6 month maxima resulted in a lengthy period of runoff decrease and low runoff. Since the maxima of the 6 month sine occur slightly before the extremes of the 12 month periodicity, the reduction in runoff to the trough is more flat than the abrupt increase to the peak during the wet period.

The presence of the six month harmonics revealed by the method of “periodicities” was also, essentially, further confirmed, through use of the succession of mean monthly runoff values averaged over the half year cycle. The difference of the two time series of repeating successions of mean monthly runoff values, averaged for the year and half year, strongly resembles the 12 month period sinusoid.

From all the forecast schemes used, the results of the forecast obtained using the repeating succession of mean monthly values of the annual cycle are best. Following this scheme, the next best performing forecast schemes were the sum of the 12 and 6 month harmonics, the 12 month sine period forecast, the succession of mean monthly values for over half a year, the 6 month sine period forecast, and, finally, the forecasts undertaken using the mean value of each dataset.

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RE-ESTABLISHING OF LONG-TERM GLACIER MONITORING AS AN IMPORTANT BASELINE OF HYDROLOGICAL PREDICTIONS AND CAPACITY BUILDING IN KYRGYZSTAN AND UZBEKISTAN

Continuous measurements of glaciers in Central Asia are an essential part of todays monitoring in the framework of climate services as defined by the Global Climate Observing Systems (GCOS) and for the prediction of regional water supply and natural hazards. The Capacity Building and Twinning for Climate Observing Systems (CATCOS) project aims to improve climate relevant measurements in data sparse regions.

As a result, glacier monitoring on four glaciers in Kyrgystan and one glacier in Uzbekistan has been (re)-established by researchers from different countries (Kyrgyzstan, Uzbekistan, Germany and Switzerland), involving direct glaciological methods to compile annual mass-balance measurements. The mass balance data is always published on the WGMS website, and can be used through free access by scientists and practitioners.

The established mass balance serves as one of the baseline components for regional runoff predictions, especially in the dry summer season, when glacier runoff constitutes a significant portion of the total river runoff.

During the project implementation special emphasis was given to the capacity building of young researchers in glaciology. Capacity building involved joint field campaigns on the glaciers and support/cooperation in data analysis and modeling, including young researcher visits to the University of Fribourg, Switzerland. Additionally, two summerschools were organized, involving students and young researchers from the wider region of Central Asian countries. This led to the establishing of a younger generation of early career scientists in Kyrgyzstan. These scientist will now be able to teach also younger scientists and they are ready to be educated in more sophisticated research approaches on the observed glaciers in the monitoring network.

B.BEKNIYAZ, A.KENSHIMOV

International Fund for saving Aral Sea, Tashkent, Uzbekistan
Executive Board of the RK

INFORMATION ABOUT THE ACTIVITIES OF THE EXECUTIVE BOARD OF THE INTERNATIONAL FUND FOR SAVING THE ARAL SEA IN KAZAKHSTAN (EB IFAS) IN 2015

В статье приводится информация о деятельности Исполнительной Дирекции МФСА в Республике Казахстан.

This article provides information on the activities of the Executive Board of IFAS in the Republic of Kazakhstan.

Мақалада Халықаралық Арал Құтқару Қорының Қазақстан Республикасындағы Атқару Дирекциясының жұмысына байланысты ақпарат.

In the last third of the twentieth century, Central Asia faced the environmental crisis of the global scale – desiccation of the Aral Sea, which was the fourth largest lake of the world. From 1960 to 1988 in the Aral Sea basin wide-ranging program on acquiring new lands has started, in the result of that the irrigated area and the volume of water intake were doubled. Consequently, the flow of water in the lower parts of the rivers and the Aral Sea fell sharply; water level of the sea was decreased to 39 m BS by 1988, and the sea was split into North Sea (Small Sea) and South (Big Sea) parts.

Small sea level was stabilized by the inflow from Syr Darya and the drying up of the Big Sea has become irreversible and it was divided into West (deep) and East part (dried up in 2009). The sea receded from the coast in some places more than 100 km away, exposing the bottom of the former bed to more than 33 thousand square kilometers.

Economic losses due to climate change, deterioration of water quality in rivers, reduction of fishing in the Aral Sea, the degradation of more than 4 million hectares of land and loss of biodiversity in the region reaches the amount of several billion dollars per year.

The consequences have affected the standard of living and health of more than 5 million people living directly in the delta of the Amu Darya and Syr Darya (the Aral Sea area). The first victims of the ecological crisis were the most vulnerable segments of population: children, women.

Consolidation of the efforts of Central Asian countries to combat the Aral ecological and economic crisis has become an urgent task. On March 26, 1993 in Kyzylorda happened an important event in the life of the peoples of Central Asia - Heads of States established the International Fund for Saving the Aral Sea (IFAS). In the first years of independent development presidents of Central Asian countries have shown the greatest political will and statesmanship, which resulted to the recognition and commitment to addressing issues of using shared water resources in the basin of the Aral Sea, taking into account the interests of all states of the region. They raised interstate water relations at high international level, keeping traditions of friendship, mutual understanding, partnership, aiming such a high potential for prosperity in the region. Over the past period, thanks to the consistent policy of the Heads of Central Asian countries, IFAS and its organizations have become indispensable political platform for the negotiation process between the countries, the development and adoption of bilateral and multilateral agreements for the integrated management, use and conservation of transboundary water resources. In his speech during the Summit of 28 April 2009 the President of IFAS - President of the Republic of Kazakhstan N.A.Nazarbayev said: "The activities of the International Fund for Saving the Aral Sea has shown the importance of joint actions of state and interstate structures in addressing both regional and global issues.".

There was created a number of international structures, documents defining the main directions for solving the problems of the Aral Sea were adopted jointly with international organizations. Regional cooperation in Central Asia in the frames of IFAS contributed to qualitatively new interstate relations in the region, which make a significant contribution to the modern life of the region.

The Fund's efforts have been positively evaluated by the United Nations, which was confirmed by assigning observer status in the UN General Assembly in 2008 and the visit of the UN Secretary-General Ban Ki-Moon to the Aral Sea in 2010.

Executive Board of the International Fund for Saving the Aral Sea in Kazakhstan (EB IFAS in Kazakhstan) is the territorial authority of the Executive Committee of IFAS and is it permanent working body in the Republic of Kazakhstan. According to the Regulations of the Executive Board of IFAS in Kazakhstan, the main tasks of the EB IFAS are: to ensure the practical implementation of the decisions made by the Council of Heads of Central Asian states, the President of the Fond and the Executive Committee of IFAS on the Aral Sea basin problems related to the Kazakh part of the basin, the implementation and monitoring of projects and programs Aral Sea Basin funded by the budget of the Republic and to raise funds from donor countries and international organizations to finance programs and projects for the rehabilitation of the Aral Sea basin, processing the information for decision-makers in Kazakhstan, members of the Board of IFAS from Kazakh side and EC IFAS.

About the Aral sea basin programs (ASBP). The aim of all the adopted Aral Sea Basin Programs is to improve the environmental and socio-economic situation in the Aral Sea basin.

THE FIRST PROGRAM (ASBP-1). Development of the first Program was initiated in 1992, with the active participation of the World Bank, UNDP and UNEP. The main goals of the Program, which was signed by the Heads of Central Asian states in 1994 in Nukus (Uzbekistan), included:

- stabilizing the environment in the Aral Sea Basin
- restoring the affected environment of the Aral Sea Region
- improving management of water and land resources in the Basin
- creating management structures at all levels for planning and implementation of the Program.

The program was aimed on assisting countries of the basin in implementation of the prior directions, as well as on strengthening measures of the social orientation, giving special importance to the fight against poverty and sustainable development of the region.

THE SECOND PROGRAM (ASBP-2) was approved by the IFAS Board on August 28, 2003. Earlier, on October 6, 2002, in Dushanbe, the Heads of the IFAS founder-states decided to develop a new program, taking into account the progress of the first phase of the ASBP-1, and agreed on its main lines of action. The resulting program included 14 priority lines of action, combined into 4 blocks: water management, socio-economic development, ecology and environmental monitoring.

ASBP-2 became the key instrument defining the main priorities in improving the environmental and socio-economic situation in the region for the period of 2003-2009. It was developed based on multilateral partnership and proposals received from all the stakeholders in the Central Asian States.

During the implementation of the “Program of specific actions to improve the environmental and socio-economic situation in the Aral Sea Basin for the period of 2003-2010 (ASBP-2)”, and of the projects under this program by the IFAS founder-states, the overall investment amounted to about USD 2 million, while donor assistance did not exceed 1% of the total.

THE THIRD PROGRAM (ASBP-3). In the period of 2009-2012, following the Resolution of the Heads of States of 28 April 2009, the Executive Committee of the IFAS

(EC IFAS), with the participation of the Interstate Commission for Water Coordination (ICWC), the Interstate Commission on Sustainable Development (ICSD), in cooperation with national experts from Central Asian countries and donors, prepared a draft of the ASBP-3, which was supported by the international donor organizations (Joint Statement of Donors, Ashgabat, July 20, 2010) and approved by the Decision of the Board of IFAS on May 15, 2012.

ASBP-3 includes:

- regional projects that will be financed mainly by international donors;
- projects funded from national budgets;
- national projects funded by international donors.

The main objective of ASBP-3 is to improve the living conditions of the people in the region by applying the principles of integrated water resources management, to develop a mutually acceptable mechanism for a multi-purpose use of water resources and to protect the environment in Central Asia taking into account the interests of all the states in the region.

Table 1 – ASBP-3 Directions

Four directions of ASBP-
Direction 1 - Integrated Use of Water Resources
Direction 2 - Environmental Protection
Direction 3 - Socio-economic Development
Direction 4 - Improving the institutional and legal mechanisms

Projects of the Third Aral Sea basin Program (ASBP-3), being implemented by the executive board of IFAS in Kazakhstan jointly with international organizations.

Acknowledging the positive activities of IFAS to overcome the Aral Sea crisis UN General Assembly adopted Resolution 63/454 "granting International Fund for Saving the Aral Sea the observer status in the General Assembly” on December, 11, 2008.

Giving IFAS observer status in the UN General Assembly enhanced cooperation between EB IFAS and UN organizations such as UNECE, UNESCO, UNDP on projects aimed on improving the environmental and socio-economic situation in the Aral Sea basin.

At the same time, EB IFAS in Kazakhstan is successfully working together with other international organizations, such as OSCE, SDC, JICA, FFEM-EECCA project and others.

EB IFAS is strengthening close cooperation and organizing effective work on the base of the following Memorandums:

- Memorandum of Understanding on water security issues and the promotion of the action programme for assistance to the countries of the Aral sea basin in the period 2011-2015 (ASBP-3) between OSCE (OSCE Centre in Astana)
- Memorandum of Understanding between UNECE and EB IFAS in Kazakhstan (2011).
- Memorandum of Understanding between the United Nations Department of Political Affairs (on the behalf of UN Regional Centre for Preventive Diplomacy for Central Asia) and the Executive Committee of the International Fund for saving the Aral sea (2010).
- Memorandum of Understanding among the United Nations Economic Commission for Europe, the United Nations Economic and Social Commission for Asia and the Pacific and the International Fund for saving the Aral sea.

Direction 1 - Integrated Use of Water Resources

Direction I – Integrated Use of Water Resources – includes projects aimed at addressing the problems associated with transboundary water resources management, improvement of irrigated lands, establishing monitoring systems and databases, modeling, basin plans development, and ensuring the safety of water facilities.

Table 2 – Implementation of the ASBP-3 in the Republic of Kazakhstan by national funds for the period of 2011-2015 as on May, 2016 (according to the data from EB IFAS, ministries and agencies of Kazakhstan)

Implementation	Q-ty of the projects	The sum
Stated by Kazakhstan	98	3967,2 mln $
Already implemented	141	516,3 mln $
Continued in 2015	18	1423,5 mln $
On the start of implementation	16	524,8 mln $
Implemented by the Executive Board of IFAS jointly with international organizations	22	0,42 mln $

Projects on IWRM (with OSCE)

As the direction one - "Integrated water resources management" of the ASBP-3 Executive Board is working in close collaboration with the OSCE Centre in Astana. Following the provisions of Memorandum signed in 2009 by both parties, the Board is implementing the project on IWRM in Kazakhstani part of Aral Sea region. This work closely intersects with the second, ecological direction of the ASBP-3, since it is working on improving the ecological state of Syr Darya delta and the Small Aral Sea. To raise public awareness about the state of water resources, with the financial support of the OSCE Centre in Astana, the Training Center for Aral – Syr Darya Basin Council was opened in 2011. According to the plan of work the series of events were held in 2014.

Within the framework of assistance of the OSCE Centre in Astana to Kazakhstan in promoting the reform of state management of water resources, in order to implement integrated water resources management in the Kazakh part of the Aral Sea region there was held a two-day training workshop "Stakeholder dialogue on protection of water resources in the context of the implementation of IWRM in the Aral – Syr Darya basin " on June 27-28, 2014.

Direction 2 - Environmental Protection

The second group of ASPB-3 projects addresses the problems associated with the environmental protection and improvement of the environment, including biodiversity conservation and natural disasters risks reduction.

Increasing the productivity of rangelands (UNDP project)

Cooperation with United Nations Development Project (UNDP) covers the second direction of ASBP-3, focused on the protection and improving the state of the environment, including improving ecological condition and increasing the productivity of rangelands.

As per request of authority of Kyzylorda oblast, Executive Board jointly with UNDP launched the pilot project on watering pastures through construction of new or rehabilitation of abundant wells using modern energy-saving technologies, materials and equipment.

On the selected demonstration field of the “Madi Khadji” LLP the project installed a water point to ensure animal husbandry which is successfully operated by the Farmer. The project facilitated the Famer in the improvement of rangeland conditions and provided the seeds of forage crops for planting.

Work on this project will be continued in 2015. In the first quarter of 2015 UNDP project plans to purchase and install wind and solar-based generators while EB IFAS is planning to held workshops and issue publications to disseminate the project experience and outcomes.

Project on phyto-amelioration of the absolute wasteland on the north-east coast of the Aral Sea (JICA Grassroots program)

The project on phyto-amelioration of absolute wasteland on the north-east coast of the Aral Sea" was launched in 2011 in the frames of "Grassroots" program, implemented by a grant from the Government of Japan to supply equipment for agricultural plantations on the dried bottom of the Aral Sea.

Executive Board of IFAS in Kazakhstan took part in funding the project by financing "Baytak dala" NGO with the annual funds for the purchase of fuel for the equipment.

In 2014, the "Baytak dala" NGO continued planting seedlings of haloxylon. To this purpose, EB IFAS in Kazakhstan has signed a new contract with "Baytak dala" and allocated funds for planting haloxylon on the area of 30 hectares at 10 km far from Karateren village located on the way to Big Aral.

In addition, EB of IFAS in Kazakhstan assisted the above NGO in procuring 15 thousand of transplants from the nursery of the World Bank forest conservation and reforestation project in Kazakhstan.

Monitoring Ramsar wetlands on the delta of Syr Darya and Small Aral sea

The brochure on “Monitoring Ramsar wetlands on the delta of Syr Darya and Small Aral Sea” was published in 2014 in the framework of cooperation between EB IFAS in Kazakhstan with OSCE and implementation of comprehensive project on integrated water resources management in the Kazakh part of the Aral Sea region. The comparative analysis results of bio-inventory surveys used in the brochure were obtained in 2011 and 2013 by the expert group consisted of a botanist, an expert on ecosystems, entomologist, ichthyologists, ornithologists, hydrobiologist, GIS specialist and manager of the field work.

Direction 3 - Socio-economic Development

The third group of ASBP-3 projects addresses socio-economic issues, including the focus on improving living conditions, ensuring sustainable development, increasing employment, improving water and power supply systems, education and public health.

Project on creation of information-analytical center on the kazakh part of Syr Darya and operational hydrological Bulletin for Syr Darya river basin (FFEM-EECCA project)

In order to create information-analytical center of the Aral-Syr Darya Basin Council for the Kazakh part of Syr Darya river basin, in August 2012 EB IFAS started working jointly with the FFEM-EECCA project on the formation of linear interactive charts and maps on Syr Darya river, in cooperation with Kazhydromet, Emergency Agency, South Kazakhstan and Kyzylorda oblast departments of water resources. The main objective of this project is to improve the exchange of information between all organizations involved in the management of water resources in the basin of Syr Darya river, considering the importance of exchange of operational and historical data on water flow as a vital tool in increasing the efficiency of water resources management and transparency of governmental water management institutions.

Establishment of an operational hydrological bulletin for Syr Darya river basin is closely linked to the development of the French project FFEM-EECCA «Capacity building in data administration for assessing transboundary water resources in the countries of Eastern Europe, the Caucasus and Central Asia (EECCA)."

Interactive hydrological bulletin allows to receive operational data on water level and discharge in agreed sectors of rivers, level and volume of water in reservoirs, level and discharge in the head of gauging channels. On -line information on Syr Darya river basin, including schedules of releases during the growing season, ice-formation situation, etc. provided in the form of interactive charts and maps is used in water resources management decision-making process . The bulletin will keep track of not only inflow to the Small Aral

Sea, but also the loss, and thus ensuring due adoption of appropriate measures. The developed software can also provide data on water balance in respective sections of river, collect and store data on daily, decade, monthly and annual basis format for all gauging stations.

Under this pilot project there were developed User's Guide and the web-site for institutions and agencies concerned. It provides users with summary of the joint work of involved parties such as FFEM-EECCA project, EB IFAS, supplying data organizations in the field of water management – Kazhydromet, Kazvodhoz and Emergency agency. The Guide is intended to improve the collection, storage, processing and exchange of data between organizations requiring quick receiving of data and information, whose daily work is directly related to the use of data.

EB IFAS in Kazakhstan hopes that project area can be extended and cover the whole Syr Darya river bed thus becoming a real help to transboundary countries in improvement of water resources management. .

Project on creating daily interactive hydrological Bulletin on Chu and Talas rivers (project of SDC in Kyrgyzstan)

The work on creation of the interstate bulletin on the Chu and Talas rivers, similar to the one, done in Kazakh part of Syr Darya river by the FFEM-EECCA project jointly with the Executive Board of IFAS (for more details - paragraph 2.3.1) has started in 2014. Swiss Agency for Development and Cooperation in the Kyrgyz Republic supported the above-mentioned activities and signed an agreement to develop the concept of an interactive bulletin for Chu-Talas basin.

In order to successfully implement the project there was held the series of meetings and discussions with the Committee on Water Resources of the Ministry of Environment of the Republic of Kazakhstan (now Committee of WR in the Agriculture Ministry) and its basin organizations, Department of Water Resources of Agriculture Ministry of Kyrgyz Republic, Hydromets of Kazakhstan and Kyrgyzstan, the Executive Board of IFAS in Kazakhstan and Kyrgyzstan, as well as with professors and doctoral students of the Kazakh National Agrarian University, representatives of the Swiss Consular Agency for Cooperation and Development in the Kyrgyz Republic and the French FFEM-EECCA project.

Project on developing handicraft (with UNESCO)

As part of the third socio-economic area of ASBP-3 Executive Board is striving to address the socio-economic problems in the region, including the establishment and development of rural small businesses, create new jobs, thereby increasing local employment, with particular emphasis on involvement of the female population in the active life. This approach solves both the problem and the conservation of biological diversity, helping to find types of employment alternatives to hunting and fishing, as positive trend of increasing the fishery resources, migratory waterbirds nest attracts locals to fishing and hunting, causing irreparable damage to slowly reviving but not firmly established ecosystems.

In this regard, the Executive Board jointly with the UNESCO Cluster Office in Almaty for Kazakhstan, Kyrgyzstan and Tajikistan implemented joint project in Aralsk city on development of crafts and producing souvenir production.

The training conducted jointly by EB IFAS in Kazakhstan and the UNESCO Cluster Office in Almaty with the support of Kyzylorda Oblast Administration and Barsakelmes nature reservation, was a successful start aimed at continuation of such trainings for increasing awareness of local people about the biodiversity of native land through the development of handicrafts. The approach in this project contributes to the development of tourism cluster and will enhance local employment, especially for women, through supporting activities alternative to fishing and hunting thus saving biodiversity revived in the Kazakh part of the Aral Sea region.

Project on "Implementation of sustainable fishing in the framework of the promotion of the principles of the Green Economy in the Aral sea region" (with OSCE)

The project on "Implementation of sustainable fishing in the framework of the promotion of the principles of the green economy in the Aral sea region" allowed to conduct training for local people to develop the fisheries cluster and make recommendations for the conservation of fish stocks reviving in Syr Darya and Small Aral Sea, to prevent the threat of contamination and re-exhaustion.

This project addresses the real and urgent needs not only on promoting knowledge and awareness of local people about the principles of the green economy in the fishing cluster, but also meets the needs of water and fisheries sectors, which is to raise awareness of the local population about the joint management of natural resources in order to prevent contamination and re-exhaustion, as well as providing water and food security in the region.

Direction 4 - Improving the institutional and legal mechanisms

This direction includes projects aimed at addressing the issues associated with institutional development, improving regulatory frameworks and institutional structures, strengthening the capacity of regional IFAS bodies. Moreover, the projects will contribute to strengthening of regional cooperation, sustainable development strategies, training water resources management personnel , and increasing public awareness.

Regional project on “Safety of hydraulic structures in Central Asia: capacity building and regional cooperation” (with UNECE)

One of the main focuses of the fourth direction of the ASBP-3 is the safety of hydraulic structures. In this area, UNECE together with the EB IFAS is implementing the project "Safety of Hydraulic Structures in Central Asia: Capacity Building and Regional Cooperation" (hereinafter SHS in CA).

This project is the part of the "Environment and Security Initiative» (ENVSEC), implemented with the financial assistance from the Government of Finland and the partial financial support of the Russian Federation Government.

To date, two phases of the project on SHS in Central Asia were completed: the first phase (2004-2006) and the second phase (2008-2010). Since 2012 the third phase is being implemented.

The objectives of the project are:

1. Strengthening national capacity for the safety of dams and other hydraulic structures

- improvement and, if possible, harmonization of regulatory frameworks and organizational forms of state regulation on safety of hydraulic structures;
- improvement of the normative - technical documentation;
- Developing human capacity.

2. Strengthening the regional cooperation

- preparing regional agreement;
- exchange of international experience.

As the part of the SHS in CA project three training workshops and round tables were held in 2014. The purposes were to discuss and exchange views on issues of state regulation of relations in the field of safety of hydraulic structures, nowadays condition and the necessity to improve the legal framework for dam safety in the Republic of Kazakhstan.

Improving the legal framework. In facilitating the SHS in CA project implementation the Executive Board of IFAS is assisting in improving the legal and regulatory framework and organizational forms of state regulation of hydraulic structures safety. Particularly, EB supports the promotion of the bill "On the Safety of Hydraulic Structures" and projects (subordinate acts) to the Government of the Republic of Kazakhstan related to the hydraulic structures.

Executive Board of IFAS, together with an expert on Kazakhstan water legislation Igor Petrakov prepared materials substantiating the necessity for a specific law on dam safety (the concept of the bill "On safety of hydraulic structures” and a comparative table on "Correlation of the bill on dam safety with the Water Code of Kazakhstan and the Law on Industrial Safety").

In 2015 it is planned to conduct expert assessment of the financing necessary for implementation of the bill on dam safety (funded by OSCE) taking into account creation of (i) an independent supervising body (2) hydraulic structures diagnostic center and (iii) expert council (based on the experience of the Russian Federation and Uzbekistan).

Regional agreement on safety of hydraulic structures. The SHS in CA project developed a draft agreement on "Cooperation in the field of dam safety in Central Asia". This draft agreement was discussed during the regional and national meetings and workshops with the participation of the Central Asian countries. Versions which was agreed and finalized by the ministries and departments of Kazakh side were presented to the Executive Committee of IFAS through diplomatic channels.

Developing human capacity. An important aspect of sustainability of water sector is human resources capacity. This issue is also reflected in the ASBP-3, so since 2011, the Executive Board of IFAS in Kazakhstan (with the financial support of the UNECE) has started an active process for the development of training centers to upgrade qualification of water sector staff in Kazakhstan and other countries.

EB IFAS with the assistance of donor-organizations established two Training centers aiming to improve water management skills: International Training Centre on safety of hydraulic structures operating under the Kazakh scientific-research institute of water resources (Taraz) and the Training Center of the Aral-Syr Darya Basin Council which operates under the Kazakh scientific-research institute of rice named after Zhakhaev (Kyzylorda).

The process of establishing training center at the Kazakh National Agrarian University in Almaty has started in 2014.

In 2014, the United Nations Economic Commission for Europe and the Executive Committee of the International Fund for Saving the Aral Sea in the framework of the Regional Project "Dam Safety in Central Asia, capacity building and regional cooperation" with the help of Technical assistance fund of the Eurasian Development Bank, prepared and published Toolkit on "Development and creating set of measures to ensure the safety of hydraulic structures ", which was another valuable contribution of the UNECE to the implementation of ASBP-3.

In addition to the abovementioned organizations, during the implementation of all projects EB IFAS in Kazakhstan worked closely together with the Ministry of Agriculture, Environment, Emergency, Committee on Water Resources of the Ministry of Agriculture, Hunting and Forestry of the Ministry of Agriculture, Kazhydromet, local authorities and research institutes, water management organizations in Kyzylorda and South Kazakhstan regions, CAREC and non-governmental organizations.

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THE QUALITY OF DOMESTIC AND DRINKING PURPOSES WATER ALONG THE AFFECTED AREA OF EURASIAN TRANSIT THROUGH THE TERRITORY OF KAZAKHSTAN

The article presents results of drinking water quality evaluation in rural inhabited areas, located in the zone of Eurasian transit through the territory of Kazakhstan along the road of a large multi-modal transport corridor Korgas - Aktau.

Introduction. Water saving and harmonious exploitation of water resources are one of the main problems for many countries located in the arid zone, as for the Kazakhstan. Along with this, the most important task is to provide people with enough amounts and common quality water for domestic and drinking purposes. This question has been distinguished as a separate aim in national policy plan of our country “Kazakhstan 2050 Strategy”: “To develop a state program on water management with solving the problem of water supply by introducing innovate experiences including new extraction technologies and use of underground water on the first stage till 2020” [1].

The article presents results of drinking water quality evaluation in rural settlements, located in the zone of influence of Eurasian transit through the territory of Kazakhstan along the route of large multi-modal transport corridor (MMTC) Korgas – Aktau. MMTC crosses the territories of 8 Kazakhstan regions: Mangystau, Aktobe, Kyzylorda, South Kazakhstan Region, Zhambyl, Almaty, Karagandy and East Kazakhstan Region (figure 1). Multiple increase of the freight flows on the route of corridor extending from “west” to “east” Kazakhstan gates, joining Western Europe and Western China, will have multiplicative effect on the development of adjoining territories [2]. At this point, the evaluation of the resource potential of mentioned regions is needed as well as the evaluation of water supply in rural inhabited areas.

Data Sources. Long-term data of the State program on development of rural areas for 2004-2010 (The Decree of the President of the Republic of Kazakhstan dated July 10, 2003 N 1149) and regional akimat (2011-2014) over the quality of drinking water and the nature of using natural sources for rural districts and settlements have been analyzed in details [3]. Published data of LLP “Institute of geography”, Committee on Statistics of Ministry of National Economy of the Republic of Kazakhstan and RSE “Kazhydromet” have been widely used also [4-7].

Research methodology. The estimation and mapping of the water security of rural settlements by the type of distribution system (centralized, decentralized, imported) and water quality have been made with the use of statistical, comparative and spatial analysis methods along with the geographic information systems mapping software (ArcGIS 10.1). Spatial sampling methods have been used to identify the research area (impacted territories) within the boundaries of rural districts and their settlements.

Research results. On the whole, **t**he estimation and mapping of the drinking water security have been made over the territories of 8 Kazakhstan regions, including 561 rural districts and 1026 settlements.

The length of the research area along the track of MMTC is 8 150 kilometers. The population of the impacted area of MMTC is coming to 2 741 thousand people, which constitute 25,6% of the population of these regions.

Drinking water quality in rural settlements of Mangystau region. The amounts of Total Dissolved Solids (TDS) in the water of rural settlements of Mangystau region on 01.01.2015 are in an acceptable range and vary from 0,25 to 0,95 g/L (figure 2) [3]. Average TDS concentration in drinking water of the region is 0,45 g/L. Water of Kizilolen village of the Tupkaragay district has the highest levels of TDS. Centralized water supply is used by 27% of population of the region, decentralized by 72,8% and imported water is used by 0,2% (figure 3).

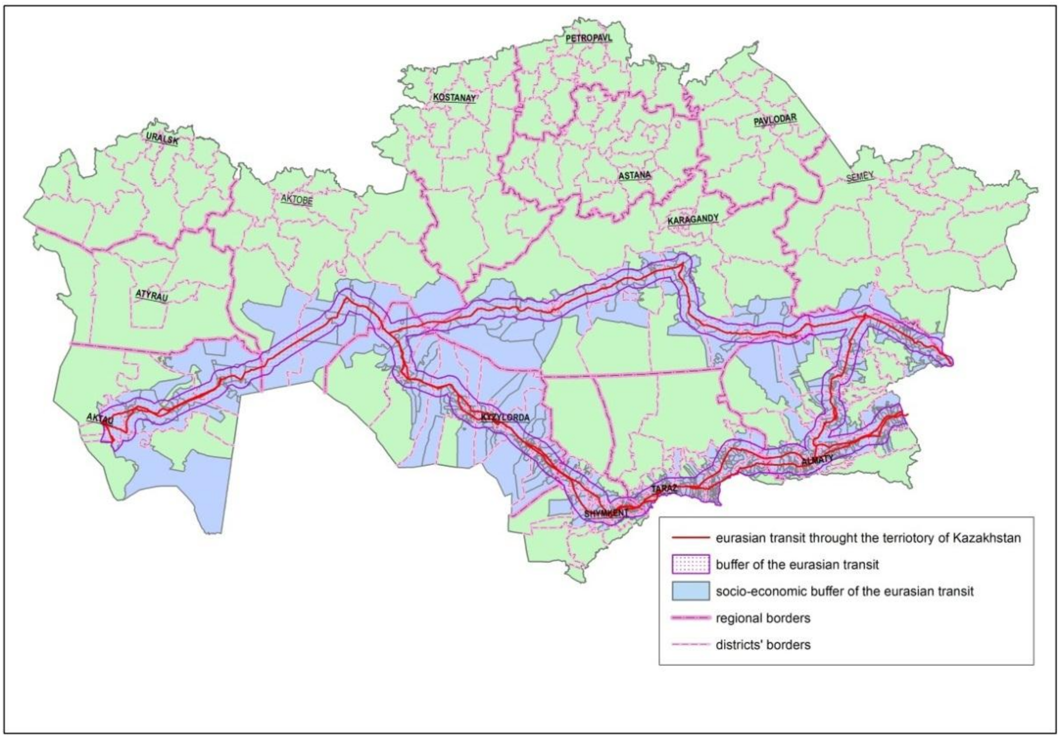

Figure 1 – Korgas-Aktau MMTC and the impacted territory within the boundaries of rural districts of 8 Kazakhstan regions

46 from 60 rural settlements of Mangystau region are located in the study area – zone of impact of the Eurasian transit. According to the data of 01.01.2015 the amounts of Total Dissolved Solids in the water of this region lie within 0,25-0,8 g/L and don’t exceed an acceptable range. The smallest TDS levels (relative to the region), lying in upper acceptance limits (0,2-0,5 g/L), have water of 64,5% of rural settlements (figure 4). They are mainly concentrated on the north-east of the region and to the south and south-east from the Aktau city. A bit higher, but lying in lower acceptance limits, amounts of TDS (0,5-1 g/L) have water of 35,5% of rural settlements of the area, they are located principally to northeast of Aktau.

Drinking water quality in rural settlements of Aktobe region.

According to the data of 01.01.2015, the amounts of Total Dissolved Solids in water of rural settlements of Aktobe region lie within 0,01-1,1 g/L.

Elevated values of TDS in water exceeding permissible level belong to rural settlements of Nura rural district of Irgiz district, located on the west of the region (figure 5) [3]. Average concentration of TDS in drinking water of the region is 0,49 g/L. Centralized water supply is used by 74,8% of population of the region, decentralized by 24,2% and imported water is used by 1,1% (figure 6) [3].

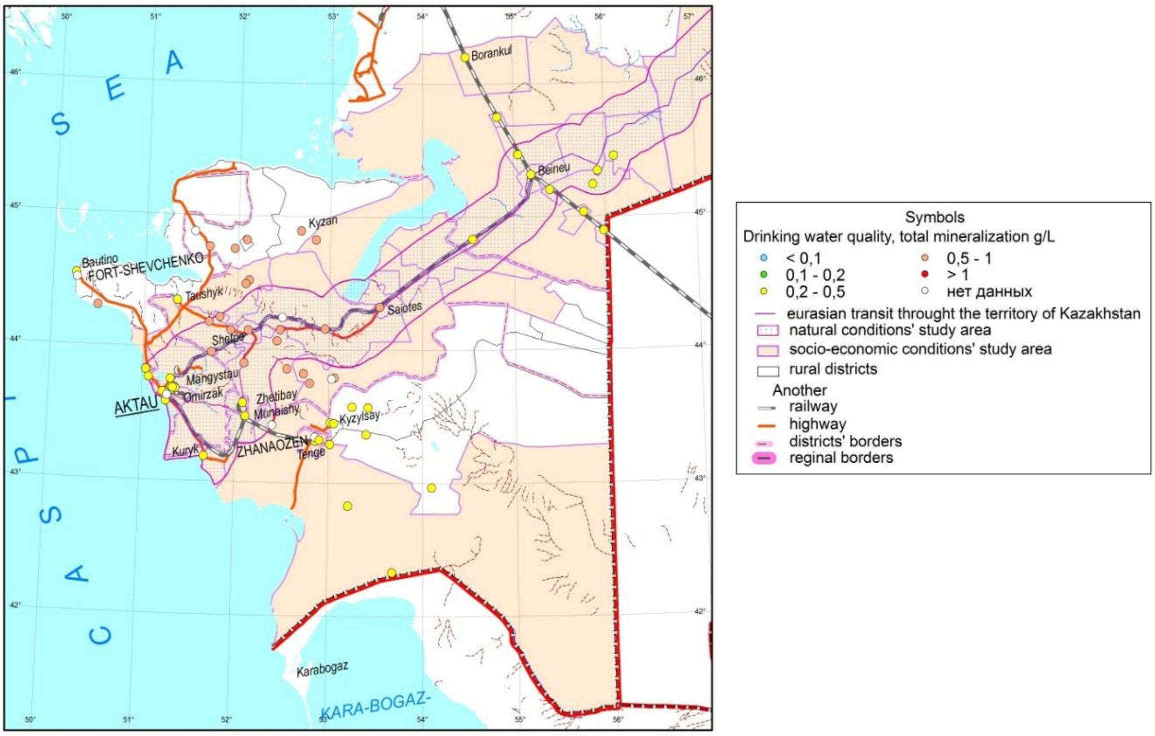

Figure 2 – Drinking water quality in the rural settlements of Mangystau region broken down by districts

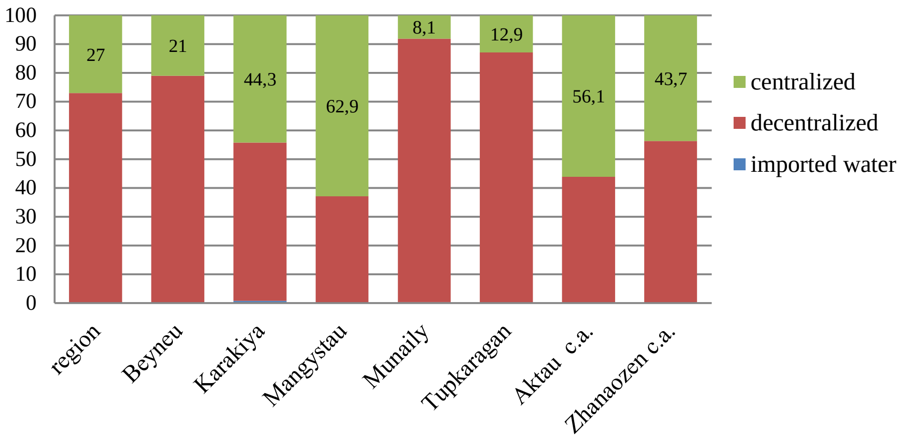

Figure 3 – Types of water supply of Manystau region broken down by districts

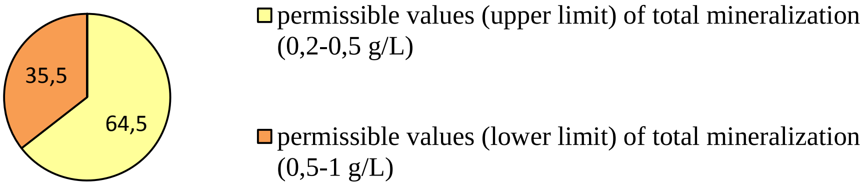

Figure 4 – Mangystau region affected area's rural settlements' distribution over the levels of water quality

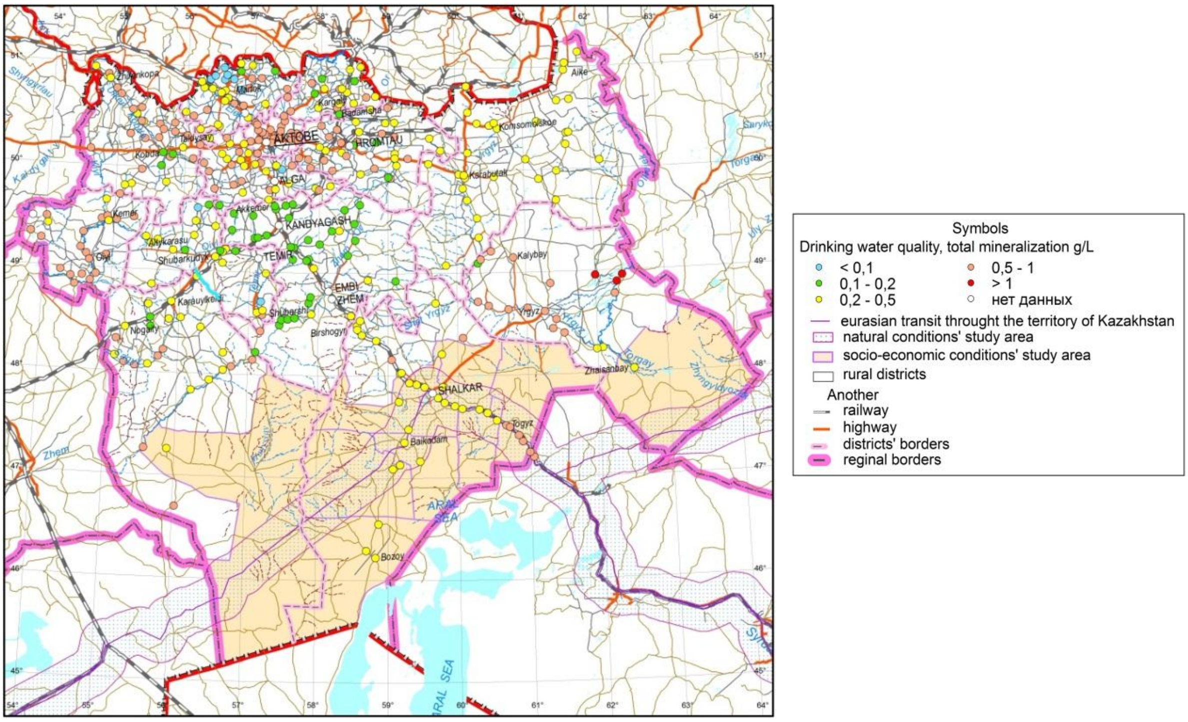

Figure 5 – Drinking water quality in the rural settlements of Aktobe region

Eurasian transit and it’s affected area crosses the south part of Aktobe region, covering 33 of 372 rural settlements. According to the data of 01.01.2015, the amounts of Total Dissolved Solids in the water of rural settlements of the region vary from 0,37 to 0,52 g/L and don’t exceed an acceptable range (figure 7).

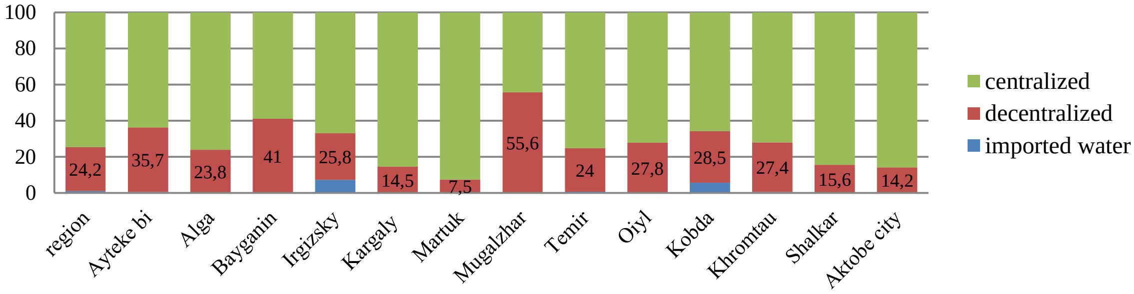

Figure 6 – Types of water supply of Aktobe region broken down by districts

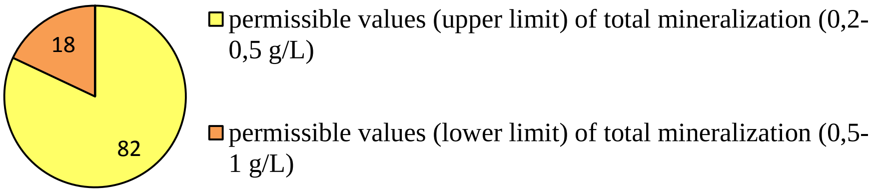

Figure 7 – Aktobe region affected area’s rural settlements’ distribution over the levels of water quality

Drinking water quality in rural settlements of Kyzylorda region. According to the data of 01.01.2015, the amounts of Total Dissolved Solids in the water of rural settlements of the region vary from 0,7 to 1,4 g/L (figure 8) [3] Water of the settlements of Karmakshy and Zhalagash districts has TDS values, outreaching allowable. Average concentration of TDS in drinking water of the region is 1,05 g/L which is slightly larger than acceptable. 93,4% of population of the region is using centralized water supply, decentralized - 6,6% (figure 9).

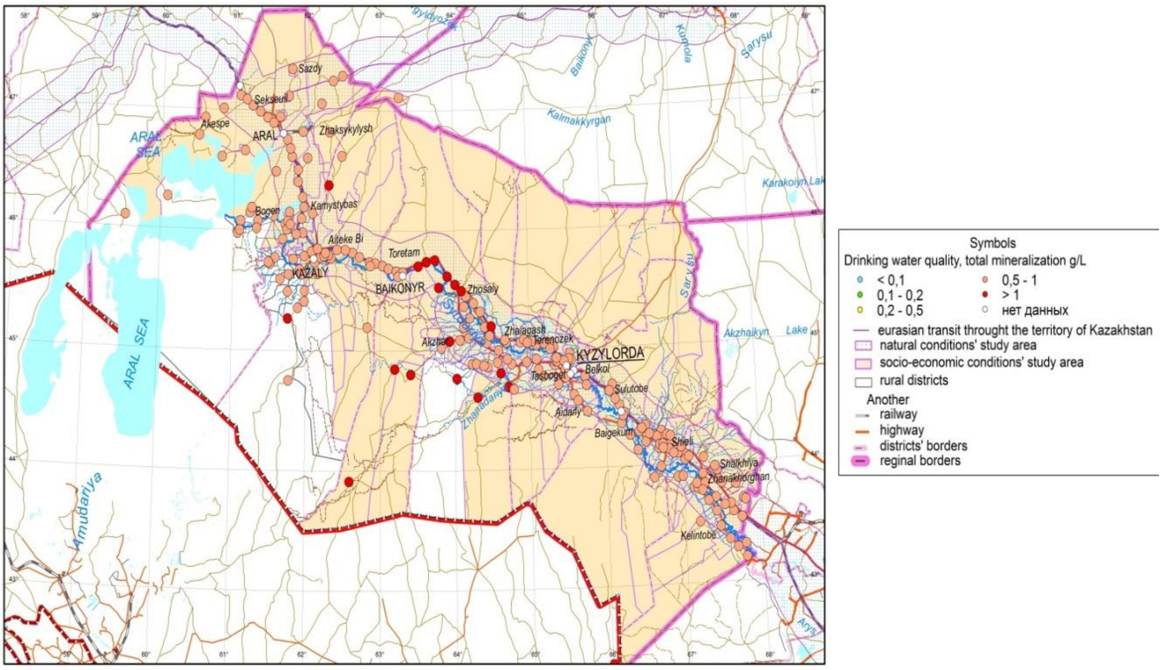

Figure 8 – Drinking water quality in the rural settlements of Kyzylorda region

Affected area of Eurasian transit crosses the entire Kyzylorda region, including 204 from 262 rural settlements. According to the data of 01.01.2015, the amounts of total mineralization in the water of the region’s rural settlements lie between 0,7 and 1,4g/L.

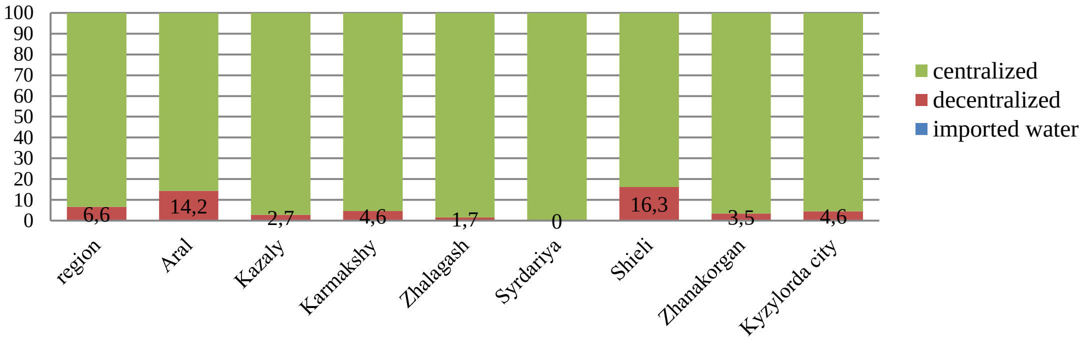

Figure 9 – Types of water supply of Kyzylorda region broken down by districts

Within the territory of the affected area, as well as on the whole region territory, there are no settlements with the amounts of Total Dissolved Solids in water within the normal range. Water of 92% of rural settlements have allowed values of TDS, the water of 8% of settlements, located between Baykonur and Kyzylorda cities, is inapplicable for drinking purposes (figure 10).

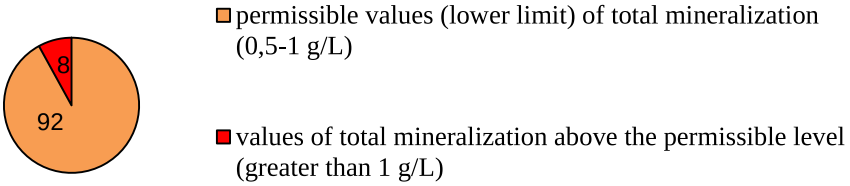

Figure 10 – Kyzylorda region affected area's rural settlements' distribution over the levels of water quality

Drinking water quality in rural settlements of South Kazakhstan region

According to the data of 01.01.2015, the amounts of total mineralization in the water of the region's rural settlements vary from 0,027 to 2,5g/L. Water of Tasty and Shu rural districts of Suzak district, situated on the north of the region, have TDS values, outreaching allowed. The level of TDS in the water of rural settlements near Shymkent and Kazygurt cities, and also of the Maktaaral district, located on the outside of the south of the region, is higher than it's permitted (figure 11). Average concentration of TDS in the drinking water of the region is 0,6 g/L. 84,4% of population of the region is using centralized water supply, decentralized - 15,6% (figure 12) [3].

The affected area of the Eurasian transit within the South-Kazakhstan region covers 237 of 879 rural settlements. According to the data of 01.01.2015, the amounts of total mineralization in the water of the region's rural settlements lie between 0,027 and 1,25g/L.

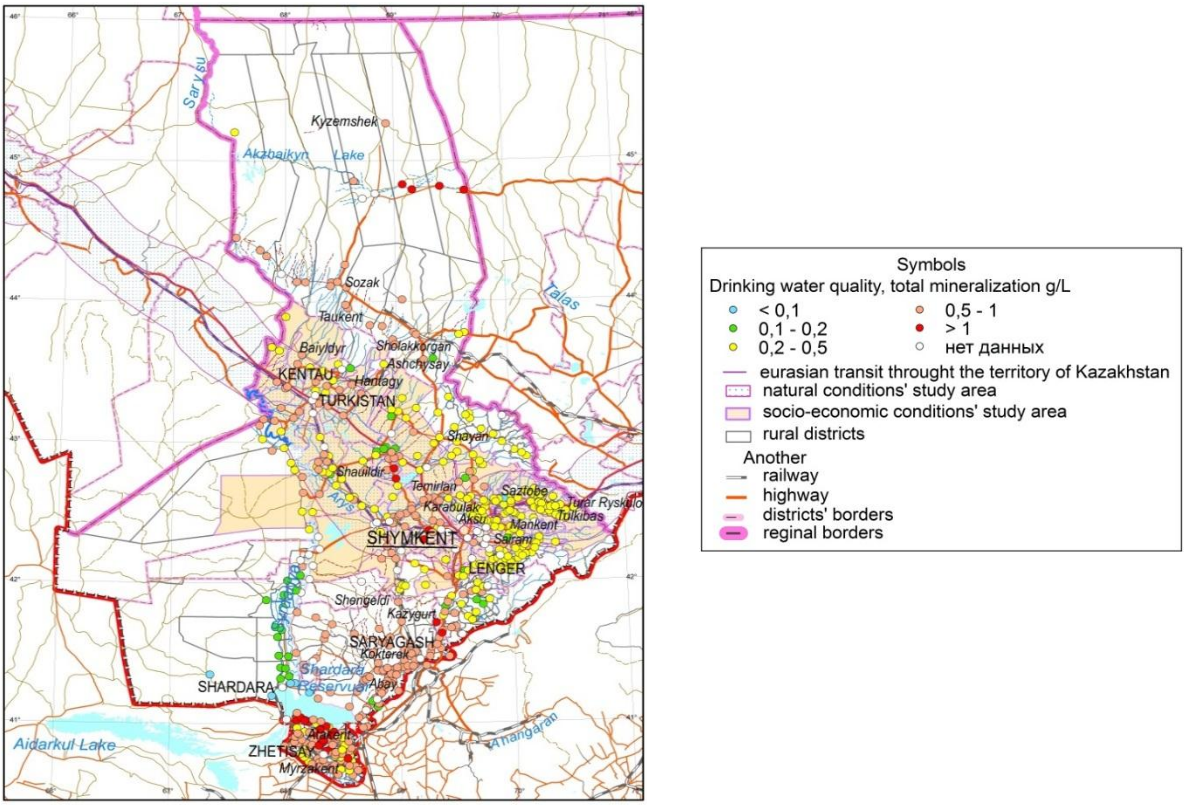

Figure 11 – Drinking water quality in the rural settlements of South Kazakhstan region

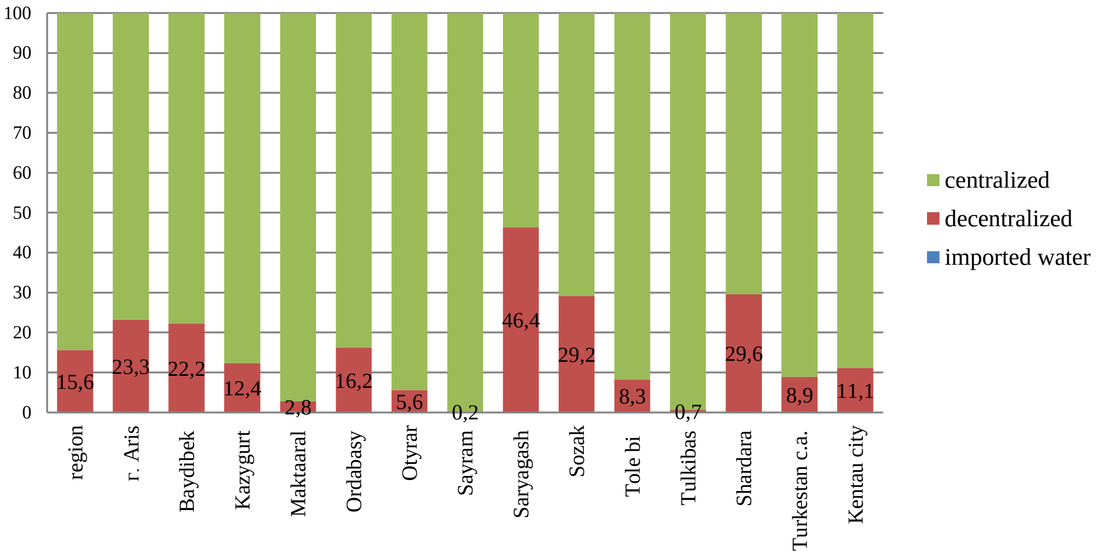

Figure 12 – Types of water supply of South Kazakhstan region broken down by districts

The amounts of total mineralization in water of the main part (93,5%) of the rural settlements located in the affected area lie within allowed levels. Water with TDS levels lying in upper acceptance limits are basically concentrated on the east of the region (figure 13).

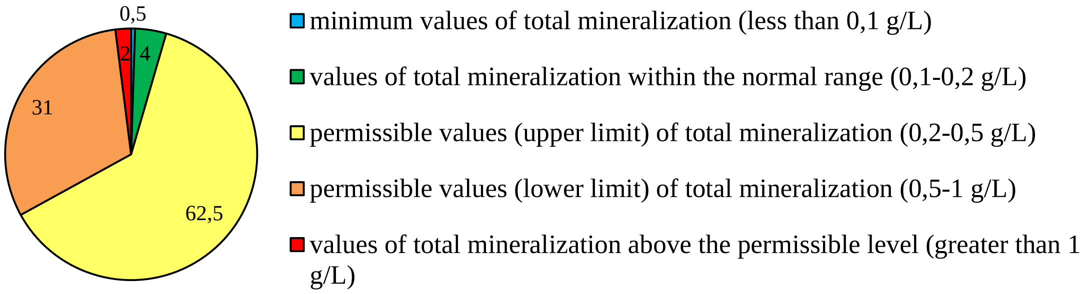

Figure 13 – South Kazakhstan region affected area's rural settlements' distribution over the levels of water quality

Drinking water quality in rural settlements of Zhambyl region. According to the data of 01.01.2015, the amounts of total mineralization in the water of the region's rural settlements vary from 0,07 to 1,3 g/L. Water of Akbakay and Karaboget villages of the Moinkum district, located on the north and at the center of the region, have TDS values, outreaching allowable. Average concentration of TDS in drinking water of the region is 0,45 g/L (figure 14).

Centralized water supply is used by 59,7% of population of the region, decentralized by 39,4% and imported water is used by 0,9% (figure 15) [3].

The affected area of the Eurasian transit within the Zhambyl region includes 181 from 373 rural settlements. According to the data of 01.01.2015, the amounts of total mineralization in the water of the region's rural settlements lie between 0,07 and 1 g/L. Water of 22,2% of rural settlements of the affected area which are concentrated on the south of the region and to southwest from Tasotkel reservoir have amounts of total mineralization within the normal range (less than 0,2 g/L) (figure 16).

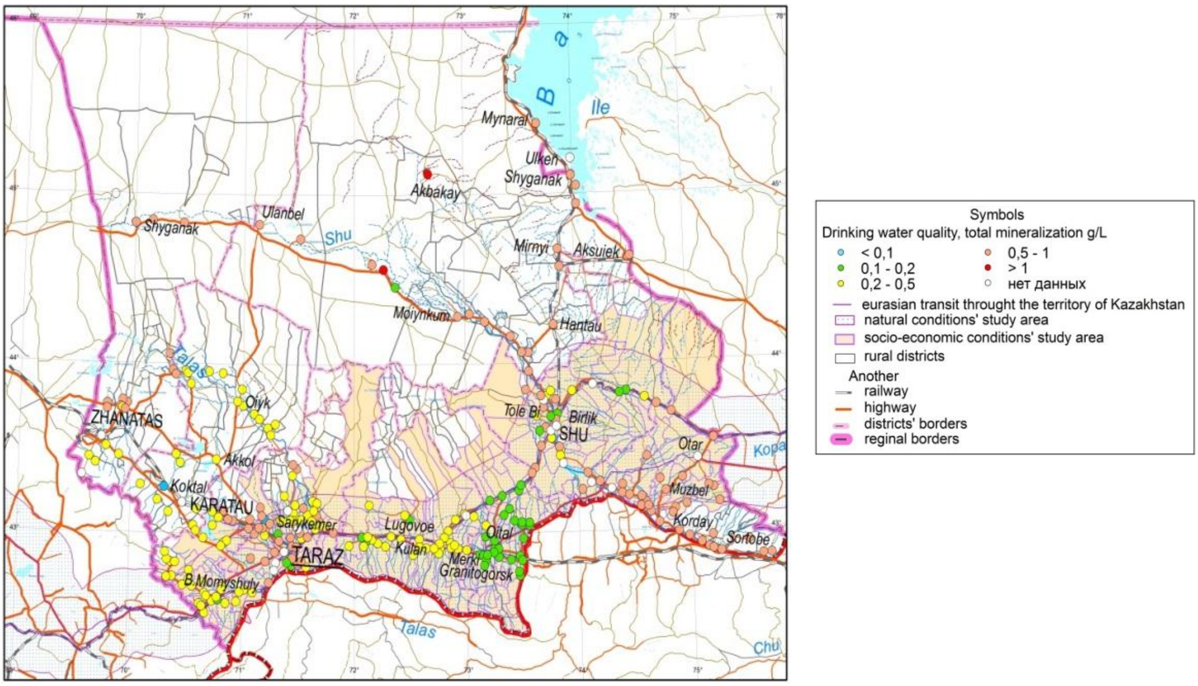

Figure 14 – Drinking water quality in the rural settlements of Zhambyl region

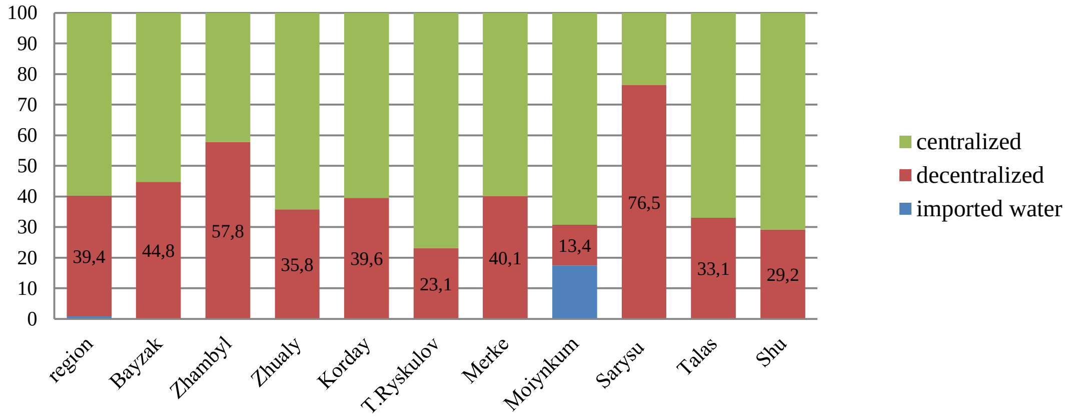

Figure 15 – Types of water supply of Zhambyl region broken down by districts

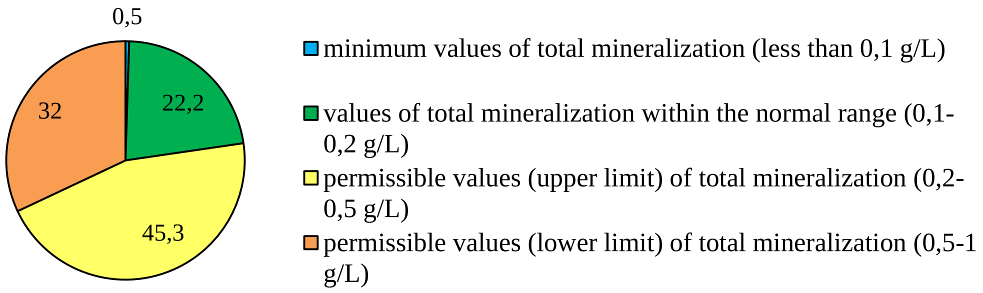

Figure 16 – Zhambyl region affected area’s rural settlements’ distribution over the levels of water quality

Water of the settlements with TDS levels, lying in upper acceptance limits are mainly situated on the south and southwest of the region. Water of the settlements with TDS levels, lying in lower acceptance limits are predominantly located on southeastern edge of the region.

Drinking water quality in rural settlements of Almaty region

According to the data of 01.01.2015, the amounts of total mineralization in the water of the region's rural settlements lie between 0,1 and 0,96 g/L. Average total mineralization of drinking water of the region is 0,36 g/L. Centralized water supply is used by 91,2% of population of the region, decentralized by 8,7% and imported water is used by 0,1% (figure 18) [3].

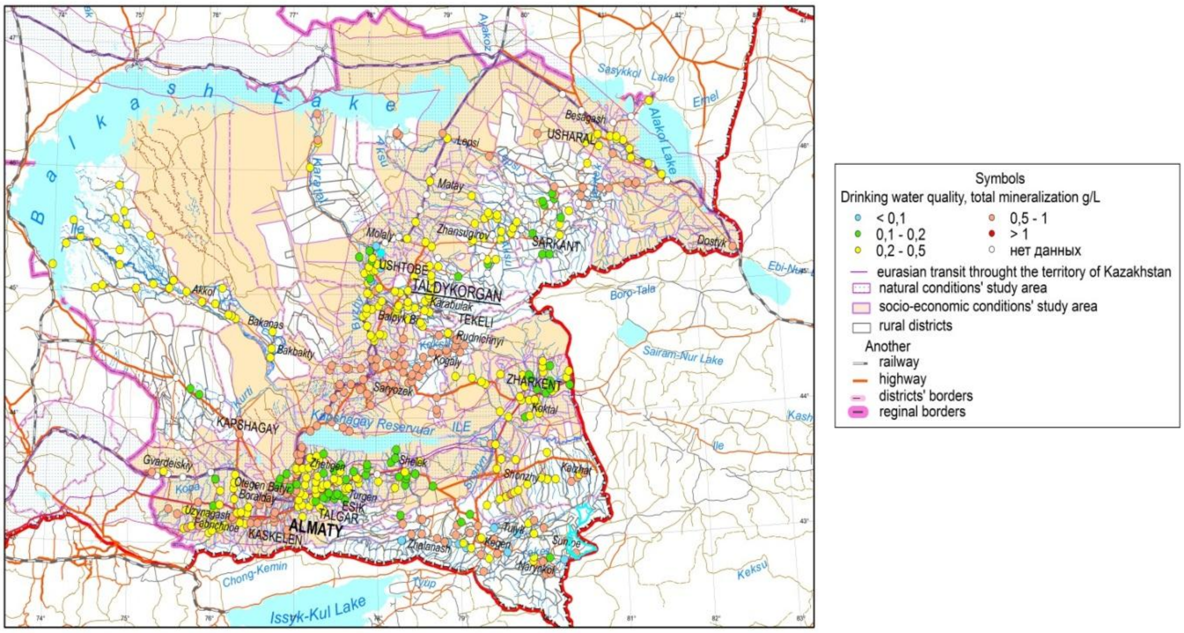

Figure 17 – Drinking water quality in the rural settlements of Almaty region

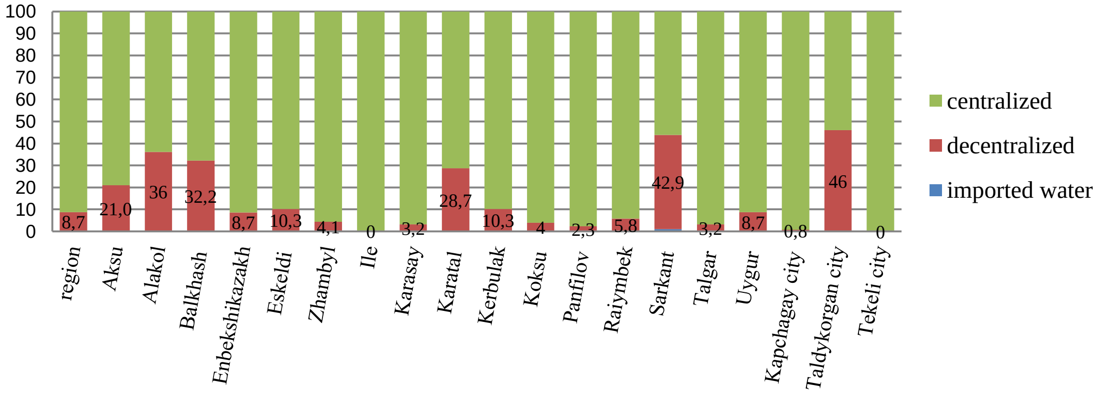

Figure 18 – Types of water supply of Almaty region broken down by districts

The affected area of the Eurasian transit includes 281 of 760 rural settlements of Almaty region. According to the data of 01.01.2015, the amounts of total mineralization in the water of the region's rural settlements vary from 0,1 to 0,96 g/L. Most of the affected area's settlements (83%) have allowed amounts of TDS in drinking water, 17% - in the range of norm and situated basically to the northeast from Almaty city. Settlements with allowed values of TDS in water are distributed all over the region (figure 19).

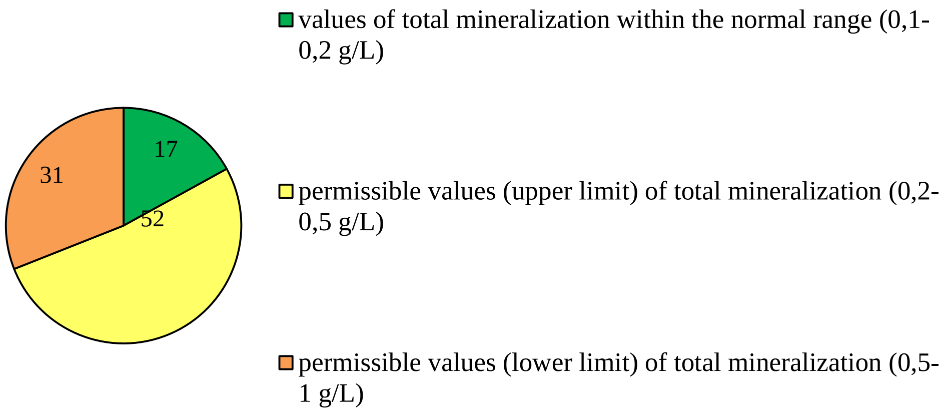

Figure 19 – Almaty region affected area's rural settlements' distribution over the levels of water quality

Drinking water quality in rural settlements of Karagandy region. According to the data of 01.01.2015, the amounts of total mineralization in the water of the region's rural settlements lie between 0,065 and 1,5 g/L. Located on the east of the region, Shabanbay bi and Karamende bi villages of Aktogay district have water with outreaching allowed levels amounts of total mineralization (figure 20). Average total mineralization of drinking water of the region is 0,54 g/L.

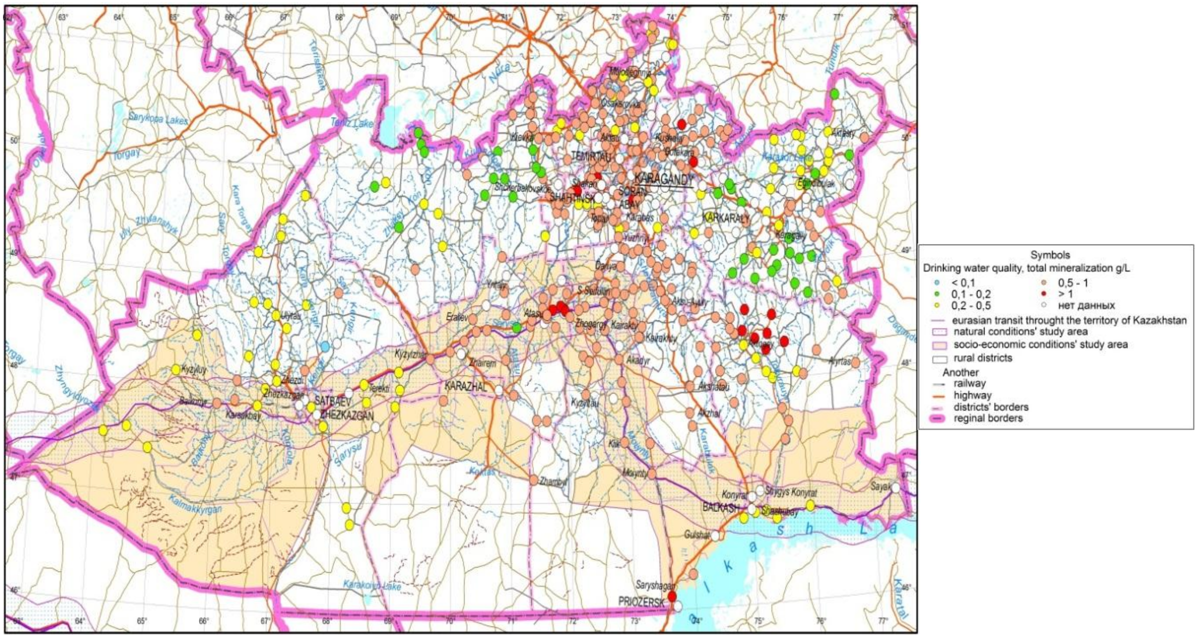

Figure 20 – Drinking water quality in the rural settlements of Karagandy region

Centralized water supply is used by 83,2% of population of the region, decentralized by 16,5% and imported water is used by 0,3% (fig.21). [3]

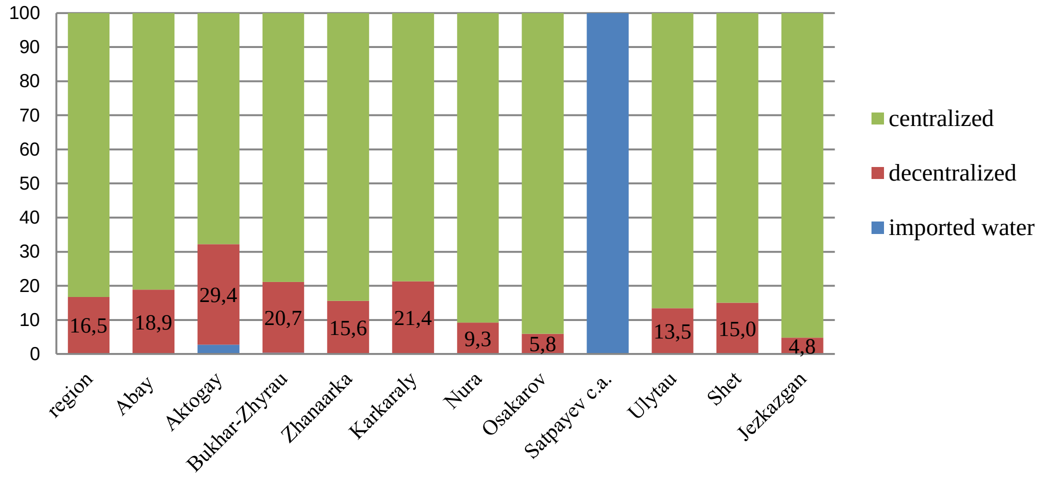

Figure 21 – Types of water supply of Karagandy region broken down by districts

The affected area of the Eurasian transit within Karagandy region covers 73 out of 421 rural settlements. According to the data of 01.01.2015, the amounts of total mineralization in the water of the region's rural settlements are 0,16 - 1,01 g/L. 1,4% of rural settlements have normal TDS levels in drinking water, 93,1% - allowed level (lesser than 1 g/L), and water of 5,5% of settlements isn't suitable for drinking (figure 22). Settlements with allowed values of TDS concentration in water are distributed all over the region.

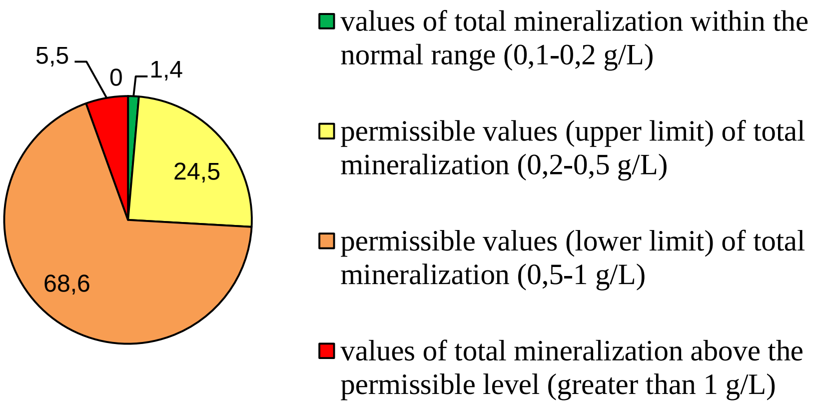

Figure 22 – Karagandy region affected area's rural settlements' distribution over the levels of water quality

Drinking water quality in rural settlements of East Kazakhstan region

The affected area of the Eurasian transit within the East Kazakhstan region includes only 17 of 765 rural settlements of the region. According to the data of 01.01.2015, the amounts of total mineralization in the water of the region's rural settlements are 0,38-0,7 g/L (figure 23) [3].

Centralized water supply is used by 66,6% of population of the region, decentralized by 32,2% and imported water is used by 0,1% (figure 24).

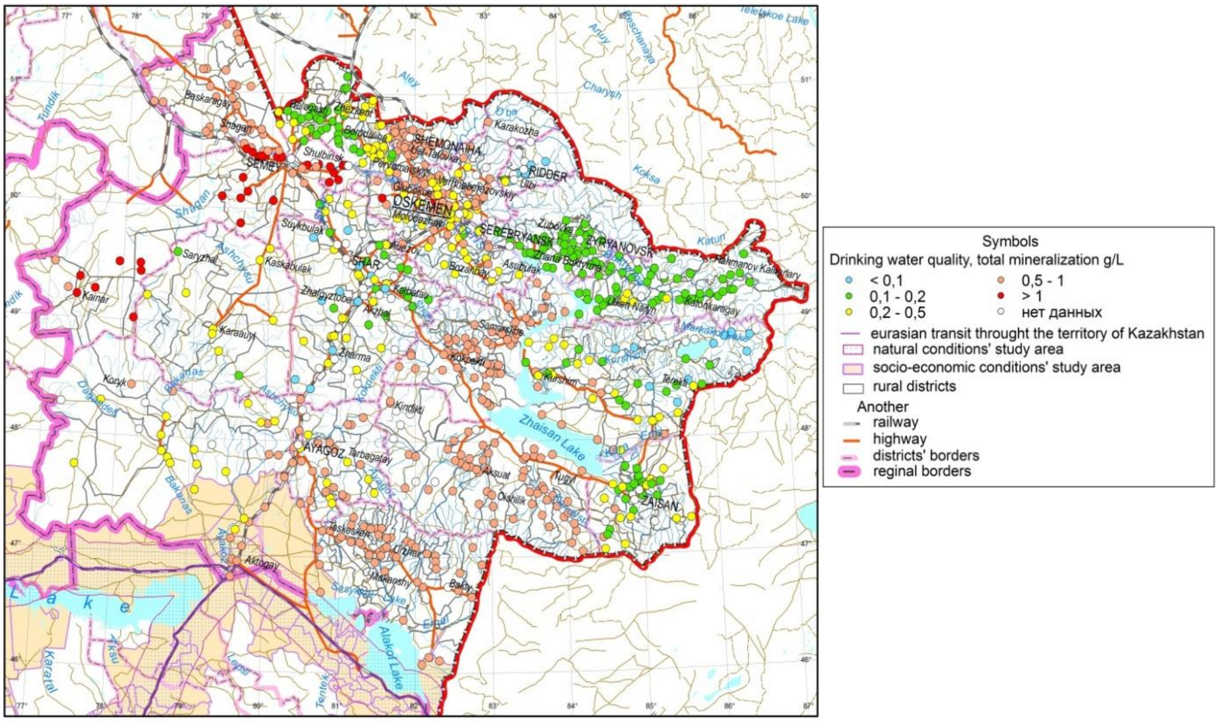

Figure 23 – Drinking water quality in the rural settlements of East Kazakhstan region

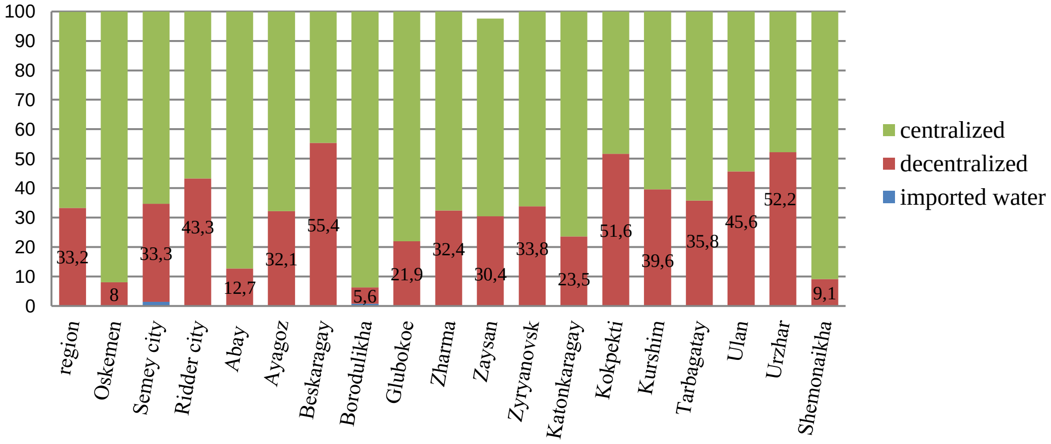

Figure 24 – Types of water supply of East Kazakhstan region broken down by districts

Conclusion

Thus, the amounts of TDS in drinking water exceeding norm are inherent for Kyzylorda region's rural settlements of the affected area of the Eurasian transit (figure 25, 26).

The estimation of drinking water quality in rural settlements in the affected area of Eurasian transit crossing 8 Kazakhstan regions indicated that the main amount (92%) of the settlements has permissible values of TDS of drinking water lying between 0,2 and 1 g/L.

Only 0,5% of Zhambyl and South Kazakhstan regions' settlements are characterized by drinking water with total mineralization lesser than 0,1g/L.

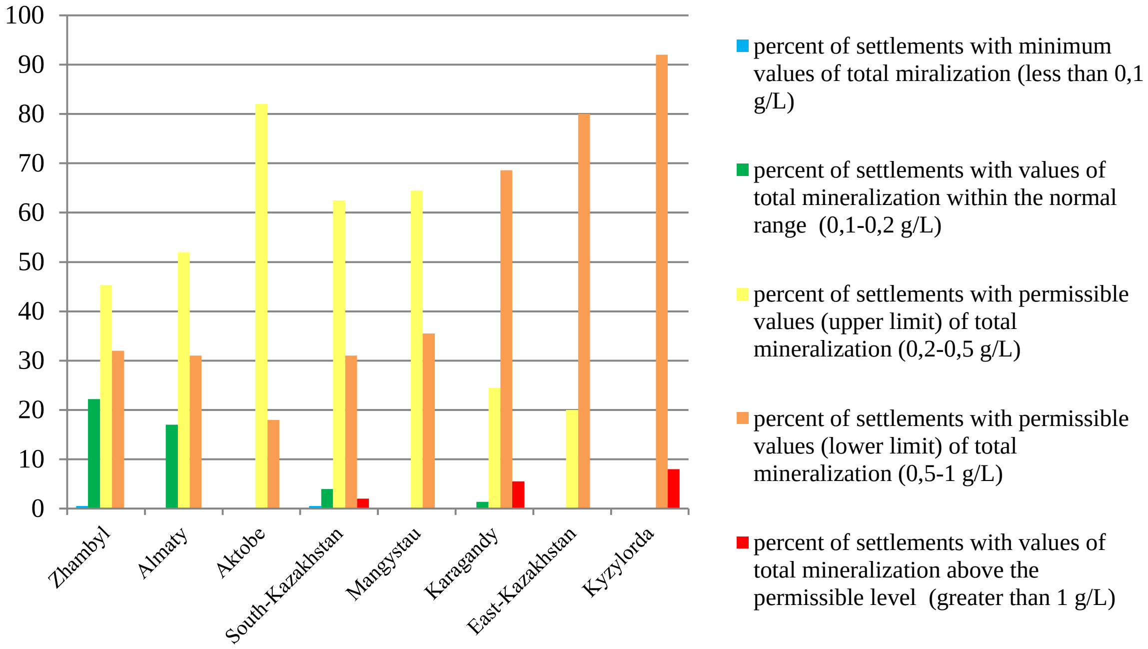

Figure – 25 Affected area’s rural settlements’ distribution within 8 regions over the levels of water quality(summary table) (%)

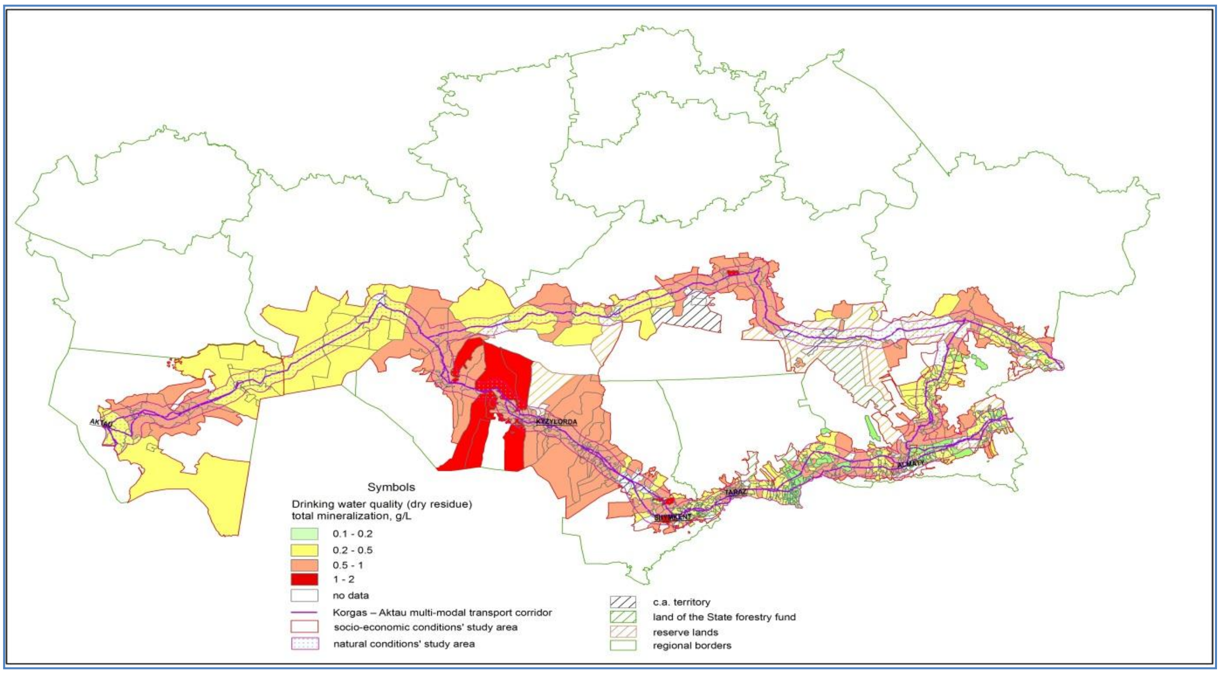

Figure 26 – Drinking water quality assessment map (over total mineralization, g/L)

Slightly larger percentage of the settlements with water TDS values within the normal range is related to Almaty, Zhambyl and South Kazakhstan regions.

Karagandy, Kyzylorda and South Kazakhstan regions have settlements with water unsuitable for drinking.

Regions crossed by Eurasian transit have different surface water availability [4] (figure 27, 28).

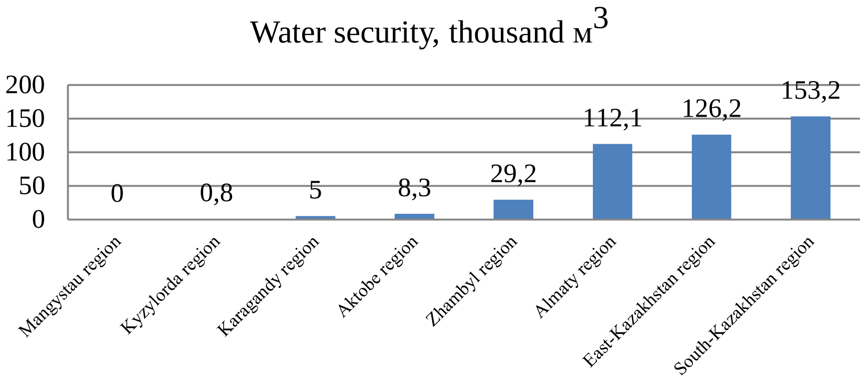

Figure 27 – Surface water availability, per square kilometre

The highest water availability levels (more than 100 000 m^3) is related to Almaty, South and East Kazakhstan regions, the lowest (critical values of less than 17 000 m^3) to Mangystau, Kyzylorda and Karaganda regions.

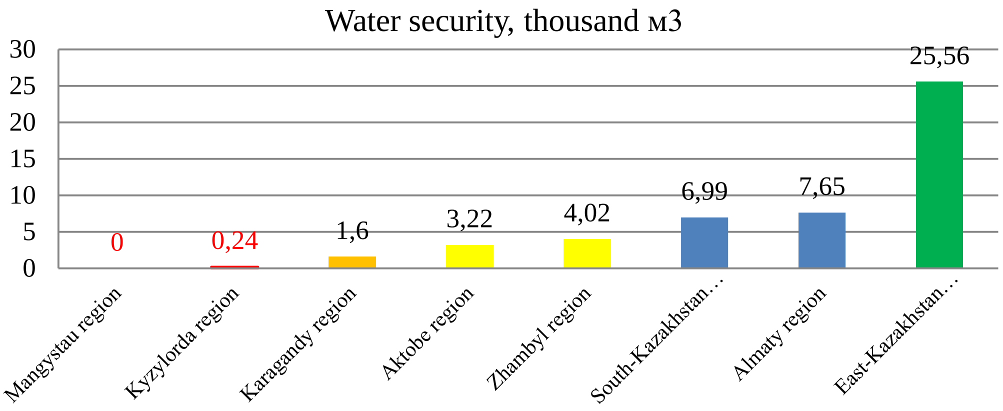

Figure 28 – Water availability per capita

Water availability per capita of Mangystau, Kyzylorda and Karaganda regions doesn't reach the threshold of 17 000 m^3 and corresponds to the situation of water crisis [5]. In compliance with preliminary forecast estimation of the population for 2030, conducted under General scheme of territory organization of the Republic of Kazakhstan, rural population of reviewed 8 regions is expected to grow in general by 1 100 000 people. Based on the fact that at that time most of the population of the viewed regions doesn't have enough resources of qualitative drinking water, considering also inflow of people serving MMTC, it must be said that to provide increased in the future number of people, a set of assistant activities is highly requested to be scheduled today.

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TRANSBOUNDARY GOVERNANCE OF THE RHONE RIVER, THROUGH INTEGRATION, MONOFUNCTIONALITY AND POLYCENTRICITY

The Rhone in one of the major European transboundary Rivers. It stretches from its source in the Swiss Alps, and then down through France toward the Mediterranean Sea. Considered mainly as a source of hydropower production for many decades, the increase of environmental norms and the emergence of new water uses (nuclear power plants, irrigation, etc.) strongly modified how the river was managed.

Today, the Rhone is undergoing different changes that challenge its governance structure, leading to new types of crisis and uncovering an increasing number of uncertainties that need to be answered. In this framework, the Rhone Basin is particularly interesting especially because of its lack of institutionalized transboundary coordination mechanisms between France and Switzerland. In consequence, this case shows issues of upstream-downstream coordination comprising a great multiplicity of involved stakeholders.

With this contribution, I will follow two main objectives. Firstly, I will focus on the main changes (and challenges) that the Rhone River’s governance structure experiments. I will focus on how governance structure deals with major changes at the political and economical levels but also with changes occurring due to climate changes. Then, reflecting upon these different changes, I will present different governance scenarios regarding the transboundary management of the Rhone River. Grounded into both empirical and theoretical insights, three regimes are identified helping to reflect on river's transboundary governance: i) integration, ii) monofunctionality and iii) polycentricity.

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DOMESTIC WATER LAWS FOR EFFECTIVE GOVERNANCE AND FOR COMPLIANCE WITH INTERNATIONAL COMMITMENTS

An articulate, comprehensive and effective domestic legal framework for water resources is critical to the effectiveness and stability of water governance domestically. It will also set the stage for States to negotiate with confidence and to make commitments internationally, and to honour such commitments. Comparative analysis and experience from other countries indicate that domestic legal frameworks for water have (a) consistently transitioned water resources from the landowner’s (and the polluter’s) exclusive availability to the State’s allocative control and protection and, as a direct consequence, (b) regulated water abstraction, and point-sources of pollution. More advanced contemporary legal frameworks for water tend also to address (c) the environment-support function of water in the regulation of allocation and uses; (d) the impact that uses of the land (notably, for cultivation and animal rearing) and of the subsurface space (notably, for mining and underground storages) have on water resources and, in particular, on the natural recharge& discharge processes of groundwater, and on groundwater quality; (e) linkages occurring in nature, or artificially through managed aquifer recharge, between groundwater and surface water, with a view to managing surface water and groundwater conjunctively; (f) the role of water users helping offset the limitations inherent in the reach of the State’s regulatory authority and powers; and (g) the informal rights and practices of traditional communities out in the rural areas, with a view to defusing the potential for conflict between the formal and the informal legal systems in relation to water. Insofar as they make the difference between domestic water regulation being operational and complied with, or remaining dead letter, implementation and enforcement are a critical facet of an effective legal framework for water.

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IMPACT OF CLIMATE CHANGE ON RUNOFF IN THE REPUBLIC OF KAZAKHSTAN

The dynamics of surface runoff in Kazakhstan under the impact of climate change temperature and precipitation analyzed. It is shown that in the absence of synchrony and coherence in the climate changes in temperature and precipitation throughout the territory of the Republic for the forecast of climatic changes in surface runoff it is necessary to analyze the climatic changes and the dynamics of runoff for each basin separately. For example the analysis of the dynamics and the constructed scenario runoff changes for the period up to 2040 for basin Ural River (Zhaiyk) was fulfilled. The high sensitivity of surface runoff of rivers of the arid zone to climate change was received.

Introduction. The Republic of Kazakhstan is situated in the center of Eurasian continent and ranked ninth in the world in the area of its territory (about 2.72 million km^2) and approximately the sixteenth largest in terms of surface runoff on square unit only [1]. The cause of this is a significant distance from the oceans, primarily from the Atlantic (over 5000 km), and particularities of the General atmospheric circulation, promoting the removal of dry tropical air during the warm period and the influence of the Siberian anticyclone during winter, it is also not conducive to the cloud and precipitation.

Figure1 – Location of the Republic of Kazakhstan in the Northern hemisphere.

As a result, only in the extreme North-West and the North of the territory the rainfall reaches 400 mm/y or more, the some time evaporation exceeds 800 mm/y throughout all territory of the Republic. Only for the foothill and mountain areas of the South-East of the territory and the Kazakhstan Altai is characterized precipitation exceeding 400 mm/y [2]. As a result of shortage of rainfall and regular movement to the territory of the Republic of dry tropical air masses, the share of deserts and semi-deserts accounts for up to 58% of the territory. About 10% of the territory is occupied by mountain systems: Altai in the East, Zailiyskiy and Dzungarian Alatau in the South - East. The Central part of the territory is occupied by the Kazakh low hills, and in the North-West South Ural is located with its continuation to the South as Mugodzhary ridge with a maximum elevation of 700 m [1].

The total average annual surface runoff amounts to 100.5 km³. Of these, only 56.5 km³ are formed on the territory of the Republic, and the remaining 44 km³ come from neighboring areas of China, 18.9 km³, from Uzbekistan-14.6 km³, Kyrgyzstan 3.0 km³, Russia 7.5 km³ [3]. Interannual variability of surface runoff is large. It is in wet years can be two times higher than normal, while in the dry year is three times below the norm. In addition, there is a large intra-annual and asymmetry in the distribution of runoff. Up to 90% of runoff of steppe rivers refers to spring, while 70% of the runoff of mountain rivers - to the summer. The specific water availability in Kazakhstan is about 6 thousand m³ per one citizen per year. This is the lowest supply among all the countries on the territory of the former USSR. In fact, all branches of economic activity in the Republic lack of the water, and for some, e.g. for agriculture, water scarcity is a limit to development. Security of the population, agriculture and industry by water of required quality is a strategic priority for the state.

According to estimates made by the Russian science hydrological institute at the beginning of the nineties of the last century, average long-term runoff was estimated at 126.0 km³, of which the local runoff accounted for 66.8km³ and 59.8 km³ as cross border runoff. Consequently, surface runoff has decreased over this time by approximately 25.3 km³, of which the local flow has decreased by 10.3 km³ and transboundary – by 15.2 km³[3]. The reason for this change of flow is considered as the intensification of economic activity, especially in foreign countries, and climate change. This shows that the assessment of possible changes in runoff in the coming decades on the territory of the Republic in connection with climate change is very important. Our study problem is devoted to this problem.

Seemed most expedient to adhere to the following order of studies:

- on the example of the Ural river basin to analyze climate variability time series of temperature and precipitation over the past century and to assess the sensitivity of surface runoff to such oscillations, find the matching quantitative relationships;

-then to build a scenario of climate change temperature and precipitation for the coming decades for the basin of the Ural river, as an example of similar calculations for the other basins;

- further, to construct scenarios of changes in temperature and precipitation for the whole territory of the Republic;

- to assess in principle the possibility of predicting surface runoff for the whole territory of Kazakhstan;

- based on expected climatic changes in temperature and precipitation to draw General conclusions regarding the dynamics of surface runoff under climate change.

Materials and methods. *Data.* Used in the work, first of all, official data of the National hydro meteorological service of Kazakhstan on the average monthly temperatures and rainfall for the stations in Kazakhstan during the twentieth century to the present. In General when we studied problems in addition to Kazakhstan data were used data for the South of Western Siberia and the southern Urals. All inputs are passed strict technical and critical controls. Were also used data from several field studies performed in the basin of the Ural River on the territory of Kazakhstan, and kindly provided to us.

Methods. In the study of the temporal dynamics of temperature and precipitation we have approximated our ranks by a polynomial of the sixth degree, which is good on the one hand smoothes the time series, retaining, however, climatic extremes, and on the other, the polynomial is quite sensitive to the sign change of the dynamics in just several years.

Simultaneously approximating a time series by a polynomial of the sixth degree, we widely used harmonic analysis of series, which, as we know, involves the decomposition of the original time series into trigonometric functions [4].

If a sixth-degree polynomial smoothes a time series, quickly responding to trends in dynamics, harmonics characterize the internal structure of the series. Each of the harmonics, at least basic ones, usually interpreted as the result of exposure to a particular group of factors. There is no reason to believe that the factors that existed during the formation of climate before, suddenly disappears.

The coincidence of the directions of the approximating lines and the dynamics of the sums of the amplitudes of the main harmonics shows whether the approximated changes random or they are caused by the major harmonics.

The results of studies in the Ural river basin. *The hydrological regime.* In recent decades, when determining natural runoff of the Ural River and its components, the challenges are considerable, due to the influence of the magnitude of human economic activity. Therefore, the restoration of natural runoff of the Ural River on the border with the Russian Federation represents to the Republic of Kazakhstan of critical importance in addressing issues of joint use of water resources of transboundary rivers under consideration [5-7].

Restoration of the natural runoff of the Ural River in the Orenburg station was carried out by us by adding to the observed domestic flow values of water intake for economic needs in the basin, in the amount of 25 m^3/s per year according to [5], etc.

The total water inflow from Russia by the Ural River is estimated as the sum of runoff of the river Ural – Orenburg, Sakmara – S. Keragala (Sakmara), Shagan and others. Average value of the discharge of these tributaries is still 8674 million m^3, of which 4510 million m^3 act on the Ural River and 3312 million m^3 on the river Sakmara, respectively. During the period of global warming, i.e. since 1980, water resources of the study area increased to an average of 10.8 km^3/year or 10% compared to the period of 1936...1977. On the territory of Russia is formed about 8.5 km^3/year of runoff, and within the Republic of Kazakhstan – up to 1.6 km^3/year.

The flow period of 1974...2007 is not very different from many years value. In slow runoff years 75 % probability the flow of water from the territory of Russia is reduced to 6024 million m3 respectively. In very dry years (97 % availability) these resources are at these points in time are 2349 and 3280 million m^3 respectively [5, 6].

On untributary 587 –kilometer strip from post Kushumto post Makhambet runoff value with probability 50% reduced 24%, i.e. on average by 4% per 100 km, and an average of 6500 million m^3. In dry years, the runoff decreases with the availability of 75 % to 5456 million m^3, and security 97 % –3006 million m^3 [7]. On the 118-kilometer stretch from post Makhambet, to post Guryev (Atyrau) runoff decreases by only 3...4%.

In regulated river flow to establish the relationship between the amounts of precipitation falling in her watershed and runoff is very difficult. Reservoirs smooth out the natural fluctuations of the flow. Therefore, a thorough analysis was subjected to a period of not regulated flow. Over a period of runoff of the Ural River is considered to be a series until 1958, when it started filling the Irikla reservoir of long term regulation, which ended in 1966.The total reservoir capacity is about 3.26 km^3 and useful is 2.8 km2. Long-term flow regulation is ensured with a guaranteed return of water to 0.5 km^3/year or 15.1 m^3/s. Later were built also Verkhneuralsk and Magnitogorsk reservoirs of smaller capacity. In numerous reservoirs on the territory of Russia accumulates up to 3.5 km^3.

We have found that in the context of global warming there has been a marked intra-annual redistribution of runoff and increased runoff in autumn and winter, which significantly reduced the annual variability of its values. The variability of runoff in the district of Orenburg was previously estimated $C_v=0.86$, and now we got a value of 0.55.

In the alignment post Kushum average of the annual maximum discharges has decreased by about half, and the standard deviation is almost 2.5 times. The presence of Iriklia reservoir is not the only reason for the decrease of maximum runoff. From the middle of the seventies of the twentieth century global warming has begun and it affected the runoff of the rivers of the Ural Mountains.

With the introduction of Irikla reservoir, the transformation of the maximum water flow has become even greater. Calculations show that in the period after 1974, i.e., the filling of the reservoir, the maximum flow security 1% on the strip Kushum-Topoli is declining at a rate of approximately 11% per 100 km of channel. On the strip from the post Topoli to Atyrau (118 km) average decrease of maximum of runoff is only 3.3%.

After 1974, the maximum water levels along the river declined, in some areas the reduction is greater than 2 m, and the valley was inundated much less frequently. To estimate the width of the river was used the data of gauging stations and data of number of forwarding surveys of the floodplain. The width of the flooding depends on the morphology of the floodplain. Below Atyrau, the river-bed widens from 200 m to 300...500 m at the present time, although according to the data obtained up to the seventies, in the lower reaches, the floodplain was flooded for 6-8 km, and sometimes up to 15 km [7].

The creation of Irikla reservoir has significantly changed the maximum levels and water flows in the lower reaches of the Ural River, reducing the threat of flooding. The maximum water flow rates with decreased 1.5...2.0 times. It has also been affected by the warming climate, manifested mainly through evaporation loss and infiltration along the river, and also in increasing water intake and subsequent losses.

Analysis of climatic factors. *Temperature and precipitation.* In the study of the dependence of runoff from climatic conditions seem necessary to first try to find a link between the precipitation falling on the areas of runoff formation and runoff. For this, we tried to attract data stations of Ufa, Sverdlovsk (Yekaterinburg), Magnitogorsk, etc. located in areas of runoff formation. Such data, i.e. time series of temperature and precipitation for the twentieth century are available, but for various reasons they contain gaps. Therefore, for analysis we used data from two stations Uralsk and Kostanay, located on the territory of Kazakhstan, but close to the regions of runoff formation. Ural station is situated close to the Western catchment and the station Kostanay – to the East one. Since the station Uralsk and Kostanay are close enough to areas of the watershed, they should be good enough to reflect large-scale meteorological conditions of runoff formation to the West and East of the southern Urals. For the analysis we chose the period from 1932 to 1958, when the drain of the Ural River has not been regulated. Then calculated the annual amount of precipitation at the two stations, after which was built the correlation graph of the relationship between total rainfall and runoff of the Ural River in the area of post Kushum (Uralsk), i.e. on the territory of Kazakhstan, below the confluence of the right tributary of Sakmara (Figure 2).

From figure 2 we can see that between the curves of cumulative rainfall and runoff of the Ural River there is a good agreement, especially in the years of maximum runoff. Therefore, the selection of stations for precipitation, which we studied processes in both areas of runoff formation, was successful.

The maximum flow occurs when at both stations the greatest amount of precipitation. The rule works that after a small amount of precipitation in the basin, and their sharp growth it does not lead to the same increase of runoff because of the precipitation goes into soil moisture, the filling of lakes, depressions etc [8].

It is also noticed that the sharp decrease in precipitation after max leads to the same decrease in runoff, because accumulated earlier water supportsrun off. The linear trend of the total precipitation at the stations Uralsk and Kustanai indicates that there is a noticeable growth (regression equation shown in Figure 2). This is consistent with studies [5], according to which the drain is also increased.

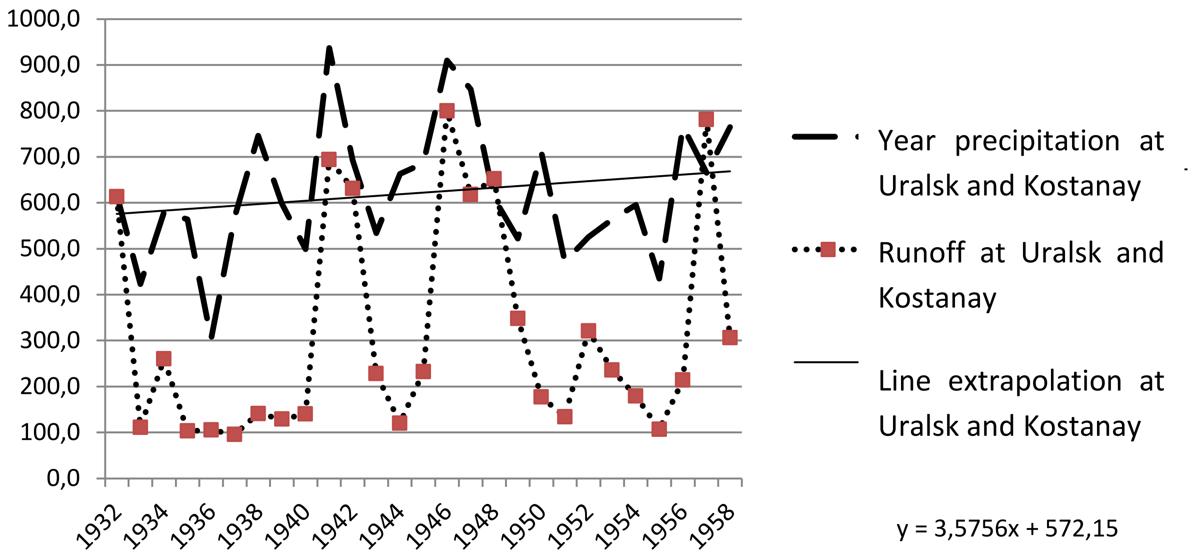
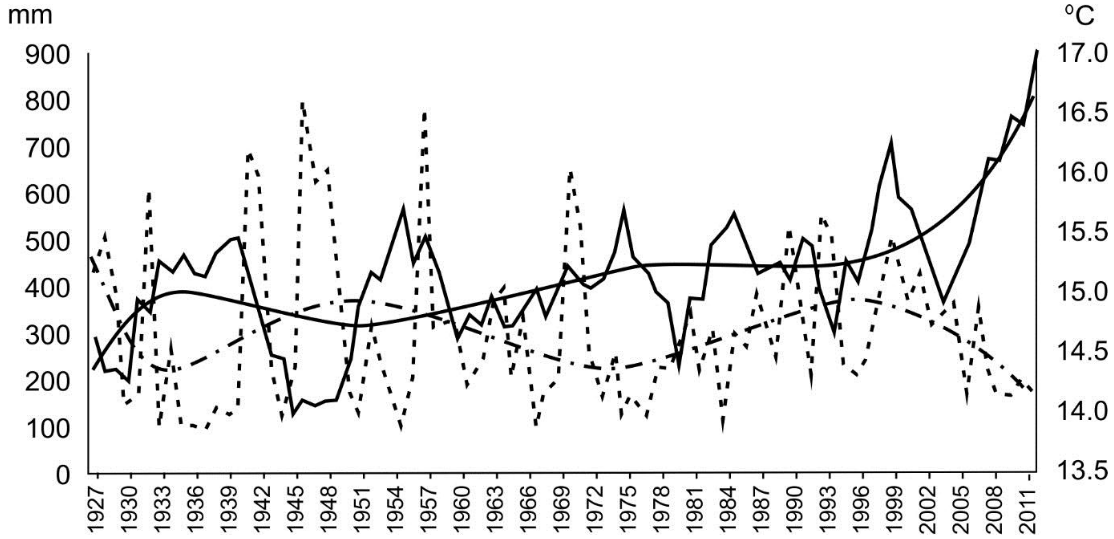


Figure 2 – Comparison of total annual precipitation values article Uralsk and Kostanay and water flow of the river Ural (Kushum post).

The dynamics of the flow It was further investigated the relationship between the time series of precipitation and temperature in the Uralsk region, on the one hand, and fluctuations of the runoff of the Ural River on the other.

The time course of water flow at the station Kushum, located almost at the entrance of the Ural River on the territory of Kazakhstan shows that during the period 1921...2007 values, the annual consumption of water varied from 89.1 to 800.0 m³/s (Figure 3 and 4).



–––– the flow waters of the Ural River; - the average air temperature in warm period in station Uralsk, calculated over a rolling five- year period; —— the trend line of average temperatures during the warm period;––––the trend line of water flow.

Figure 3 – The time course of the water flow of the Ural River and the average air temperature for the warm period in meteorological station Uralsk, calculated over a rolling five-year period.

We can notice a large variability from year to year, especially before 1973, while the polynomial trend shows that about 1930 and 1977 took place the climatic minima of precipitation, and about1950 and 1998 - climatic maximums. In the period from 2003 to 2007 there was a decrease in water consumption.

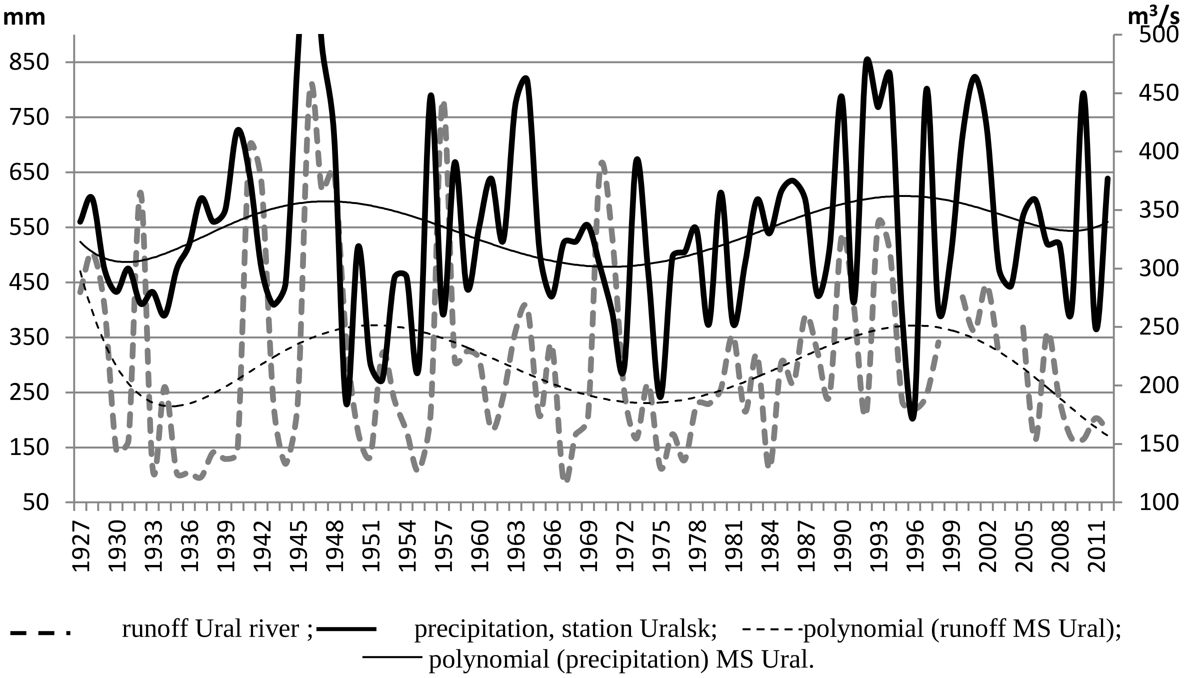


Figure 4 – The time course of the water flow of the Ural River and the annual amount of precipitation for the meteorological station Uralsk, calculated over a rolling five-year period.

Excluding the beginning and end of the rows, we can conclude that throughout the range of water flow replicates the time course of rainfall. Therefore, we can conclude that the time series of rainfall, as well as time series of temperature reflects the time course of the drain and tasks for the assessment of runoff changes under the influence of global climate change, at least at the level of General assessments, these data can be used without recourse to other information.

Purely qualitatively analyzing the time course of water flow and temperature (figure 3), as well as water flow and precipitation (figure 4), it should be noted that in the first case, there is a good negative, and the second positive connection. In this regard we tried to assess the correlation between the smoothed time series of water flow and temperature and flow of water and precipitation.

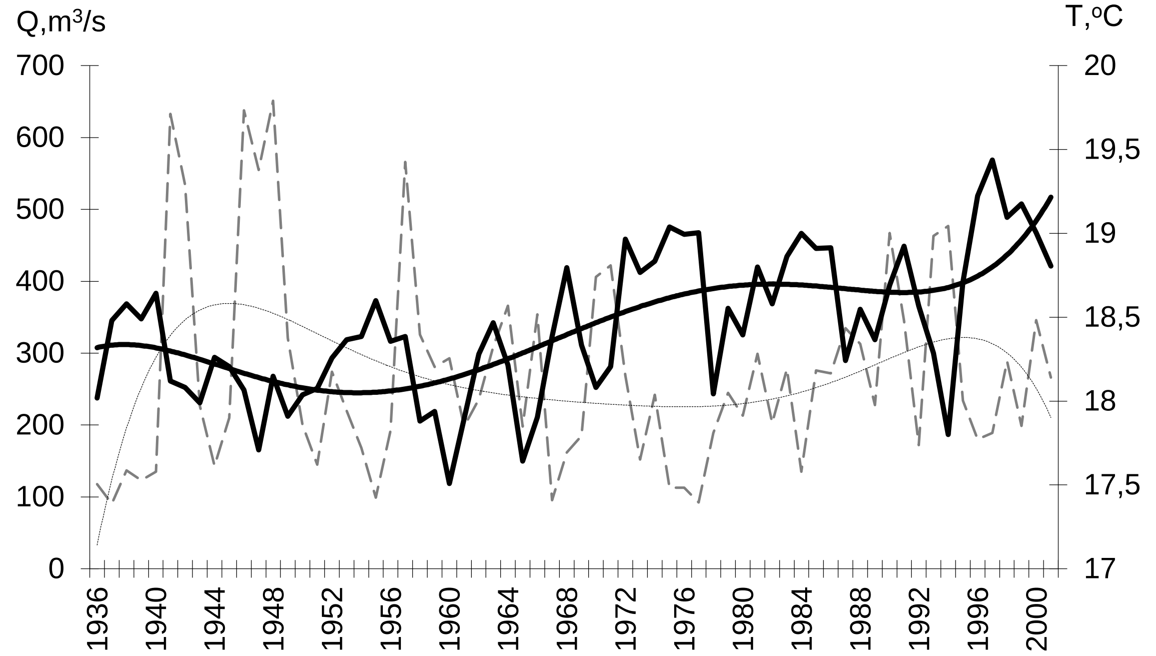
Corresponding values of parameters were taken us with smooth curves. In this case, the coefficient of negative correlation between water flow rate and temperature of the air in Uralsk increased to – 0.68, and the coefficient of positive correlation between water consumption and precipitation increased to 0.87. The coefficients of determination equal to 0.46 and 0.66, respectively. So at the decreasing (increasing) of climate temperature on 0.5°Cthe water consumption increases (decreases) by approximately 60 m3/s, and at the decreasing (increasing) rainfall at 10mm/year water consumption decreases (increases) by 20 m^3/s.

Thus, it is possible to see that, despite the relatively low correlation of annual water discharge, with annual values of air temperature and precipitation, the correlation of the smoothed speed of the water flow temperature and especially precipitation in Uralsk is high.

Since climate variations is considered to be smoothed deviations from the average within 8...10 years that we have received thus quite suitable for use in climate assessments.

Obvious, therefore, there is high sensitivity of runoff, even from weak climatic fluctuations of temperature and precipitation. It was possible to calculate quantitatively the value of communication: when decrease (increase) climate temperature 0.5°C the water consumption increases (decreases) by approximately 60 m^3/s, and decreasing (increasing) rainfall at 10mm/year water consumption reduced by 20 m^3/s. the Extreme in the averaged time series of precipitation and runoff in the zone of its formation are observed almost simultaneously.

A similar analysis of the relationships between air temperature and runoff, rainfall and runoff, we performed also for the station Atyrau, located in the delta of the Ural River, but this water consumption was assumed at the Makhambet station located near Atyrau (Figure 5).



– – ·the flow waters of the Ural River; ▬▬ the average air temperature, calculated over a rolling five year period; ----- the trend line of average temperature; ——the trend line of water flow.

Figure 5 – the time course of the runoff of Ural River water and average air temperature for the warm period for the Atyrau station, calculated over a rolling three year period

We can see that the time series of annual runoff in Atyrau is very similar to the course of flow in Uralsk. This confirms the thesis that in the area from Uralsk to Atyrau are only some of the flow losses through seepage and evaporation, estimated by us above, without impacting significantly on the time course of the flow.

A joint analysis of the time course of temperature and precipitation in Atyrau and Uralsk shows that the extreme they are not the same, especially precipitation (Figure 6). The maximum rainfall took place in Uralsk in 1948, 1965 and 1994. In Atyrau, the maximums barely visible ware in 1942, 1952, 1963. So in Atyrau time series of temperature and precipitation do not correlate with the magnitude of runoff. It was interesting to find out why.

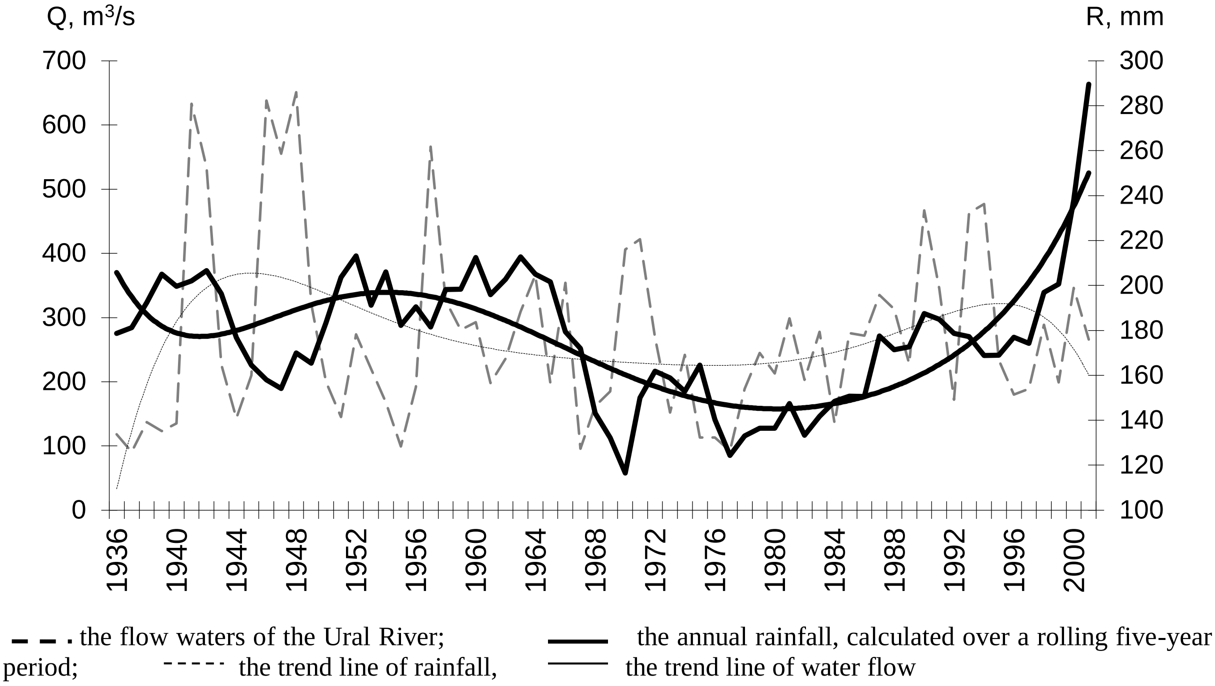


Figure 6 – The time course of the runoff of Ural River and annual amounts of precipitation for station Atyrau, calculated over a rolling five-year period

In [9-11] was done typification of the whole territory of Kazakhstan on the specifics of the temporary speed climate temperature. Northwest referred to the second type, and the South-West, where is Atyrau to fourth. Thus, there were fundamentally different changes in climatic temperature in these areas. A similar result was obtained in [12] for Almaty.

From the theory of the General circulation of the atmosphere [13, 14] it is known that the precipitation to the North and to the South of 50 ° N.L. varies greatly, as along this latitude the axis of the ridge the climate pressure is situated. Accordingly, to the north of 50 ° N.L. the maximum precipitation occurs in summer and to the South (Atyrau) – in the spring [4]. Secular variations of the position of the axes of troughs and ridges form the position of the temperature extreme in the time course, but these extremes in different regions occur at different times, and recorded in the division of the territory into types in [9-11]. Thus, climatic variations in temperature and precipitation to the South of the fiftieth latitude on the runoff of the Ural River have virtually no effect because areas of its formation located to the north of the 52 North latitude to the East and West of the Southern Urals.

The connection of the runoff of the Ural River with the forms of circulation. We carried out the search of relationships between runoff and types of macro-processes using typification of G. J. Vangengeim [13].

Analysis of the extreme of water flow of the Ural River have shown that a minimum flow in the thirties was at the prevailing macro-processes W(9) + E(15),the type C(-26) had the lowest repeatability (table 1).

High runoff in the fifties took place at prevailing processesC (+9) + E(18). The frequency of occurrence of type W(-19) was very low. The fact that the East of the southern Urals with the increased frequency of occurrence of type E is formed the conditions for precipitation above the norm was reported in [14].

Second minimum of flow in the 70-ies – 80-ies took place in the epoch of E when there was the predominant frequency of this type of E(64), with about the same frequency type(-25). Type W(-37) was expressed too weakly. Hence, having two minimal runoff of the Ural River was observed at quite different combinations of types.

Table 1 The relationship of the magnitude of the runoff of the Ural river with the forms of circulation (days)*

Extremums	Years	Types of circulation	
		Types for extremums of runoff	Types on Wangenhaim (epochs)
min	1928-30	W (9), C(-26), E(15)	E
max	1949-58	W (-19), C(+9), E(18)	E+C
min	1970-1984	W(-37), C(-25), E(64)	E
max	1998-2002	W(41), C(-14), E(-26)	W
Remark: in brackets is done the average deviation of days from norm during a year			

A maximum at two-thousand years occurred during the prevalence of the type W(41), low-frequency types C (-14) and E(-26). Consequently, the maximum runoff of the Ural River can take place at a rather different combination of types of circulation (table 1).

We can see therefore that the conclusions obtained [8], and our in general have a good agreement. Since there are essentially two catchments, one on the East and the other on the West of the Southern Urals, and the loss conditions of extreme rainfall in each watershed different, the combination of two types of macro-processes that provide the extremes of the precipitation and flow, is the expected situation. The minimum flow with maximum frequency of occurrence of type E with a low frequency of occurrence of type C and type W. High runoff occurs in type C or W with a fairly high frequency and low frequency of occurrence of type E. However, the relationship between the annual fluctuations of runoff and number of days per year a certain type of circulation was often weak, that we noted during the analysis. The years of highest and lowest water content are prepared for a long period and come usually at the end of the epoch, which determines the most favorable or unfavorable conditions for the formation of runoff in the area. These terms are formed including in the dynamics of the frequency of values and combinations of types of macro-processes

Expected changes in temperature, precipitation and runoff of the Ural River in the future. *Temperature*. We have performed the harmonic analysis of time series of temperature, precipitation in the river basin and the runoff of the Ural River. Figure 3 shows the time course of temperature approximated by a polynomial of the sixth degree for the station Uralsk, and Fig.7 - the results of harmonic analysis of the same number respectively

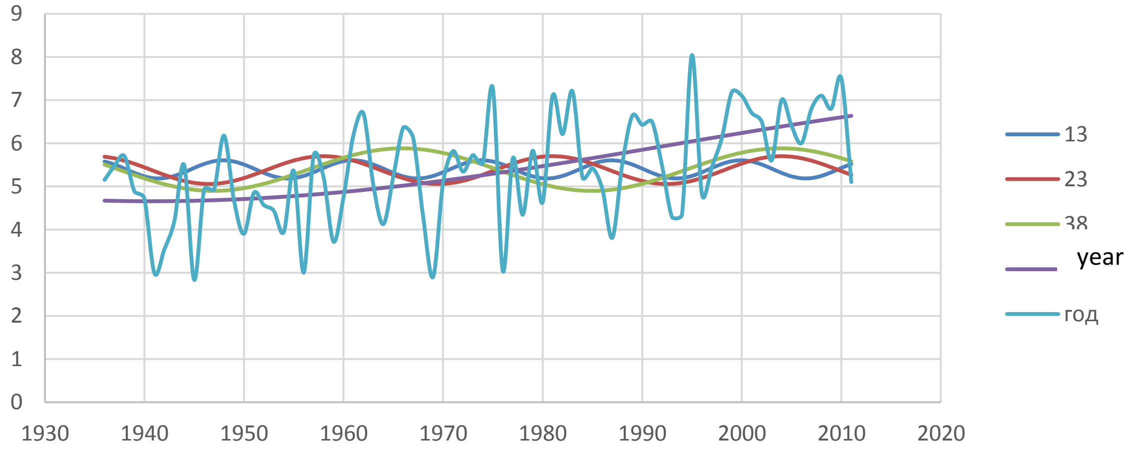


Figure 7 – Ural station. Harmonic series of temperature.

The fitted curve is, in fact, the result of the addition of the main harmonics of the time series of temperature for the observation period. We can see (figure 3) that during the analyzed period was as warming and climate cooling. Harmonic analysis of a time series (figure 7) shows that the main harmonics are secular (208y), as well as harmonics of the 38, 23 and 13 years. The addition of the main harmonics selection and trend records carried out by the method of Babkin A.V., which is widely used in hydrology for the construction of scenarios of runoff changes [15].

The amplitude of first three harmonics is about the same in both stations Uralsk and Kostanay: 1.2-1.4, 0.8-1.2 and 0.5°C, respectively.

Analyzing the time course of the harmonics of the temperature, we can see that since 2005-2006, 38 - and 23-year-old harmonics reaching a maximum, started to decrease in amplitude. Their minimum is expected in 11 to 19 years, i.e. from 2016 to 2024 consequently, until approximately 2016, a temperature reduction will occur pretty quickly under the influence of two harmonics, and then, to 2024, under the influence of only one 38-year-old harmonica.

The total temperature decreasing will be approximately 2.1°C, i.e. it will be equal to the sum of the amplitudes of the two harmonics. Eight-year-old harmonica had the max in 2013, after which its amplitude decreases to a minimum in 2017, however, the amplitude of this harmonic does not exceed 0.41°C and its contribution to the temporal course of the temperature is weak.

It is similar to the analysis of time series of temperature for the station of Kustanay. In view of the similarities of the results drawings are not given. Because in Kostanaj the amplitude of the fundamental harmonic is the same as in Uralsk, and the time of occurrence of their maxima (2005) coincide, we should expect the same speed of temperature lowering as in Uralsk, i.e. decreasing in the next one or two decades at 1-1.5°C and 1.0°C, respectively.

Therefore, the background temperature in the catchment area of 15-25 years will be lower than at present and the loss of moisture evaporation will also be lower than at present.

Precipitation We next consider the time series of precipitation and its harmonics for station Uralsk (Figure 4 and 8) and for station Kostanay.

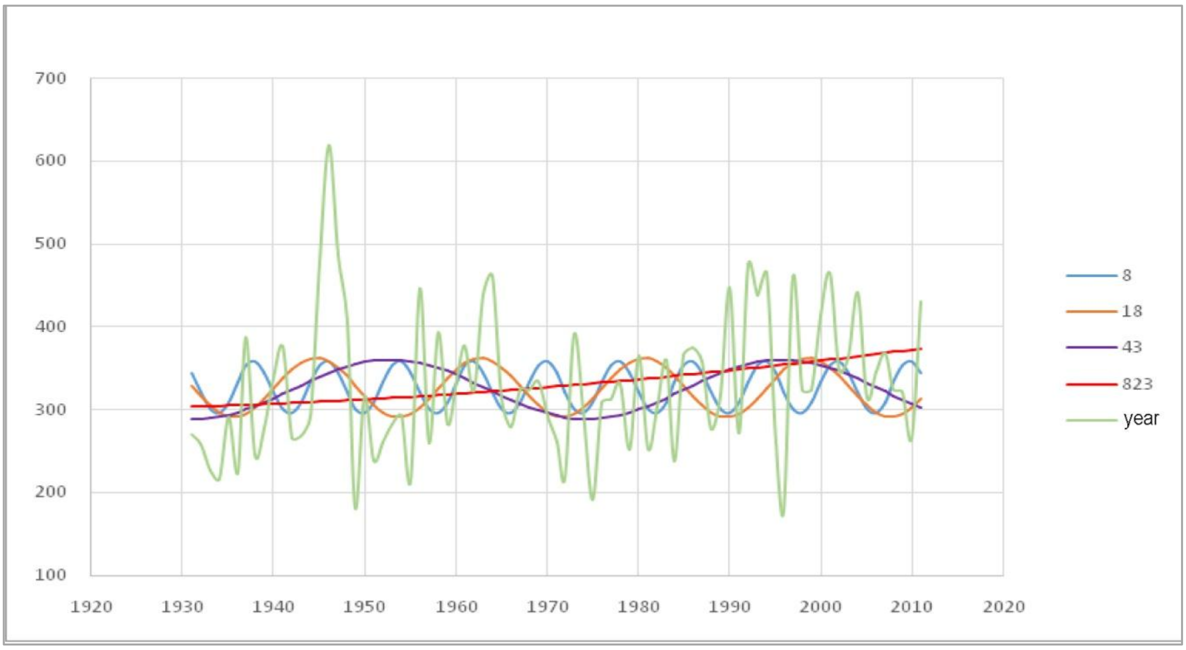


Figure 8 – Uralsk. The results of harmonic analysis of time series of precipitation

Figure 4 shows that in the time series of precipitation were the climatic extremes. In the time series of precipitation of station Uralsk there are harmonics with duration of 43, 18 and 8 years, the amplitude of the 100, 70 and 45 mm, respectively (Fig.8). In the time series of precipitation in Kostanay 38-, 23-, and 8-year-old harmonics with amplitudes of 55, 50 and 25 mm have a place respectively. However, the amplitude of the main harmonics in Uralsk almost two times more than in Kostanay [11, 16]. Accordingly, the conditions of runoff formation in the regions will be different.

Harmonic analysis series showed that in precipitation at stations Uralsk, Kostanay and almost the entire territory of Kazakhstan there is no a century harmonic, so it is difficult to build scripts. To the West of the southern Ural (the station Uralsk) the maximum 43-year-old harmonica took place about 1998 and 2020, its amplitude will decrease. Its decline from 2008 largely compensates growth of 18-year-old harmonica, and since 2013 – and 8-year-old harmonica. As a result, to the end of the decade, the amount of precipitation can fall in the range of 10 mm, and in the next decade we should expect a growth up to 50 mm due to the growth of the main 43-year-old harmonica, which will start at the beginning of the third decade.

At the station Kostanaj a maximum of 38-year-old harmonica took place about 1998 and 2020, its amplitude will decrease. This decreasing from 2012 largely will compensate rising of 23-year-old harmonica, and since 2013 – 8-year-old harmonica. As a result, to the end of the decade, the amount of precipitation can fall in the range of 10 mm. At the same time, due to the expected decreasing in air temperature, evaporation from the surface of the catchment will decrease, which should compensate decreasing in precipitation. Accordingly, the runoff of the Ural River should remain near the present values.

In the next decade we should expect a growth of precipitation up to 50 mm due to the growth of the main 38-year-old harmonica, which will start at the beginning of the third decade. Comparing the amplitude of harmonics and the time of occurrence of the extreme, we can see that the decreasing in precipitation in the current and next decade will be about 25 mm. After 2030, the precipitation will begin to increase.

According to the calculations for two catchments it is follows that in the third decade it should be expected to increasing of rainfall in the Eastern part of the catchment area to 25-30 mm and in the West area to 40-50 mm at the reduced temperature background compared with the present period. As a result, the runoff of the Ural River should increase.

Our analysis of recent temperature trends, however, showed that the climate warming trend in the region ceased. This result will be test in nearest three to five years and if the trend is confirmed, then no adaptive steps will be required. However, since this region, including its Northern part, belongs to the zone of risky agriculture, adaptation steps not to climate change, and to the great interannual variability of precipitation and drought, would be very desirable.

How can you apply the results obtained for the basin of the Ural river, to the assessment of the expected changes in surface runoff throughout the territory of Kazakhstan? You need to know how climate change temperature and precipitation throughout. In [9-11] we have shown that synchrony in change these settings there. We therefore consider more specifically how these parameters have changed in the past and what changes are expected in the coming decades.

Climatic variations of temperature and precipitation in the past century on the territory of Kazakhstan and a scenario of expected changes to 2050. The problem is quite thoroughly described in the work of one of the authors [11]. We restrict, therefore, only a summary of the result based on the data of the table 2.

Century harmonica has the maximal amplitude - 2.7 – 1.5°C. The amplitude of the second harmonic is everywhere less. The time of occurrence of the extreme of the century harmonics are remarkably different.

There were settle links for each of the cases of climatic cooling and warming with characteristics of the General atmospheric circulation [11].

It was interesting to consider intra-annual structure of the current cold snap. The first signs of cooling appeared in December 1995 and to the end of 2010, the total cooling of this month was 3°C. In January, the cold came just a year later, in 1996, but by 2010 it was 9°C. In February, the cold start recorded only since 2000, i.e. five years after its first appearance in December, and to 2010 amounted to 6°C. In March, the cold began only in 2006 and made up 2.5°C to deadline. In April, the cold began to report only from 2007 and up to 2010 only 0, 2°C.

Table 2 – The amplitude of the climatic fluctuations of temperature (°C)

Stations	Years of exstremums						
	max 30-40	min 40-50	max 65-75	min 80-90	max 2003	Century harmonica	0.5 cent. harm., years
Uralsk	0,7	0,8	0,3	0,3	1,2	2,2	60
Irgiz	0,3	0,5	0,1	0,3	0,7	2,0	54
Karaganda	0,3	0,4	0,4	0,4	1,1	1,5	51
Dzhezkazgan	0,6	0,6	0,2	0,3	0,1	2,4	53
Semipalatinsk	1,0	1,0	0,1	0,1	1,5	1,5	51
U-Kamenogorsk	1,2	1,0	0,3	0,2	1,0	1,2	50
Kzylorda	0,9	0,9	0,1	0,2	0,3	2,3	50
Aral Sea	0,6	0,5	0,1	0,1	1,0	2,7	50
Pavlodar	0,2	0,3	0,1	0,1	1,3	1,9	42
Balchash	0,3	-	0,3	-	0,1	1,4	-
Kostanay	0,8	0,9	0,3	0,3	0,7	2,4	54
Astana	0,2	0,3	0,2	0,3	0,8	2,1	54
Taldykorgan	0,4	0,5	0,3	0,2	0,7	2,2	52
Chimkent	1,0	0,6	03	04	0,3	1,8	50
Fort Shevchenko	1,0	0,9	04	0,6	0,3	1,7	60

Thus, in the period from December to April cold, first appeared in December 1995, gradually extended to subsequent months up to April inclusive for 12 years. During this time, the most significant temperature drop occurred in the winter months in December (3°C), January (9°C) and February (6°C). In the remaining months of the year, the cold was distributed without the expressed laws.

Scenario of expected temperature changes for the period up to 2050. According to the results of harmonic analysis of time series of temperature and precipitation at stations of Kazakhstan identified the most significant amplitude of harmonics with periods exceeding 10 years, and based on them built scenarios of changes in temperature and precipitation by 2050. The temperature will fall almost throughout the 1.1-:3.0°C, down to the level of the sixties of the XIX century.

Using the information contained in our [11], we performed such calculations based on the harmonic analysis under the assumption that detected in time series of temperature and precipitation are the main harmonics will remain.

In Figure 9 presents a map of the spatial distribution of average annual values of temperature (the numerator) and the expected value of changes in average annual temperature since the start of the cooling, i.e. in about 40 years (denominator). It is constructed by the method of [15], which is based on the assumption that having the harmonics will continue in the future.

You can see that in all the territory of the Republic the temperature decreases. Downside should be expected in the range of from 1.0 to 3.0°C. Values correspond roughly to the cold snap in recent decades the warming [11]. This is natural because the main contribution to the temperature fluctuation makes the age-old harmonic (about 110 years), the maximum of which took place about 2000. Accordingly, the most significant cold up to 3°C expected in the area of Turkestan and in the South-East of the Republic, 1,5-1,8°C. The same size of the cold expected in the North-East in the district of Astana-Pavlodar-Semipalatinsk. Over the Central and Western regions is expected to be less temperature decrease 1.1-1.3°C.

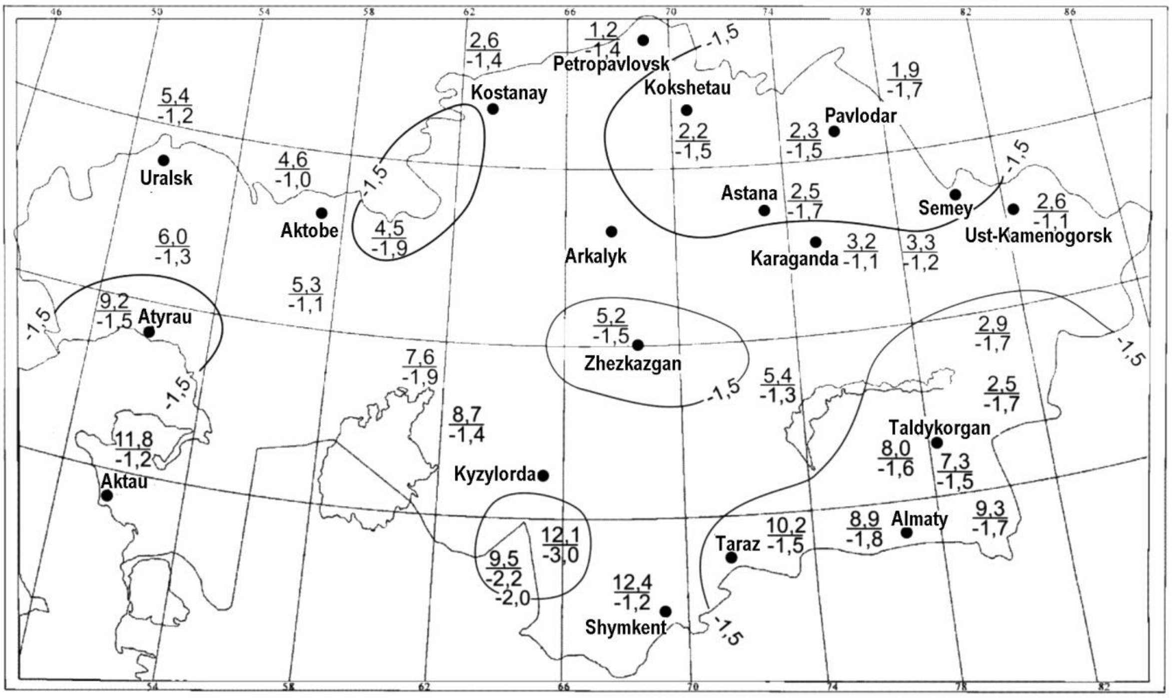


Figure 9 – The script changes the temperature field on the territory of Kazakhstan by 2050

Average annual air temperature 2050y to fall to the norm calculated for the observation period preceding the rising temperatures in the late twentieth century.

Climatic variations in precipitation in the past century and a scenario of expected changes to 2050. Table 3 presents the time of occurrence of precipitation extremes in comparison with the extremes of temperature.

From table 3 we can see that the extremes of temperature and precipitation for the territory of the Republic among themselves not associated with time of onset of any trend.

Table 4 shows the results of harmonic analysis of time series of rainfall for some stations in Kazakhstan. Data is given for the three main harmonics. First of all, you can see that in time series precipitation century harmonic is missing. For the first harmonic the characteristic period of 33 to 48 years which is known as Brickner's cycle. The period of the second harmonic is equal to 23 years. The amplitudes of the first and second harmonics close, from 20 to 90 mm of precipitation. The period of the third harmonic is unstable through the territory and varies from 8 to 18 mm, the amplitude of this harmonic is slightly less than the first two.

Table 3 – The alternation of extremes of temperature (t) and precipitation (Q) (years of the last century)

Stations	Extremums								
	Maxt	MinQ	min t	MaxQ	Maxt	MinQ	min t	MaxQ	Maxt
Pavlodar	39	-	54	64	74	-	85	98	0,2
Uralsk	35	48	44	48	68	72	88	99	98
Turkestan	37	37	52	59	69	84	84	05	06
Dzharkent	42	41	57	58	76	78	91	92	06
Astana	39	-	49	60	72	85	88	03	05
Kuigan	42	40	58	70		88		06	
Samarka	42	36	59	56	-	82	88	98	03
Atyrau	38	37	51	51	72	76	89	02	06
Karaganda	40	39	51	59	73	81	88	04	04
Dzhambul	40	38	54	58	74	82	88	03	06
U-Kamenogorsk	42	37	58	68	77	92	92	07	06
Kostanay	35	42	43	56	66	76	84	00	04

Table 4 – The main harmonics (period, years) in the ranks of precipitation and their amplitude (mm)

Stations	The first harm.		The second harm.		The third harm.	
	period	amplitude	period	amplitude	period	amplitude
Kuigan	43	10	23	20	13	18
Almaty	42	25	27	30	18	18
Dzharkent	68	20	28	40	18	40
Taldykurgan	33	30	23	35	-	-
Dzhambul	38	105	23	30	13	30
Turkestan	-	-	-	-	-	-
Shimkent	38	65	-	-	-	5
Kazalinsk	36	15	21	10	15	20
Aral Sea	-	-	28	30	8	40
Kzylorda	33	25	-	-	13	30
Samarka	53	60	23	40	13	30
Katon-Karagai	48	100	23	90	8	90
U-Kamenogorsk	-	-	23	35	-	-
Ajaguz	33	50	-	-	18	40
Karaganda	--	80	-	-	13	55
Martuk	38	60	-	-	13	40
Novosibirsk	43	120	23	65	8	20
Temir	33	60	-	-	18	40
Aktobe	38	35	-	-	-	75
Fort Shevchenko	48	30	28	30	8	35
Atyrau	33	30	-	-	18	20
Uralsk	43	65	-	-	18	65
Bajanaul	38	45	-	-	8	15
Pavlodar	-	-	-	-	15	38-50
Shcher,bakty	33	30	-	-	8	20
Astana	43	50	23	40	8	40
Kokchetav	-	-	28	65	18	65
Kostanay	38	35	23	35	8	15

Let us make a brief conclusion. For the time series of precipitation are characteristic harmonics of half a century, in a half and a third of half a century. The century harmonic with a period of 100-120 years for the time series of precipitation, in contrast to the time series of temperature, is not typical.

The amplitude of the harmonics can be analyzed basing on the data of table 4. The highest amplitude has only 50% of the first harmonics of the stations. In the remaining 50% stations the largest amplitude has the second harmonic or the third one. This fact significantly reduces the accuracy of predictive scenarios for the future.

The connection of fluctuations in precipitation rows with the types of macro-processes and harmonics in their ranks was settled [9-11].

Scenario precipitation change fields for the future Changes in precipitation to 2050 is ambiguous (Figure 10).

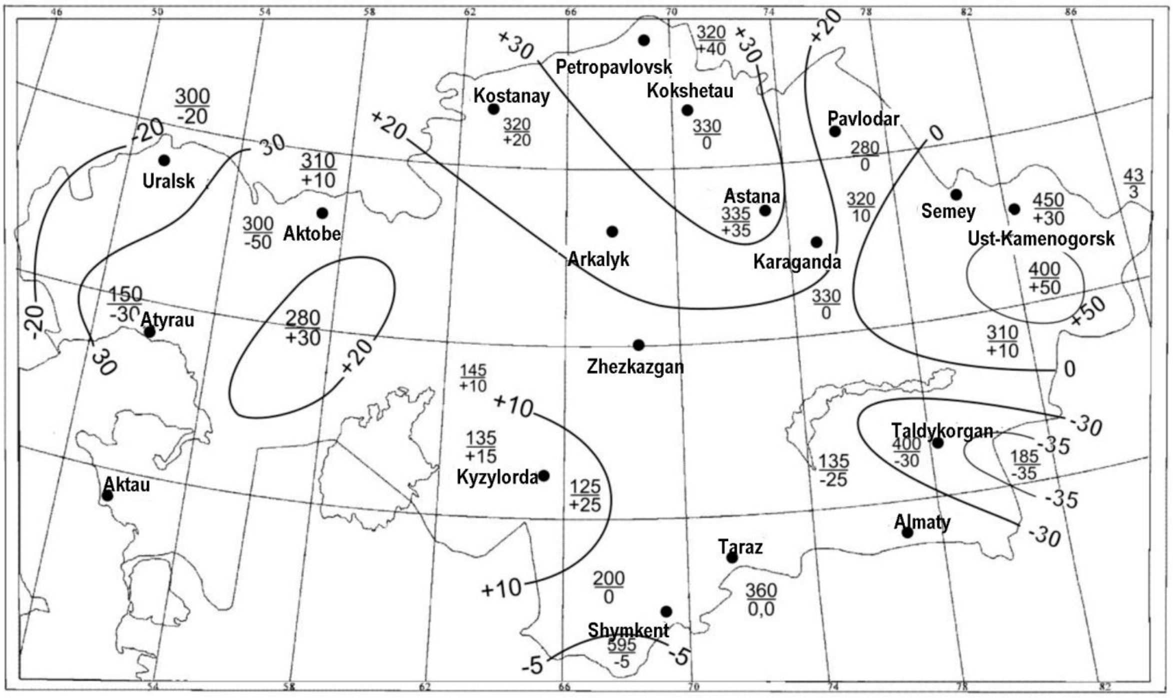


Figure 10 – Scenario precipitation change field by the 2050

Here in the numerator the norm of precipitation is given, and in the denominator - the expected changes by 2050. As can be seen from fig. 20, the amount of precipitation will undergo opposite changes. To the North, East and South-West of the Republic precipitation will increase by 20-30mm and in the West and South-East of the territory they are about the same will decrease. On the East of the country rainfall will increase by 10-50mm,approximately the same increasing in precipitation is expected over Northern Kazakhstan, 20-40mm. In the area of the Aral-Kzylorda precipitation will also increase by 10-25 m.

In the band Pavlodar-Shymkent changes in precipitation are not expected. In the West of the Republic and in the South-East is expected decreasing in precipitation by 20-35mm/year.

Only not great part of the territory of Kazakhstan amount of precipitation to 2050 will change by more than 10% of normal. In the North-West of the Republic of the expected decline will exceed this share. In the main agricultural area, Northern Kazakhstan, precipitation will even increase. Thus, the conditions for agricultural activity will remain as currently, they will not deteriorate.

Discussion. The result is that on the territory of Kazakhstan began cooling, is not entirely unexpected. At least since 2011 the national weather service of the Russian Federation fixes the beginning of the cold snap in the North of the European part of Russia, and also in the South of Western Siberia and South-East of Eastern Siberia in winter [17]. A few less cooling noted on these same areas in spring and summer, only in autumn there was no it. We noted, and this is confirmed by most researchers that the bulk of warming occurred in winter. The beginning of a noticeable cooling in this season compensates for the occurring warming.

In our research we excluded from the analysis of the mountain areas, as it requires other approaches. However, in [18] it is shown that the glacier Tuyuksu in the Zailiyskiy Alatau Mountains (South-Eastern Kazakhstan) also started cold. The some time there was an increasing in the amount of precipitation in the solid phase there.

In studies of Zandi Rahman, a thesis which we have acted as opponents, it is shown that in Iran in the Khuzestan province, in the cold season temperature rising is stopped [19]. There are a number of other studies, confirming the tendency to cooling on the Eurasian continent.

As we have shown, the onset of the cooling occurs mostly in winter and against the background of rising secular zonal harmonic transfer (type W). It is known that strengthening a zonal transfer usually leads to the outflow of warm masses from the ocean to the continent, which should contribute to warming. In fact, the zonal migration leads to the intensification of cyclogenesis, but the cyclones move along the 65th parallel, carrying out the removal of warm air in the Arctic and Siberia. In the rear of these cyclones, however, comes the cold air in temperate latitudes, where it settles down Kazakhstan [20]. Specific mechanisms for the implementation of wave fluctuations are not considered. As stated in the same [20], "the Question of the physical causes of these fluctuations remains open".

The sensitivity of the rivers in the arid region to climate changing is very high. Runoff is highly sensitive to minor climatic fluctuations of temperature and precipitation in the zone of runoff formation. Human impact on environment components in the river basin can give it the most adverse effects.

In [21], the authors, studying the climatic changes in air temperature and precipitation on the territory of the Middle and southern Urals in the twentieth century, concluded «the ambiguity of trends of changes of climatic characteristics in the twentieth century in the Urals. Installed features rhythmic changes in air temperature and precipitation". To the authors the results are similar to our own; we can only add that on the territory of Kazakhstan, adjacent to the watershed of the Ural River, and in the Kazakh part of the basin up to the Caspian Sea, we recorded also only fluctuations of climate. We and authors of [21] used different methods of analysis so we fixed the "rhythms" of different durations: a century, close to half a century (Brickner's), and shorter. The century cycle which has the greatest amplitude, over, and in the analyzed area ends, but due to the shorter harmonics and here the climatic temperature trend has become negative. In other regions of Kazakhstan climate cooling started earlier [11 and others].

In [22] using modeling techniques they studied the effect of global climate change on the hydrological system of the Aral Sea, located essentially in the center of Eurasia. Despite the fact that the area of flow formation is at a distance of about a thousand km from the sea, and the metering system of the consumed water in this area is unreliable, the authors have shown that the impact of climate change on the processes in the Aral Sea basin is significant. The water objects of the arid zone are sensitive to the slightest climatic changes in temperature and precipitation.

In [23], the authors studied the effect of climate change on underground rivers in the UK. And, although the UK is outside the arid zone, they are received, that such dependence exists. This indicates a rather strong dependence of surface runoff due to climate variability of temperature and precipitation regardless of the natural area. Existing balance between precipitation and temperature on the one hand and surface runoff on the other, being sufficiently stable for the time interval from one to several years, is very sensitive to climate change, i.e. to changes in the time period up to 10 years.

In [24] analyzed not only the temporal but also the spatial variation of the rainfall to the runoff of the Yangtze River over a period of 40 years. The obtained results confirm that the sensitivity of water systems to climate change high even outside the arid zone. There are a number of other works dealing with the problem, but with similar patterns.

Our results for the basin of the Ural River in broad outline confirm obtained for other river basins General conclusions. However, due to the presence of several features in addition to the aridity of the climate, such as the existence of two regions of runoff formation, separated by mountains, are fundamentally different conditions for the formation of extreme precipitation in each of them. We got their special connection and the expected scenarios of runoff changes in the future.

Currently, there are enough reliable data on water consumption by hydrological posts along the Ural River, and virtually no data on the abstraction of water for agricultural and household needs. Basin-wide accounting of water used and its quality control, in fact, missing. It is difficult to assess the anthropogenic impact on the runoff. At the same time, it is obvious that the system is sensitive to such influences. The solution of this problem is ahead yet.

Conclusions. As a result of the studies of the dynamics of flow in the context of climate change in Kazakhstan obtained the following:

1. *Climatic fluctuations of temperature and precipitation*:

-climatic fluctuations of temperature and precipitation that generates surface runoff, was not only currently, but in the last century. Such changes never occur simultaneously on the entire territory of the Republic. They appear anywhere on its border, and then gradually over several years spread to the entire territory;

- between the climatic fluctuations of temperature and precipitation not detected synchronism or coherence. Therefore, the construction of scenarios of change for the whole territory of the Republic is possible only individually and quotas by region;
- for the reasons stated above,the construction of scenarios of impact of climate change on runoff is possible only for each river, i.e., watershed;
- observed in recent decades, the temperature increasing at the beginning of the twenty-first century have ceased. The cooling started in the North-East at 2010, has covered the whole territory;
- in time series of temperature have taken place a century and half-century and quarter-century harmonics, which select up to 95% of the dispersion. The maximum amplitude up to 2.1°C, the amplitude of successive harmonics decreases rapidly. These harmonics can serve as a basis for developing scenarios of temperature change for the future;
- ahalf of century harmonicas, and harmonics of a shorter durationtake placein time series of precipitation. The amplitude of the first harmonic does not depend on the length. The first four harmonics choose to 90% of the variance and can serve as a basis for developing scenarios;
- while maintaining the basic harmonic series of temperature and precipitation constructed scenarios of expected changes in temperature and precipitation to 2050. The temperature will drop and it will reach by the time the level of the minimum observed near the thirties of the last century. The amount of precipitation will fluctuate, remaining on most of the territory around the norm. Interannual variability of precipitation will remain significant.

Our results, primarily the results of harmonic analysis and analysis of spatial-temporal shifts in climatic extremes in temperature and precipitation are in good agreement with the results of studies of the General circulation of the atmosphere and also with the results of analysis of atmospheric dynamics on spectral models.

2. *Basin of the Ural River:*

-by us as an example evaluated the sensitivity of flow in the Ural River basin to climatic changes in temperature and precipitation obtained the following:

-water flow of the Ural River is very sensitive to even small climate variations. At the decreasing (increasing) climate temperature on 0.5°C the water consumption increases (decreases) by approximately 60m³/s, and decreasing (increasing) rainfall at 10mm/year water consumption reduced by 20 m³/s. For this reason, it is possible to speak about a particular relationship of temperature and precipitation on runoff value;

- the presence of reservoirs on the territory of Russia while in any way does not impair the flow of water to Kazakhstan. Moreover, in dry years is supported by relatively high water consumption. This flow over the years the reservoir has never dropped to the minimum, which often took place before the construction of reservoirs in the 20-ies – 50-ies of the last century;

- our analysis of recent temperature trends have shown that climate temperature rising in the region ceased. In the coming decades we should expect a gradual lowering of the temperature at 2.1°C. The Amount of precipitation may decrease up to 2025 within 10 mm. At the same time, due to the expected decreasing in air temperature, evaporation from the surface of the catchment will decrease, which should compensate for the decreasing in precipitation. Accordingly, the drain of the Ural River should remain near the present values. By the end of the third decade is expected increasing ofprecipitation up to 50 mm/year and the increasing in flow on the background of decreasing air temperature.

3. *The forecast runoff for the territory of the Republic as a whole*:

-despite the fact that the prediction of surface runoff is only possible in specific basins, some General conclusions on the basis of this work possible:

- as climatic variation and temperature and precipitation for the territory of the Republic do not occur synchronously and at the same time to expect the simultaneous climate fall or rise of runoff should not be;

- onset of climatic temperature drop throughout the territory of Kazakhstan will contribute to a slight increase in climatic runoff;

since climatic variations of temperature and precipitation at the site is small, the inter-annual variability of runoff would be significantly greater than the climatic one. So the forecast of annual runoff in a particular basin will be the main task in this area for hydrologists.

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REMOTE SENSING AND GIS FOR SUPPORTING THE AGRICULTURAL USE OF LAND AND WATER RESOURCES IN THE ARAL SEA BASIN

Globally, the sustainable management of water resources is in the spotlight of academic and institutional, respectively governmental interest and activities. Against the background of climate change, drylands such as in the Aral Sea Basin (ASB) in Central Asia outline a focus area on the water usage for the purpose of irrigation towards food security and promotion of sustainable agriculture. Additionally, the fact of transboundary rivers, thus, water resources highly elicits a call for action to coordinate interstate water relations towards an efficient water usage. Here, the regional research network 'Central Asian Water' (CAWa) aims at developing a scientifically sound and reliable regional database for theimplementation of sustainable water management strategies in the ASB. The CAWa work packageIII 'Online Tool for the Monitoring of the Water Use Efficiency and the Agrarian Land Use' focuses on the generation ofsuch a database on land use and water usage in the ASB by means of state-of-the-art remote sensingtechniques. The application of this technology is promising in Central Asia due to favoring atmospherically (i.e., cloud-free) conditions. It enables for a regular derivation and monitoring of biophysical parameters on the state of land and water resources (i.e., land use, biomass, crop yield, evapotranspiration). The use of Geographical Information Systems (GIS) enables, among others, the derivation of supportive information on irrigated cropland area and its productivity for gaining abetter understanding of the land use intensity. These modern techniques can now contribute to andfurther develop a system of existing, effective and analytical land and water use related indicators forestimating the productivity of irrigated agriculture, for comparing irrigation systems, and for monitoring performance of irrigation systems over times. With the development of the web-based GIS tool WUEMoCA, the CAWa team is working on anautomated monitoring and visualization instrument that particularly addresses sustainable decisionmaking and program planning processes to ensure environmental and socio-economic stability in Central Asia and Afghanistan.

Introduction. In 2015, the UN declared in its World Water Development Report that never before the earth has been thirstier than now [1]. Without any substantial reforms on the consumption, management, and allocation of the water resources, water scarcity in all sectors will mainly endanger drinking water and food security. By the year 2030, the gap between water demand and natural groundwater recharge could increase to 40% [1]. Population growth, the increasing demand of irrigation water, urbanization, and climate change are assumed to even aggravate this situation [2,3].Water scarcity already constitutes the most urgent problem and most challenging issue of prospective politics in water management. According to the UN report, particularly dryland regions such as the Aral Sea Basin (ASB) in Central Asia will be affected [1]. The ASB gained prominence in the recent past with the desiccation of the formerly world's fourth largest lake, the Aral Sea, to 10% of its original surface by 2007 [4]. This environmental catastrophe [5,3] is largely considered to result from serious anthropogenic interferences into the vulnerable arid ecosystem by inappropriately performed land development programs and excessive use of irrigation water during the Soviet Union [6,7]. The ASB constitutes one of the largest irrigation cropping areas in the world [7]. Latest results from a studyincorporating moderate and high resolution RS-data (MODIS and Landsat) and covering an observation period of 13 years indicate a total area of 8.4 Mio ha of total irrigated cropland, thus confirming further according results in the ASB [7].Irrigation water amounts to more than 90% of the total intake from all water sources [8]. However, the reduced manageability at lowest (on-farm) level and transboundary problem [9] in combination with the above challenges have been further stated as immanent recent factors threatening water as the most precious resource and towards a source of conflict [10]. Land and water management in the ASB is a multisector topic highly requesting an integrated holistic approach on the sustainable water and land management and addressing different institutional levels. Proclaimed in the Sustainable Development Goals (SDGs), it is of key importance to look at the water cycle in its entirety and the role of all uses and users [11]. Particularly, international cooperation and stakeholder participation present important aspects in the mutual goal of sustainable water resource management [11].

During the international decade for action ‘Water for Life’ (2005-2015), the German Federal Foreign Office has launched the German water initiative for Central Asia (so called ‘Berlin Process’) in April 2008 within the framework of the European Union strategy ‘Central Asia’. As the scientific component of this initiative, the regional research network «Central Asian Water» (CAWa) was designed to support scientific cooperation and communication between Central Asian countries and Germany in the sector of water resource management. Important activities of CAWa (2009-2017) cover the development of a scientifically sound and reliable regional database for the implementation of sustainable water management strategies in the ASB. In its third phase (2015-2017), CAWa holistically aims at the consolidation, capacity building, and transfer as well as dissemination of data and scientific resultsin the context of limited water resources and towards the development of sustainable land and water management options.Since the agricultural sector presents the largest consumer of water in the ASB, a distinct focus of CAWa lies on the data-driven analysis of the role of irrigation water in an integrated manner [7]. Key topic within the CAWa work package III ‘Online Tool for the Monitoring of the Water Use Efficiency and the Agrarian Land Use’ is the efficient water use for irrigation purposes implying a bundle of issues to be addresses first. These *inter alia* include thecomprehensive understanding of the quality and quantity of land use and cropping intensities and their spatio-temporal variability as well as determining factors (e.g., evapotranspiration) for estimating the productivity of irrigated cropland (i.e., yield estimation).

Monitoring is considered to offer great potential in the operational and systematic recording, observation, and early estimation of all irrigation related questions. It denotes for the periodic or continuous collection of data by measuring the relevant parameters in a broad range of environmental processes using consistent, respectively, standardized methods.Remote sensing (RS) can contribute some of the keyindicators for monitoring in land and water management by serving as fast supplier of high-quality data of often high spatial and temporal resolutions and covering large areas, and by enabling change detection through repeated spatially-explicit earth observations [12].Thus, RS data allow for a continuous monitoring of parameters to achieve the data-driven, indicator-based stateof water use efficiency within the framework of CAWa. Required indicators derived from gathered parameters and feeding the monitoring system ideally present simple, developed and validated measures and serveas practical numerical values on the complex state of water use efficiency in the ASB [13]. Anumber of effective indicators can be consulted to provide scientific insight into the state of the environment and the anthropogenic impact on it [13]. Relevant indicators allow to reveal the trigger mechanisms and responses steering that system, however, provided that they fulfill a list of standard requirements, which basically stress the relevance and reliability of information, the easy interpretation and comprehensibility of information indicated as well as their response to changes in the system and their projection to different geographic scales [12,13,14,15].

Problem definition. In context of the development and operationality of the water use efficiency monitoring in the highly complex human-environment system of the ASB [16,17],the overall aims of CAWa work package III are basically: (i) generation of a database using RS techniques, (ii) derivation of supportive information on irrigated cropland using GIS, and (iii) development of a set of land-, crop- and water related indicators. Finally, theirimplementation will serve as key prerequisites for the development of an automated monitoring and visualization instrument to provide a platform linking scientific results and decision making in sustainable land and water management.

With this contribution to the international scientific-practical conference 'Water Resources of Central Asia and their Use', the authors would aim at presentinga brief overview on the current state of joint research and development of that monitoring tool.

Research methodology.

Study area. Study activities spatially focus on the irrigated cropland extent (iCE) in the landlocked ASB (Figure 1). In its southeast, it is framed by the high mountain ranges of Pamir, Alai, Tian Shan, and Hindukush where runoff contributing to the major water supply in the ASB [7] is generated from precipitation and largely depends on the rhythm of glaciation [18]. The central inner ASB is characterized by the plains of the deserts of Kyzyl Kum and Kara Kum. Climate is continental, arid to semi-arid. Resulting from the topographic gradient with altitudes ranging from 0 to 7,500 m a.s.l. [19] average annual precipitation (mainly in winter and spring) ranges from80 to 200 mm in the lowlands and valleys (e.g., Fergana), from 300 to 400 mm at the foothills, and from 600 to 800 mm in the mountain ranges [10]. The ASB typically shows hot and dry summer seasons and cold humid winters [20,21,22]. Due to high annual evapotranspiration rates up to approximately 1,200 mm in Turkmenistan [23], the annual water balance is negative, thus water is a limited resource. Cropping heavily depends on irrigation water supplied by the two main river systems of the Amu Darya and Syr Darya as well as the artificial Kara Kum Canal [7].

Main crops are wheat, rice, maize, and barley totally amounting to an area of almost 49% of the entire iCE, as well as cotton with an area percentage of approximately 23% [10]. Smallest area proportion (approximately 16%) is cropped with fodder and permanent crops [7]. In a RS-based analysis of cropping intensity in the ASB,Conrad et al. distinguished eight large-scale irrigation zones (Figure 1) with a total irrigated area estimated to 8.4 Mio ha [7]. These are: (i) Fergana valley (Uzbekistan and Kyrgyzstan, (ii) Tashkent and Syr Darya (Uzbekistan and Kazakhstan), (iii) Chardara, Aris, and (iv) Kyzyl Orda (all Kazahkstan), (v) Upper Amu Darya (Uzbekistan, Tajikistan, and Afghanistan), (vi) Zerafshan and Amu Darya (Uzbekistan and Turkmenistan), (vii) Kara Kum Canal (Turkmenistan), and (viii) Amu Darya Delta (Uzbekistan and Turkmenistan). The long-term (2000-2012) average cropping intensity referring to the number of harvest for a cropland area per year [24] has recently been reported to vary between highest 1.09 in Fergana to lowest 0.83 in the downstream irrigation zones alongside the Amu Darya River [7].

Data sources and Geodatabase. Data for monitoring originate from 250m MODIS (Moderate Resolution Imaging Spectroradiometer) MOD09Q1 data products that are automatically obtained through the online Data Pool at the NASA Land Processes Distributed Active Archive Center (LP DAAC), USGS/Earth Resources Observation and Science (EROS) Center, Sioux Falls, South Dakota (https://lpdaac.usgs.gov/data_access). Data is provided as an 8-day aggregate, ensuring cloud-free images with a high temporal resolution. The Normalized Difference Vegetation Index (NDVI) is then calculated for each scene from the provided red and near-infrared spectral bands of the MODIS product. Even though the pixel size of 250m does not allow for the detection of single fields, the MODIS data sets were selected because WUEMoCA is designed as a regional tool for monitoring and MODIS is currently the only satellite system in space that covers extensive areas such as the ASB with the required temporal resolution for the generation of consistent time series from 2000 until today.Vector data on the administrative and water distribution levels in the ASB are provided by the Scientific-Information Center of the Interstate Coordination Water Commission of the Central Asia (SIC ICWC). Actual data on the land use distribution, the crop types as well as yield (i.e., biomass) to be harmonized and use as training and validation data originate from comprehensive field surveys by the Central Asian partners.

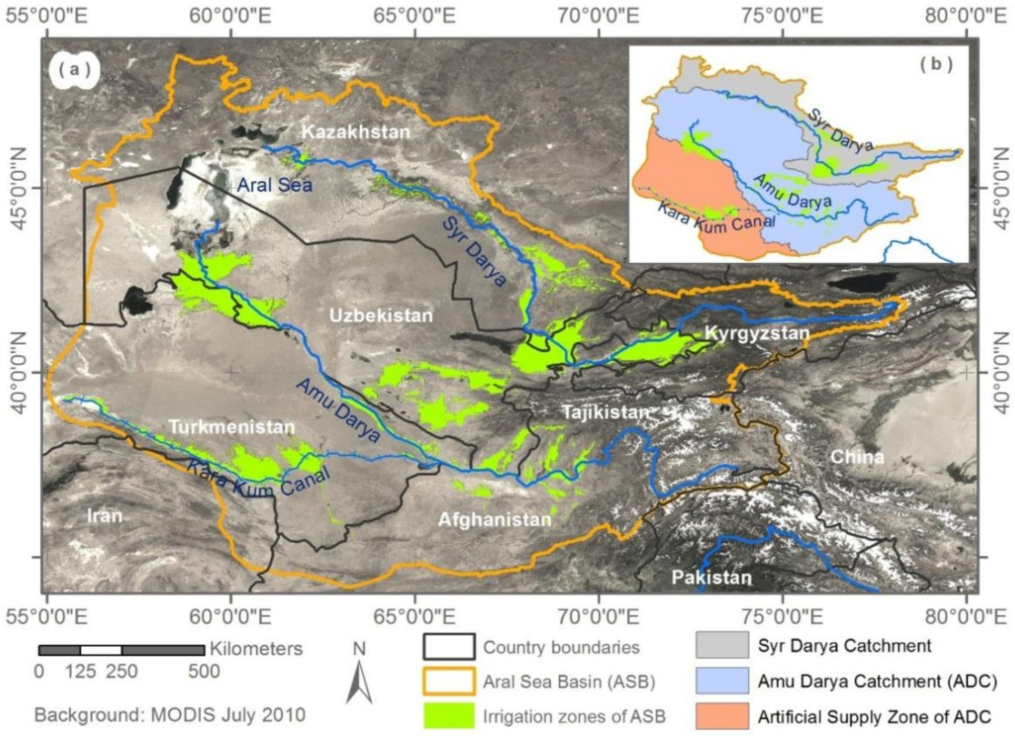


Figure 1 - (a) Geographic location of the Aral Sea Basin in Central Asia and covering countries as well the location of the irrigation zones alongside the courses of the rivers Amu Darya and Syr Darya, and the Kara Kum Canal. (b) Overview on the location of the largest river catchments of Amu Darya and Syr Darya in landlocked Central Asia and the artificial water supply zone receiving water from the Kara Kum Canal. Source: Conrad et al. (2016).

Development and design of the monitoring and visualization tool. The monitoring and visualization tool WUEMoCA (Water Use Efficiency Monitor in Central Asia) is designed as a coherent and fully automated processing chain to visualize relevant indicators at different levels of aggregation within an interactive, freely accessible web-based platform (i.e., webGIS). The automated classification and processing of MODIS images is therefore the basis for data provision. Land use and yield data will be derived annually for the observation period from 2000 to 2015. An additional near-real time mode is considered to provide bi-weekly biomass estimations during the operational status of the system. The system architecture of WUEMoCA is sub-partitioned into five main modules: (i) land use classification, (ii) yield estimation, (iii) geodatabase processing, (iv) map server and client application, and (v) user database and on-the-fly aggregation. Generally, WUEMoCA starts with the continuous automated download of new MODIS data (8day-step) independently from manual control, and their automated storage on a local folder of the WUEMoCA server that subsequently triggers the automatized process of land use classification and yield estimation, and providesthe results to the PostGIS geodatabase. PostGIS acts as a spatial database for vector and raster data and is used as a storage from where a MapServer converts the data to web-based services and transfers them to a web client (i.e., web browser). Within the database, the tables of vector geometries such as administrative levels (e.g., oblast/province and rayon/district and water distribution levels (e.g., in Uzbekistan, Basin Irrigation System Authority (BISA), Irrigation System Authority (ISA), water use associations (WUAs), and channel command areas) are populated through spatially aggregating the raster-based results. The resulting vector data tables present the basis for the visualization in the web mapping application. The specific technical requirements for MODIS image processing and data processing as well as for the client application, the mapping standards, and the software applied for developing WUEMoCA are given in Table 1.

Table 1 – Technical requirements and software applied for developing WUEMoCA.

Purpose	**Software, Standards**
Satellite image processing	R & JAVA programming libraries
Database with spatial extension	PostgreSQL, incl. PostGIS
Database processing	Python programming libraries
Web mapping application (client)	HTML, CSS, JavaScript APIs (OpenLayers, ExtJS, GeoExt), JSP
Data exchange formats	WMS, WMTS(both Open Geospatial Consortium Standards)
Map server	GeoServer
Web server	Apache Tomcat
Operational system	Windows server

Indicator system on land and water use. Indicators calculated and visualized in WUEMoCA generally aim at estimating the performance of the irrigated cropland within the focused boundaries of irrigations system (e.g., WUA, channel command area) in the irrigation planning zones in the ASB (Figure 1). They further aim at comparing the irrigation systems such as by indicating the productivity in the different planning zones of riparian countries (e.g., Fergana and Khorezm). By incorporating multi-temporal RS data (2000-2015), derived indicators might also spot at the performance of the irrigation systems over time (multi-annually and annually). Indicators recently implemented can basically be grouped into land related and crop related indicators (Table 2) since they are considered to serve as essential prerequisites in further developing an indicator systems stressing the water use efficiency of the irrigated cropland.

Research results. WUEMoCA is anopen-source coherent, fully automated, online RS and GIS-based tool for the regional monitoring of irrigated cropland in the Aral Sea Basin. It allows for interactivelyexploring, filtering and analyzing the indciators implemented at different aggregation levels.Scientific information is provided to the userin Russian and English languages via commonly applied web mapping standards and routines (client-server-data system). The open-source software GeoServer therefore acts as map server that links the client application and spatial database (PostgreSQL/PostGIS). The map server creates WMS (web map service) and WMTS (web map tile service) map layers from geospatial tables that are are synchronized and compliant to the standards by Open Geospatial Consortium (OGC). User-specific request from the client, which is written in HTML, CSS, and JavaScript (OpenLayers), are sent to and processed by GeoServer (map server reading the geodatabase), which then returns the desired responses to the client. WUEMoCA is a three-component WebGIS (database, map server, and client application; Figure 2), which surface is designed to be freely available via internet with every current web browser.It contains detailed annual maps of land use and crop yield based on openly accessibleMODIS data for the observation period from 2000 to 2015. It allows to calculate and visualize relevant annual and multi-annual land and crop related indicators at the administrative level and the water distribution level as well as aggregated in a raster with a cell size of currently 5 km * 5 km. Important features of the WUEMoCA graphical user web-interface are presented in Figure 3.

Table 2 – Land and crop related indicators (alphabetical order) currently implemented in WUEMoCA. For the annual indicators, the calculation is based on one single year within the total observation period (2000-2015). For the multi-annual indicators, the average is taken from 2000 to 2015. State: July 2016.

Name of indicator	**Time scale**	**Notes**
Land related indicators		
Gross irrigated land area	annual	Net irrigated land area (ha) + the related area under canals, structures, roads, and buildings
Net irrigated land area	annual	Potentially usable irrigation area (ha)
Land use coefficient	annual	Quotient of the net irrigated land area and gross irrigated land area
Land use intensity	annual	Percentage (%) of area showing double season cropping
Net irrigated land use	annual	Actual use of net irrigated land area (%), double season is counted twice
Unused irrigated land	annual	Percentage (%) of net area classified as fallow land
Fallow land frequency	multi-annual	Number of years with fallow land
Crop related indicators		
Actual yield	annual	Yield (t ha^{-1}) of main crop types*
Actual farm gross output	annual	Farm output (tons) for main crop types**
Major land use	multi-annual	Predominating crop type (cotton, wheat, rice, fallow, orchard/vineyard, urban garden, other crop)
Crop rotation	multi-annual	Number of crop types
Irrigated crop acreage	annual	Irrigated area (ha) cultivated with different crops and total irrigated crop acreage for all crops
Irrigated land use per crop	annual	Percentage (%) of irrigated land cultivated with different crops (cotton, wheat, rice, orchard/vineyard, other crop, urban garden)
State order land use	annual	Percentage (%) of area cultivated with cotton and wheat

*currently available for cotton and wheat, **currently available for wheat

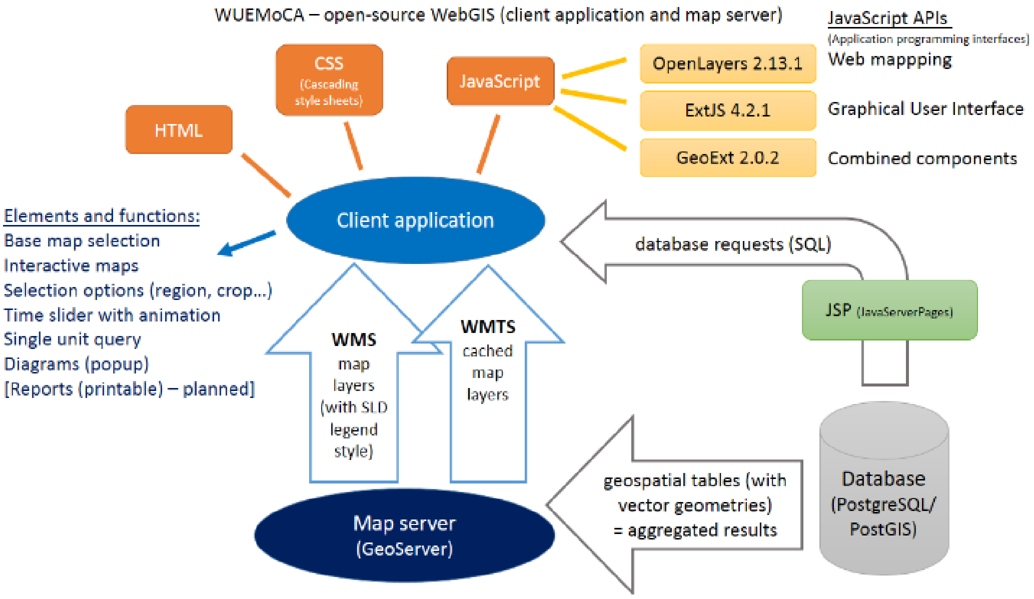
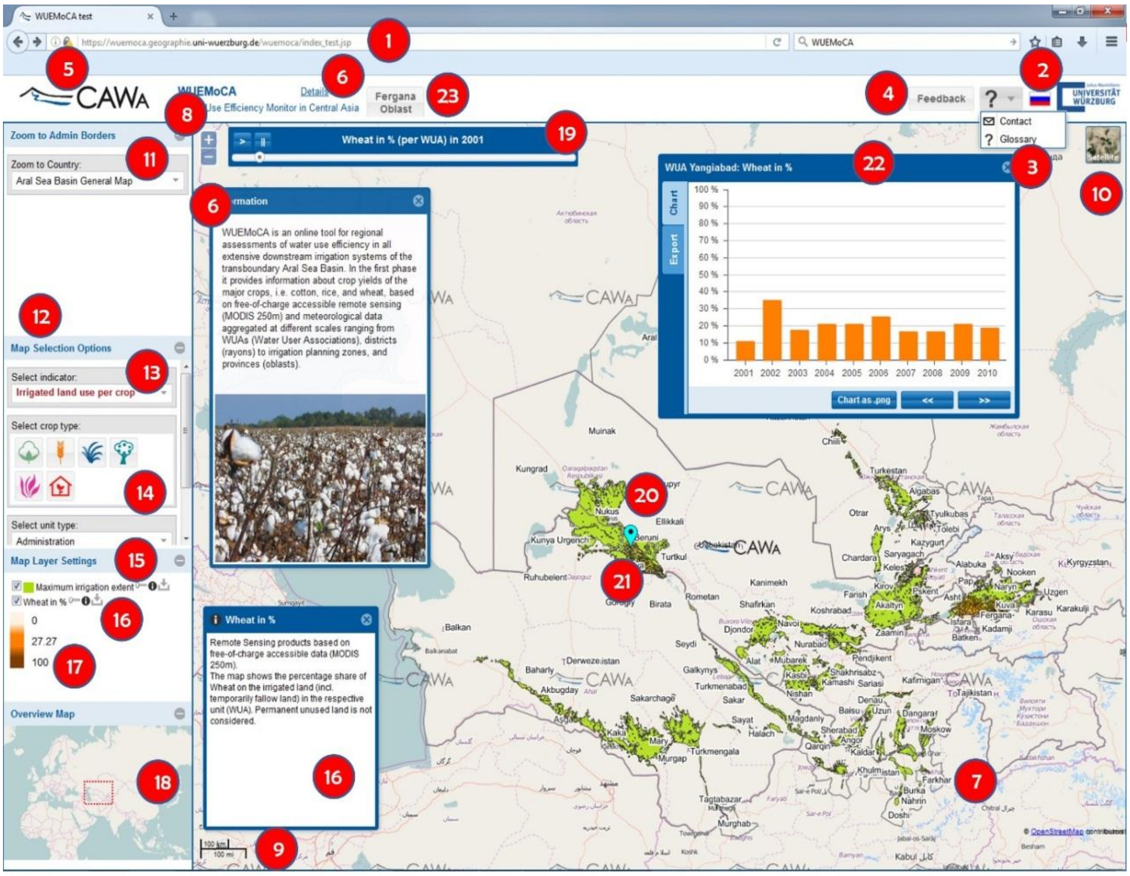


Figure 2 – WebGIS - Interaction between client application, map server, and database.



Zoom to Country: Aral Sea Basin General Map

Select indicator: Irrigated land use per crop

Select unit type: Administration

WUEMoCA is an online tool for regional assessments of water use efficiency in all extensive downstream irrigation systems of the transboundary Aral Sea Basin. In the first phase it provides information about crop yields of the major crops, i.e. cotton, rice, and wheat, based on free-of-charge accessible remote sensing (MODIS 250m) and meteorological data aggregated at different scales ranging from WUAs (Water User Associations), districts (rayons) to irrigation planning zones, and provinces (oblasts).

Wheat in %

Remote Sensing products based on free-of-charge accessible data (MODIS 250m).
The map shows the percentage share of Wheat on the irrigated land (incl. temporarily fallow land) in the respective unit (WUA). Permanent unused land is not considered.

Figure 3 – WUEMoCA features at a glance are: (1) Website URL, (2) language (Rus, Eng), (3) glossary and disclaimer, (4) user feedback template, (5) link to CAWa homepage, (6) WUEMoCA information, (7) Web-interface window, (8) Zoom button, (9) Scale bar, (10) Satellite map, (11)Country Selection, (12) Map selection (e.g., administrative level, water distribution level), (13) Indicator selection, (14) Crop type selection, (15) Unit type selection, (16) Map layer settings and information, (17) Legend, (18) Overview map, (19) Time slider (2000-2015), (20) Single unit query, (21) Tooltip, and (22) Diagrams/export option. Screenshot of WUEMoCA test version, June 2016.

Currently, 14 land and crop related indicators are implemented into WUEMoCA (Table 2).

Figure 4 exemplarily shows preliminary, visualized results of the requested annual indicator ‘yield’ in Kashkadarya Province (approximately 28,500 km²) in southern Uzbekistan (divided into two planning zones (PZ): Karshi PZ and Kashkadarya PZ, [25] in the interactive web-interface WUEMoCA. The resulting yield from the MODIS-based land use classification is aggregated to a grid of a cell size of 5 km * 5 km clearly spotting at pixels of averagely low (yellow color) yields to averagely medium (orange color) and averagely high (green color) yields of the crops wheat and cotton.

Discussion. Since WUEMoCA is yet in the process of developing, results need to be considered as preliminary. However, first results as exemplarily shown in Figure 4 are assumed to approximate the RS-based land use and crop information in a valuable manner since they are in close agreement with scientific results from this region [7]. Figure 5 indicates a similar production pattern in the Kashkadarya Province with wheat as typical winter crop spatially concentrating in the southern and south-eastern irrigation area in the mountain foothills and cotton as typical summer crop mainly concentrating in the central irrigation area in the Karshi steppe (in 2005). WUEMoCA (Figure 4) - in contrast to the scientific output (Figure 5) - is designed to give overview information rather than a zoom to every single field. However, at both scales, the 250m pixel level and the WUEMoCA grid of

5km * 5km, particularly for cotton, but also for wheat (which is indicated in Figure 5 by a high amount of double cropping in 2005), both figures show an area increase between 2001 and 2005. This is considered to mainly result from the fact that in the Amu Darya catchment,the years 2000 and 2001 were identified as drought years [26]and 2005 as 'water-rich' year as visible in the CAREWIB database [27].

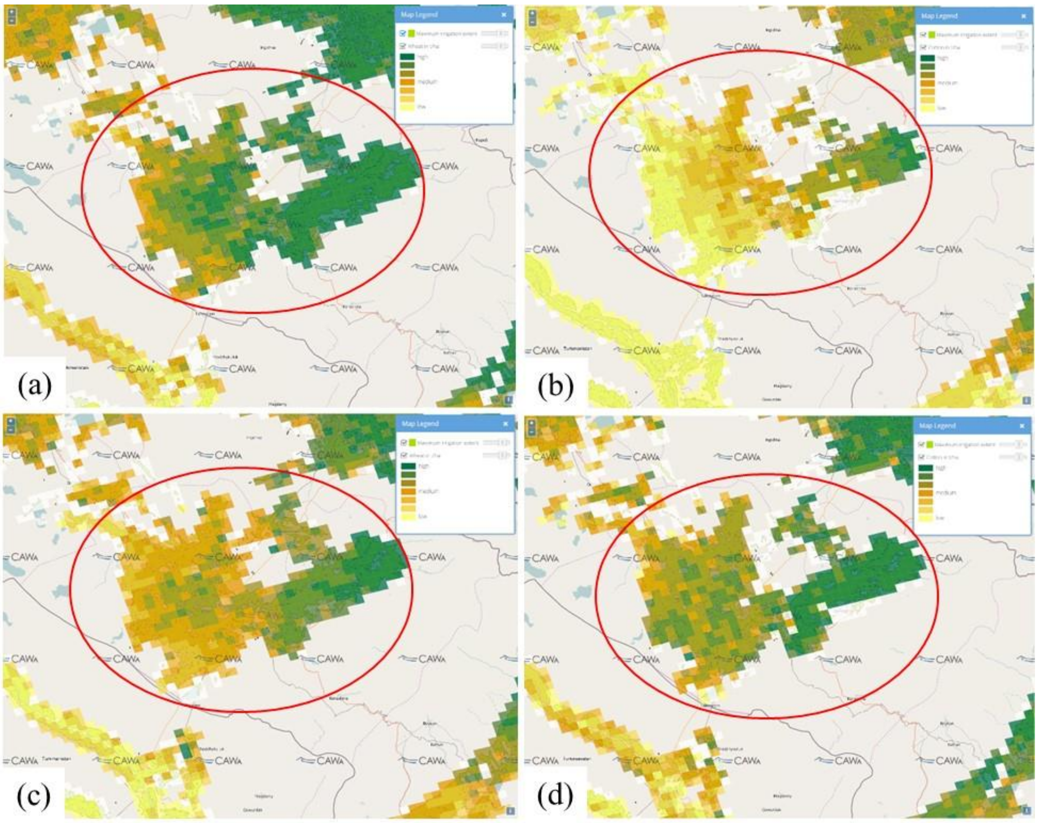


Figure 4 -Visualization of irrigated cropland use in WUEMoCA;output of the query on the indicator 'yield' use' in Kashkadarya Province (red framed) as exemplarily shown for (a) wheat in 2001 and (b) cotton in 2005 as well as (c) wheat in 2001 and (d) cotton in 2005. Results are aggregated to raster cell sizes of 5 km * 5 km. State: August 2016.

As a next step in developing the monitoring tool, validation of results will be conducted using field data, annual reports, and official statistics for Central Asia as this is mandatory to meet the need of reliability. Moreover, the tool itself will be further developed towards becoming increasingly user-specific. For instance, during the process of development and specification of user demands it turned out that the acquisition and/or provision of reliable aggregation geometries (e.g., administrative and water distribution levels) is challenging for WUEMoCA. Indicators aggregated directly to water supply zones that are assigned to a certain water source (e.g., channel command areas) are of particluar interest since they enable for directly evaluatingresult of water management decision, e.g., to assess the amount of water supplied via the different sources to the command area. Future developments will therefore also focus on theimproved applicability by providing a user polygon tool. This will allow for the interactive input of defined focus areas to get demand-specific results of all available post-processings (e.g., share of crop types, yield estimation). To avoid manipulations of the common database and to meet the necessity of plausibility checks, a client side user database will be developed, too.

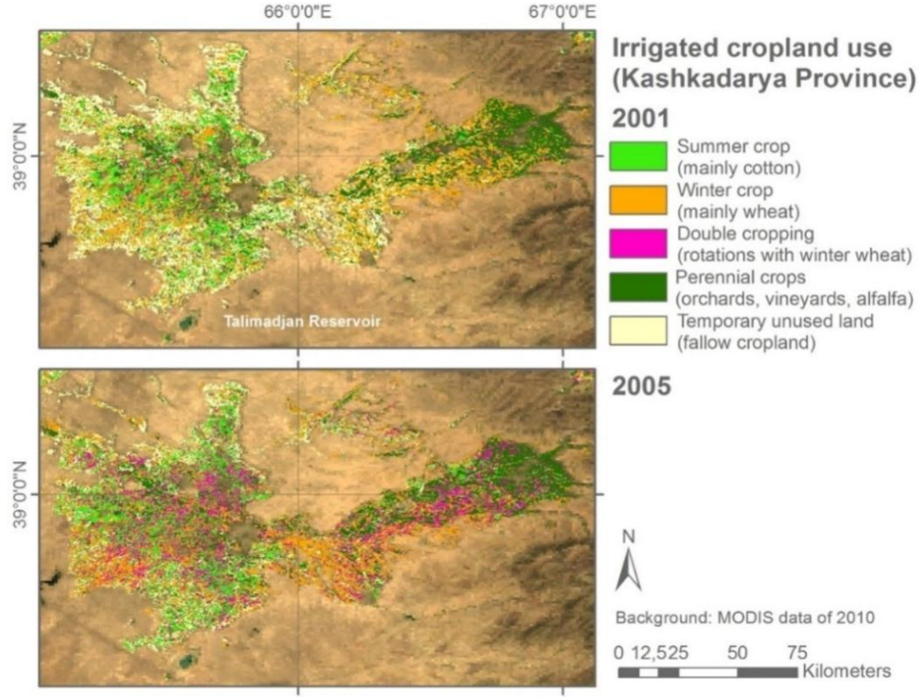


Figure 5 - Production pattern in 2001 (above) and 2005 (below) in the Kashkadarya Province in southern Uzbekistan. Results shown are based on results given by Conrad et al. (2016).

Furthermore, the system of indicators will be extented towards the integration of water-related indicators providing detailed information on the water supply for irrigation purpose and crop-specific water consumption, e.g. evapotranspiration [28]. Based on the concept of water accounting[29], the future proposed system of indicators is then considered to describe quantitativelyhow efficient the supplied water was used for crop production.Current activities focus on the challenging level of uncertainties resulting from the geometrical properties of the MODIS pixels by introducing a multi-level appproach on the calculation of gross and net areas of indicators and incorporating high-resolution Landsat data into the process of derivation of aggregation levels. The authors are aware that WUEMoCA is not ready yet. Moreover, it is clear that it may not supply every potential user with the desired data, for instance because it is not able to monitor every single field. However, the current state of WUEMoCA is promising in context of providing critical indicators to get an improved understanding of the land use and its intensity as well as the productivity of irrigated cropland for future comparison of irrigation systems, at least at regional scale.

Conclusion. WUEMoCA is an online, openly accessible GIS-based tool for the regional monitoring of irrigated cropland in the Aral Sea Basin. With the designed system of indicators, it aims at providing scientific results towards a broad user-community in Central Asia. The methods will contribute to the current data base and indicator systems at the regional scale and are foreseen to be implemented in modeling future perspectives, e.g., through the ASBmm model of SIC ICWC (http://sic.icwc-aral.uz/asbmm_e.htm). Potential future applications are considered to include assessments of marginal lands with low productivity, the intensity of land use, the early estimation of harvest shortfalls, and the assessment of water use efficiencies. WUEMoCA is concluded to lay the foundation for transferring scientific results to the regional applicants, not only in water management institutions. With the introduction of the new technologies this is expected also to attract the young generation and universities, which can be seen as important step towards long-term maintenance and regional spread of the potentials of RS and geoanalytical methods in context of in water management. Altogether, WUEMoCA might become a useful tool in support of planning in national and transboundary water-management organizations for refining principles in the land and water managements against the background of water scarcity in the vulnerable Aral Sea Basin.

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THE INTEGRATED WATER RESOURCES MANAGEMENT AT THE RIVER BASINS

The establishment of the complex Water Resources Management should be integrated at the river basins. This is a long term process undertaken together with neighboring countries (upstream, downstream), including municipalities, cities and infrastructure systems, small communities, industry locations, rural and distant settlements. In addition, flood and drought management at the basins' level should be managed upon institutional strengthening, capacity building at all levels in the state, from governmental to the local authorities aiming at the food provision, environment, employment and energy, particularly renewable sources.

Education is the basis for all of those aspects and development at all levels of education, including elementary, grammar school, higher education, specialization, master and doctoral studies. Also, dissemination of information to wider audience and people at inland and distant streams and water resources.

Applied research, planning, design projects in local conditions, accounting for tradition, culture of living, public health for people and animals including climate, global and climate change is the other end of a story. As a wider information and education is better will be integration of the water resources management from the general river basin plan developed with neighbours and international support, all the way to small setllements and agriculture fields. In order to accept such a strategy of water resources and environmental protection approach „millions of people if not each and everybody“ have to be informed and thousands of people have to be educated. Many of those could be employed in inland waters, not only in Capital city.

Networking of Universities, faculties and institutes, professional associations, Governmental agencies and stakeholders is the right and theonly winning concept that can conquer increasing demands for water, challenging trans-boundary problems that should be active and promising bases for evelopment, rather than sole developing of any entity at State level, aiming at quenching the world thirst.

Introduction. Integrated water resources management is a complex, timely and high professional human resources demanding. It is also demanding at several levels of governing, including international, regional and within the state. Moreover, it is a very complex and demanding within the each settlement, either small or big city where the complexity is increasing to a very difficult and time consuming solution.

Concerning large river basins that are shared among many countries it is difficult to define a list of priorities of significant water management issues instead of tedious and long run discussions, negotiations and information of the interested parties – stakeholders (EU, 2000). Among the best practice as an example of a management at the large river basins could be used experience of the IHP UNESCO Danube countries informal association that hold meetings, conferences and project performance for more than 50 years. Also are established several protocols on flood protection, navigation, water quality and else, but also the Danube river basin management plan. This plan is the basic for establishment similar plans at lower or the river sub-catchment, such as Tisza, Sava etc.

International basin level. In Figure 1 is presented the Danube river basin, of app 800.000 km^2 that have been shared by many countries trough the history, so far 15 of those in Europe. For more details interested people could consult the following web portals: http://www.danubecommission.org, and www.icprd.org.

After some decades, floods and poor water qualyty management in Europe raised the question of watre quality, so lots of initiave was put into this issue, and so called ICPDR Commision was established. In all of the countries along the river Danube and their tributaries many issues were discussed, particularly, river Danube Hydrology and major infrastructure projects, such as construction of the Iron Gate river dam at the Danube. It is between Roumenia and Yugoslavia, now Serbia, in year 1978. The Danube river basin connects more than 15 countries, as could be seen in Figure 2. All the time after the II Worls War several internatinal Commissions were established, as follows:

- The Danube commission for navigation, in Budapest,
- The ICPDR, in Wienna,

and many others.

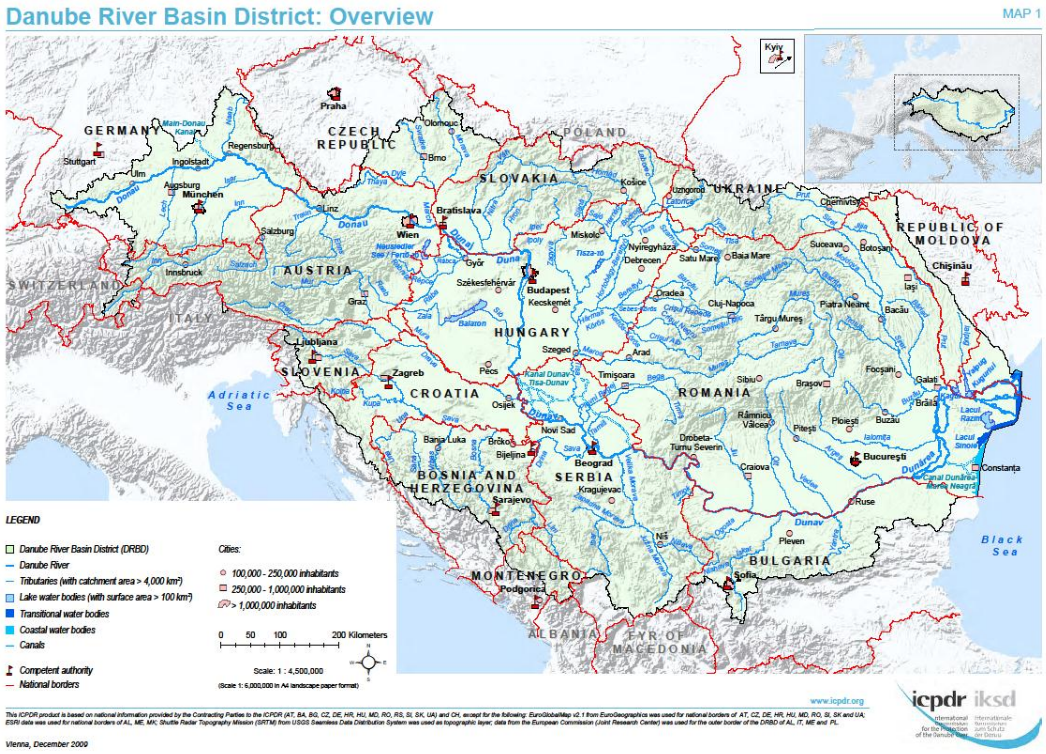

Figure 1 – The Danube river basin is the largest watershed in Europe, of app. 801.000 km^2

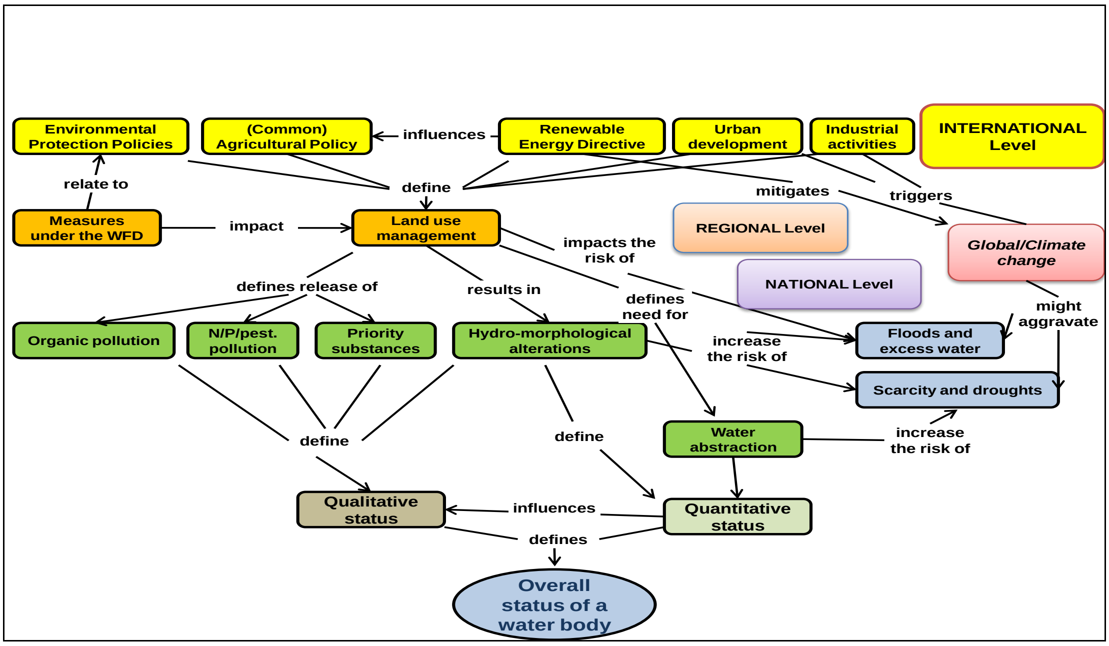

Figure 2 – Integrated water resources management as discussed at the Danube river basin management preparation and planning sessions all along the series of Inernational conferences, workshops, bilateral agreement, joint monitoring and lots of other activities for mote than 65 years, unofficially

The goals were set and the activities were planned and performed in accordance to the goals.

Unofficial cooperation could be very much useful for other regions of the World where sharing and common management of water resouces is a must, and there is no other means for solving a numerous accumulated misunderstanding. In Figure 2. is presented an integrated water resources management, discussed many times at the Danube river conferences but also at meeting at other sub catchments.

International sub-basin level. An example of a good practice was establishment of the sub-basin of the Danube, as International Sava River Basin Commission by ex Yugoslav republics, after war times so that aspects of navigation, water quality, flood protection and development at the whole watershed is planned and implementation started. So, in many regions of the World a numerous water conflict could be avoid or decreased if discussions, conferences, negotiations could be organized. Maybe the International Hydrologic Program UNESCO is most reliable and promising ground bases for such an initiative: in Figure 3 is presented the Sava river basin shared amog Slovenia, Croatia, Bosnia and Herzegovina and Serbia, but very small parts in Montenego and Albania.

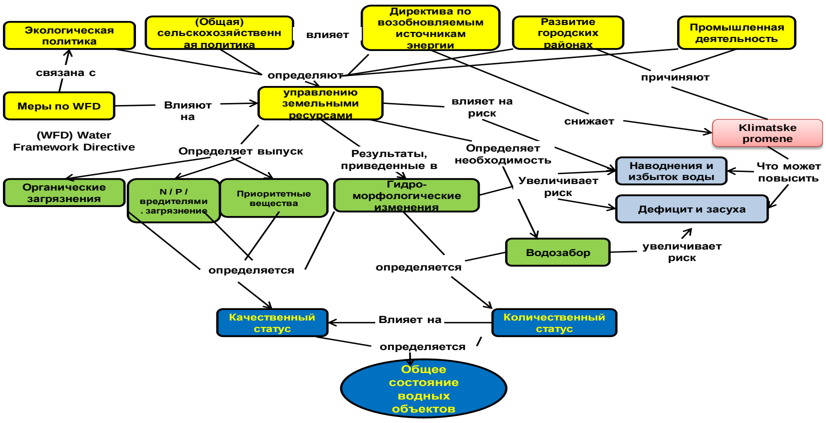

Figure 3 – Integrated water resources management (ЕУ ОДВ, 2000)

Much latter is established also Internatinal Commission for the Sava river Basin – ISRBC, aiming at the following topics and goals:

1. Navigation, all the way trough Zagreb, but also Slovenian border,
2. Water quality preservation and improvement, the whole Sava river.
3. Flood protection,
4. Development of cooperation in economy sector of the 4 countries.

Economy is improving although particular economies of certain countries are very poor.

Thus, philosophy of integral water resources management should be based form the whole basin level, but also from the each country aim and plan of developmet. In other words, communicationa of joint projects, particularly monitoring and field maserements should be manadged in a coordinatin and in an open mind way.

In addition, every state at the Danube and the Sava rive basin established an experimental – pilot river sub-basin that have been taken for performing all of the monitoring, field, study and other activities aiming at research, education and implementation of numerous Guidances based on the EU Water Framework Directive, and other directives.

State – country or Natonal sub-basin level. At regional level lots of issues of a “lesser” importance should be shared and solved, such as water resources for drinking and irrigation purposes. Lots of farmers and people in agriculture are interested for those waters, as well as people and utility companies. Those demands and justification of problems could be solved if only they are settled within the regional water resources evaluation and assessment.

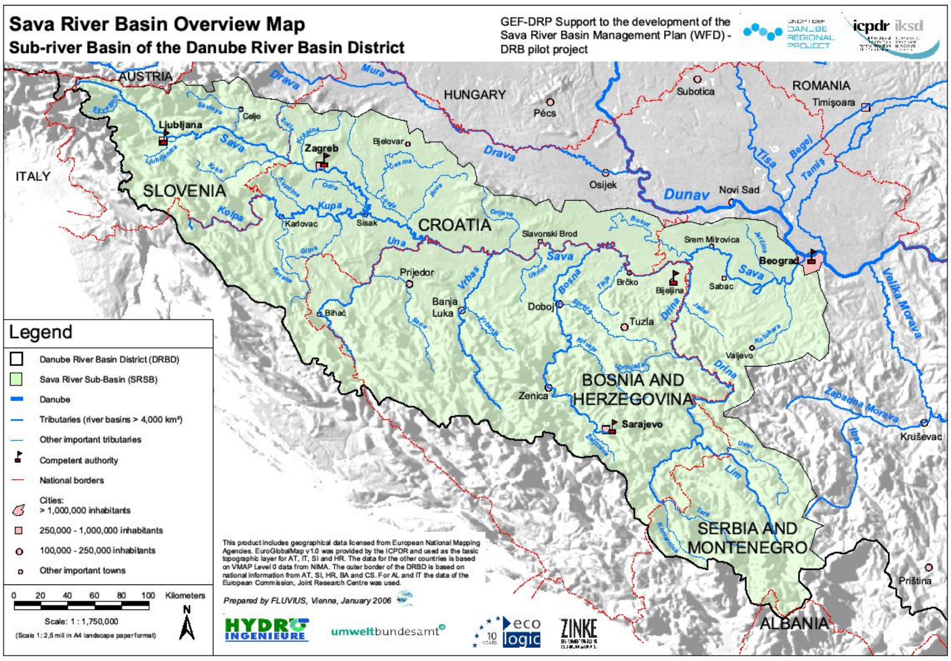

Figure 4 – The Sava river basin plannng and management at the 4 countries shared

At the national level a wide range of activities of people and professionals are available for improving the water quality and total environment measures of resilience. In Figure 5. is presented such a pilot basin in Serbia, named after the Kolubara river basin, which is the only one pure basin within the borders of the State, of app 3.600 km^2. In Figure 6 are presented details of the chosen pilot basin Kolubara.

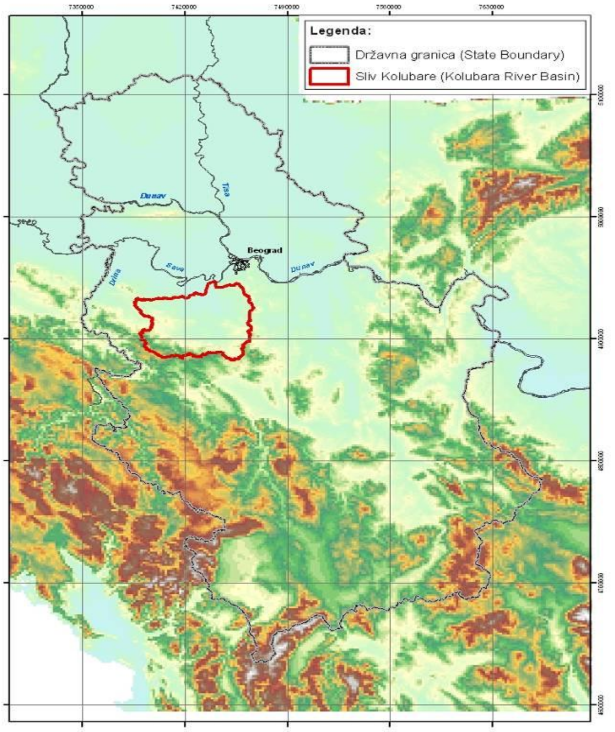

Figure 5 – The Kolubara river basin as the only Serbian river as a whole

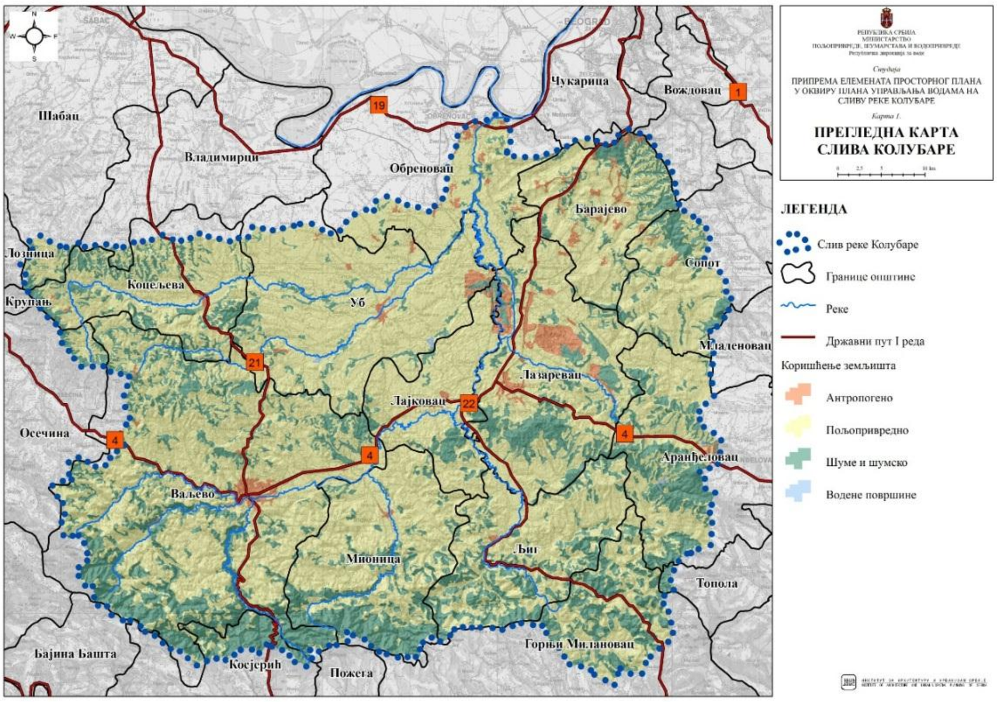

Figure 6 – The pilot eperimental basin Kolubara, sub-basin of the Sava river basin flooded in 2014

There are numerous studies and implementation projects that were performed, concerning the integrated eater resources integrated management, but most of the resultswere destroyed by and during the historical floods in.

Conclusions. Experince gaind for more than 65 years at the Danube river basin for cooperation and common work should be used and implemented, but without very much important first step, answering what would be goals for all of the interested countries, and parties at the basin? In other words, all of the interesrted parties, also named the stakeholders should participte at the international cooperation in the region of the Central Asia, Caucasus, Caspian and Black Sea, including beside all of the countries at the banks or the coast ot the mentioned lakes, seas and rivers, also all of the neoighbouring countries, such as China, Russian Federation, Turkey, Iran,

The water resources of the Black Sea and Caspian Sea and also Caucasus countries, such as Armenia, Georgia, Islamic Republic of Iran, Turkey, Russian Federation, Kazakhstan and Turkmenistan, directly or indirectly share the large amount of waters. Nevertheless, no international and jointly gained results, study work or projects, have been shared so far, e.g. Azerbaijan is at the downstream and of the rivers Kura and Aras, so that all of the impacts and consequences of water abstraction at first place, including decreasing of low flows, and water pollution along the two rivers is collected, deposited and infiltrated at the soil and waters of Azerbaijan. Some time ago there was a project Kura – Aras, but even more important is the Caucasus Sea which is also shared among major users of oil and gas from the sea and soil along it, so that pollution and other impacts are shared with neighboring countries, but the sources of potable water for the city of Baku could be influenced.

Most important also is the assessment of natural river flow potentials: after decades of poor management of water resources, either for agriculture irrigation, or hydro energy production could lead to non accurate estimation of future projects or development. Such an example is rather poor quality of water at the Kura/Aras system, and also poor conditions of the rivers Syrdarya and Amydary including drying of the Aral Sea. Improving of water dem and management at the entire basin, including all settlements, industry, sources of pollution and future demands have to be assessed

General aspects, conclusions, visions and measures for improvement of the waster body status from the river basin management plans should be conveyed and adapted at the regional and/or national levels. Major conditions and terms for water quantity and aspects of water quality should be cross -checked at the border monitoring profiles, by joint work of the institutions from the two countries, e.g. Iran/Azerbaijan, or Azerbaijan/RF or else. There is a strong need for establishment of International Commission for the each and every water basin, such as Aras / Kura, the Caucasus, The river Ural, since many countries are affected by decrease of the water quality, no matter if they are upstream or downstream. Health of entire world of rivers, riparian surfaces and even wider areas is endangered if numerous water abstractions, for human or industry purposes, are increasing at the river basins are. In addition, numerous sources or point and/or non-point pollution ones also decrease the quality of a whole life cycle of a river basin, to a higher or lesser degree.

Last, but not the least, ultimate aims and goals have to be defined in cooperation and coordination, together with the professionals from the Danube river basin for their long term tradition, experience, education and research.

Finnaly, National and International professionals from neighbouring countries from river basin should discuss major / significabt water isues, either water for agriculture or industry, for municipalities, water supply or hydro power plants, navigation, flood protection. There is also a strong recommendation to schedule a compound education at all levels, a pilot ared/sub basin for research and monitoring, an also an implementation phases, what could also be within International Hydrology Program UNESCO and family of UNESCO Chairs and Centers. The IHP UNESCO Phases VIII just started, so it is the time to join the Group II.

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RESOURCES OF RIVER RUNOFF OF KAZAKHSTAN

Работа посвящена оценке и использованию ресурсов речного стока Казахстана. Проведена оценка водных ресурсов и сценарные прогнозы на уровне 2020 и 2030 гг. восьми ВХБ на территории Казахстана.

Бұл жұмыс Қазақстанның өзен ағындысын бағалау және пайдалануға арналған. Сегіз США және Қазақстан аумағының су ресурстарын бағалау және 2020 және 2030 жылдар деңгейіндегі сценарийлік болжамдар жасалған.

The work is dedicated to the assessment and use of resources of river runoff in Kazakhstan. The assessment of water resources and scenario forecasts were made for the level of 2020 and 2030 years by eight WMBs on the territory of Kazakhstan.

Water problems and possible consequences of global climate change are a special priority for Kazakhstan. Here, a significant intensification of production is expected in the near future, the problem of water scarcity threatens to become particularly acute. We have less than 40 thousand m^3 of river water per year per 1 km^2 of our vast territory, which is several or even ten times less than in any other country in Central Asia.

Assessment of the current state of water resources and their forecast for the future is complicated by the fact that the river runoff is an integral characteristic of interaction of many geophysical processes and physical-geographical conditions of watersheds.

Many papers are dedicated to the assessment of river runoff resources, their long-term fluctuations [4-8]. The issue of the stability of the norm of river runoff over time is controversial [9-15]. The essence and importance of the problem of water resources assessment are evident, and the urgency of scrupulous accounting of water resources and especially the river runoff is also very clear.

A literature review of research on water resources assessment shows that the total resources of river runoff (observed in the average in terms of water content year) have a clear downward trend: after the high-water 40-ies of the last century, they were estimated at 150 km^3/year, in 70-80-ies - at 115-125 km^3/year, at the level of 2000 - at about 100 km^3/year, and finally, at the level of 2010 - at 94 km^3/year [16].

The reasons for this decrease are the increased anthropogenic load on water resources and their watersheds, general climatic trends, and the main ones are the growing water intakes from our transboundary rivers outside the territory of the Republic of Kazakhstan. This is due to the fact that about 44% of the runoff of our rivers came to us from China, Russia, Central Asian countries until recently. Seven of the eight water management basins relate to transboundary ones.

Also, generalizations on river runoff in Kazakhstan, the performance based on a single methodological basis relate to 50-70-ies of the last century [17]. At the same time, the calculations were made on the basis of the dominant at that time concept of stationarity of climate and river runoff. It is quite obvious that there is an urgent need to reassess these data, taking into account the additional information and on the basis of other initial concept.

Such work is carried out by research groups of the Institute of Geography and the Department of Hydrology of land of the Al-Farabi Kazakh National University under the auspices of the MES of the RK. The assessment of the total current and expected resources of river runoff in the context of the eight water management basins (WMB) was made. Their main results are described in this article.

Background. Analysis of the hydrological study of all eight WMBs has shown that it is insufficient for a reliable assessment of water resources, their spatial distribution, derivation of the calculated dependencies. Short series dominate, up to 30-50% series contain data of not more than 10 years. But also the longer series usually contain significant omissions. At the part of the stations, observation were conducted not in all months in some years.

The painstaking work has been done on the reconstruction of series of observations. Its basis is a method of hydrological analogy with the use of techniques of pair and multiple correlation. At the same time, the current regulatory requirements were observed, as well as the latest Russian developments were taken into account. As a result, the continuous long-term series of annual runoff at 497 stations are restored, including: in the Aral-Syrdariya basin - by 77 points, in the Balkash-Alakol basin - by 74 points, in the Yertis basin - by 60 points, in the Yesil basin - by 26 points, in the basin of Nura and Sarysu rivers - by 38 points, in the basin of Tobyl river - by 15 points, Torgai river - by 15 points, in the Zhaiyk-Caspian basin - by 80 points, in the basin of Shu and Talas rivers - by 109 points.

In addition, the data of the stations with short and ultra-short series were reduced to long-term period (also in compliance with known techniques and norms).

Assessment of the runoff rate. The analysis of long-term course of the annual runoff by major rivers was made. In particular, the following techniques were used: integral (cumulative) curves, moving averaging, the differential integral curves. As a result of the analysis made, the findings of climate scientists about the new phase of climate from the mid 70-ies were generally confirmed. [8, 9]. The beginning of the progressive warming of the global climate and directed changes in the volume of water resources of the regions are related to this period.

The results of quantitative analysis for water management basins (WMB) show that the runoff of the major rivers of the northern half of Kazakhstan in the last decades, from about 1974, has decreased - in particular, the runoff of Kara Yertis and large rivers of the West Altai, Tobyl, Togyzak, Nura , B.Hobda, Oyyl, as well as the rivers of the northern Balkash Lake region. At the same time, the opposite trend is observed on rivers with glacier feeding (south and south-east of Kazakhstan) - of some increase in water content of rivers. At the same time, the interannual variability of river runoff has decreased on the absolute majority of gauging stations.

In this regard, the following calculation periods were appointed: 1) long-term (its beginning - from the 30-40-ies - in different WMBs determined by the characteristics of hydrological study of the territory); 2) the period that characterizes the modern phase of climate and runoff; it is 1974-2007 for most of WMBs; 3) period, the significant part of which is characterized by a conditionally-natural runoff (mainly, it is the period up to 1974).

In such variants, the runoff rate is calculated on all 8 WMBs. The rate of runoff is assessed, including by short series on 857 points, while earlier 420 points were used for that in the "Resources ...".

The rate of runoff in the last period in the basin of the Upper Yertis was lower than the long-term one by 6,7%, in the basins of the Zhaiyk-Caspian WMB - by about 10% (although the runoff of the right bank of Zhayyk river, on the contrary, has increased). More significant was the reduction of runoff in comparison with the values published in the "Resources of surface water".

This trend is not observed in Central Kazakhstan, and river runoff has even increased in the basin of Sarysu river in the last decades.

The rate of runoff in the last period (1974-2007) on the rivers of the South and South-East of Kazakhstan has increased by 1,7% (basin of Syrdariya river), 5,2% (basin of Shu-Talas rivers) and 3,0% (Balkash -Alakol basin), except for the rivers of the northern coast of Balkash lake, where there has been some decrease in runoff during the last period.

Assessment of the impact of economic activity. Assessment of distortion of runoff as a result of economic activity and recovery of values of natural (climatic) runoff were made in different ways: on the basis of taking into account the value of water intake, assessment of the impact of water reservoirs and ponds on the runoff (in particular, in terms of the volume of their content, the magnitude of additional loss through evaporation), in terms of links with stations with undisturbed runoff, according to the method of linear trend.

The greatest changes in the runoff under the impact of economic activity occurred in the south of the country. Thus, the value of reduction of water resources of the basin of Syrdariya river is an average of 65% of the climatic runoff. But in recent years (2000-2007), there has been a positive trend in the runoff of Syrdariya river, which is associated with an increase in the water content in the zone of its formation and, accordingly, - with an increase in the inflow to the border of Kazakhstan and to the Shardariya reservoir up to 20%. Very significant anthropogenic reduction in runoff - to 35-55% - occurred in the basins of Arys, Badam, Bogen rivers. In Central and Northern Kazakhstan, the anthropogenic impact strongly affected in low-water years. In the basin of Sarysu river in a very low-water year (probability of P = 95%) at different gauging stations, the runoff reduction was 50-90%; runoff of Yesil river in low-water year (P = 80%) at the gauging stations of Astana and Petropavlovsk reduced respectively by 46 and 65%, and in a very dry year actually the entire runoff is held by reservoirs.

Renewable resources of river runoff. Renewable water resources of the basins are usually composed of the runoff recorded in the closing gauging stations of rivers, water inflow lower than these stations, as well as the runoff of the unstudied rivers. Since the runoff usually disperses in the lower sections of the rivers in the plains of Kazakhstan, sometimes up to complete disappearance, data of gauging stations with maximum runoff were used for the calculation of total water resources.

The total water resources were assessed in two ways: based on the observed (household) and natural (restored) runoff. In addition, the values of the local, Kazakhstan's, and runoff coming from neighboring countries were separated.

Both the average water resources, and resources in the typical in terms of water content years (50, 75, 95% of probability) were assessed on a scale of 8 WMBs.

The values of water resources of different probability within each WMB were taken from the curve of probability, built on the values of the total river runoff within each WMB. Total water resources of the Kazakhstan's territory during the years of various probability of runoff were determined by summing the equal probability values of runoff by all the WMBs.

Average water resources during long-term period up to 2007 are as follows:

- for the observed data - 99,5 km^3/year,
- for the restored natural runoff - 115 km3/year.

Note that the first figure is very close to the estimations for 2000.

Total resources of river runoff in Kazakhstan (household runoff) for the observation period of 1974-2007 are equal to 91,3 km^3 /year (50% probability), of which 44,3 km^3/year comes from neighboring countries, 47,0 km^3/year is made by the local runoff (Table 1).

Thus, due to the economic activity, resources of river runoff in Kazakhstan have decreased by 23,8 km^3/year (by 21%), including transboundary runoff - by 15,9 km^3/year (by 26%), local runoff - 7,9 km^3/year (by 14%). The greatest impact of economic activity was manifested in the Aral-Syrdariya water management basin (decrease by 47%), the smallest - in the Nura-Sarysu and Yertis basins (decrease by 8%)

Table 1 - Current state (household runoff for 1974-2007/natural-climatic runoff for the same period) of water resources of Kazakhstan by WMBs [16]

№	Water Management Basins	River runoff (50%), km3		
		Total	Including	
			neighboring countries	RK
1	Aral-Syrdariya	15,9/29,8	14,2/26,5	1,74/3,28
2	Balkash-Alakol	25,6/29,0	11,9/12,7	13,7/16,3
3	Yertis	30,9/33,7	6,45/7,32	24,5/26,4
4	Yesil	1,66/2,21		1,66/2,21
5	Zhaiyk-Caspian	10,5/12,8	8,31/9,87	2,23/2,93
6	Nura-Sarysu	1,14/1,15		1,14/1,15
7	Tobyl-Torgai	1,42/1,71	0,307/0,413	1,11/1,29
8	Shu-Talas	4,13/4,65	3,31/3,36	1,00/1,29
	RK	91,3/115,1	44,3/60,2	47,0/54,9

Scenario forecasts of water resources. It is, of course, important to anticipate the volume of water resources in the future in order to address strategic issues related to their use. Unfortunately, there is still not reliable forecasting methodology of regional runoff (even in the presence of a reliable meteorological forecast, which is also quite problematic).

A number of methods of forecasting of natural (climatic) water resources is tested, of which the the following are found to be the most promising for the prediction of the situation at the level of 2020 and 2030.

1. By the line of the linear trend derived for a multi-year period.
2. On the basis of the derived regional relations of the runoff of major rivers with the determining meteorological factors. At the same time, the forecast of meteorological characteristics of an average of nine atmosphere and ocean general circulation models (AOGCM) of new generation (CMIP3 - coupled model intercomparison project) was used. This forecast is given in the two known variants of changes in the concentration of greenhouse gases in the atmosphere: B1 ("soft") and A2 ("hard").
3. In addition, the G.Ya.Vangengeym's forecast [10] of the forms of atmospheric circulation, as well as the derived for this purpose relations of water content of the major rivers within each basin with its various forms, were used for five WMBs of the northern half of Kazakhstan.
4. The average of all variants of forecast was used for the scenario forecast for the level of 2020 and 2030. But if one of the methods gave non-consistent with the others ("bouncing off") forecast values of water resources, such scenario was not used in averaging.

The values of scenario forecasts of natural water resources are shown in Tables 2 and 3.

As shown in Tables 2 and 3, at the level of 2020, total natural water resources will amount to 117,7 km^3 in the average for water content year, which is slightly higher than the long-term average and 3% more than modern resources. This increase will occur mainly due to the southern basins, where glaciers participate in the formation of the river runoff. Total water resources in five northern WMBs, on the contrary, will decrease by 1,5% in comparison with the multi-year period.

At the level of 2030, a significant increase in water resources - up to 120 km^3 - is expected, and this increase in runoff will be found almost everywhere.

At the same time, in our opinion, the possibility of significant water shortage in the northern half of Kazakhstan in the nearest decade - 2012-2021, cannot be ignored. According to [10], the dominance of the eastern **E** form of circulation is expected in the atmospheric processes in this period, which is usually accompanied by a significant reduction in river runoff in this part of Kazakhstan. Exactly the same situation happened in the 30-ies of the last century, when a catastrophic water shortage swept not only the northern half of our continent, but also part of North America. Fortunately, Kazakhstan has not experienced a similar water shortage since that time.

According to this scenario, the total water resources in the basins of West, North, Central and East Kazakhstan (five WMBs) will amount to 43,6 km^3 in the average for water content year, which is 12% lower than the norm of the last 34-year period and by 15,5% lower than the long-term norm.

Table 2 - Forecast of natural (climatic) runoff for 2020 [16]

№	Water management basins	River runoff in the year of average water content, km^3		
		Total	including	
			neighboring countries	Kazakhstan
1	Aral-Syrdariya	31,0	27,6	3,42
2	Balkash-Alakol	31,0	13,6	17,4
3	Yertis	32,9	6,90	26,0
4	Yesil	2,12	-	2,12
5	Zhayik-Caspian	13,0	10,4	2,60
6	Nura-Sarysu	0,755	-	0,755
7	Tobyl-Torgai	2,03	0,418	1,62
8	Shu-Talas	4,87	3,61	1,26
	Kazakhstan	117,7	62,5	55,2

№	Water management basins	River runoff (50 %), km^3		
		Total	including	
			neighboring countries	Kazakhstan
1	Aral-Syrdariya	30,42	27,1	3,32
2	Balkash-Alakol	30,4	13,5	16,9
3	Yertis	32,2	6,77	25,5
4	Yesil	1,68	-	1,68
5	Zhayik-Caspian	12,3	9,12	3,15
6	Nura-Sarysu	0,621	-	0,621
7	Tobyl-Torgai	1,668	0,345	1,323
8	Shu-Talas	4,99	3,78	1,21
	Kazakhstan	114	60,6	53,7

№	Water management basins	River runoff (75 %), km^3		
		Total	including	
			neighboring countries	Kazakhstan
1	Aral-Syrdariya	25,78	23,1	2,68
2	Balkash-Alakol	26	11,9	14,1
3	Yertis	27,247	5,449	21,798
4	Yesil	0,868	-	0,868

5	Zhayik-Caspian	8,683	6,233	2,45
6	Nura-Sarysu	0,341	-	0,341
7	Tobyl-Torgai	0,919	0,19	0,729
8	Shu-Talas	4,36	3,41	0,95
	Kazakhstan	94,2	50,3	43,9

№	Water management basins	River runoff (95 %), km^3		
		Total	including	
			neighboring countries	Kazakhstan
1	Aral-Syrdariya	20,25	18,3	1,95
2	Balkash-Alakol	20,8	10,1	10,7
3	Yertis	21,192	3,814	17,378
4	Yesil	0,246	-	0,246
5	Zhayik-Caspian	4,95	3,313	1,637
6	Nura-Sarysu	0,113	-	0,113
7	Tobyl-Torgai	0,305	0,063	0,242
8	Shu-Talas	3,58	2,93	0,65
	Kazakhstan	71,4	38,5	32,9

Table 3 - Forecast of natural (climatic) runoff for 2030 [16]

№	Water management basins	River runoff in the year of average water content, km^3		
		Total	including	
			neighboring countries	Kazakhstan
1	Aral-Syrdariya	31,3	27,8	3,45
2	Balkash-Alakol	31,3	13,7	17,6
3	Yertis	33,4	7,00	26,4
4	Yesil	2,17	-	2,17
5	Zhayik-Caspian	13,3	10,6	2,66
6	Nura-Sarysu	1,34	-	1,34
7	Tobyl-Torgai	2,24	0,459	1,78
8	Shu-Talas	4,90	3,66	1,24
	Kazakhstan	**120,0**	**63,2**	**56,6**

№	Water management basins	River runoff (50 %), km^3		
		Total	including	
			neighboring countries	Kazakhstan
1	Aral-Syrdariya	30,64	27,3	3,34
2	Balkash-Alakol	30,7	13,6	17,1
3	Yertis	32,711	6,869	25,842
4	Yesil	1,725	-	1,725
5	Zhayik-Caspian	13,427	9,206	4,221
6	Nura-Sarysu	0,914	-	0,914
7	Tobyl-Torgai	1,834	0,377	1,457
8	Shu-Talas	5,02	3,83	1,19
	Kazakhstan	117	61,2	55,8

№	Water management basins	River runoff (75 %), km^3		
		Total	including	
			neighboring countries	Kazakhstan
1	Aral-Syrdariya	26,0	23,3	2,70
2	Balkash-Alakol	26,3	12,0	14,3
3	Yertis	27,638	5,528	22,11
4	Yesil	0,89	-	0,89
5	Zhayik-Caspian	8,807	6,293	2,514
6	Nura-Sarysu	0,502	-	0,502
7	Tobyl-Torgai	1,011	0,207	0,804
8	Shu-Talas	4,38	3,45	0,93
	Kazakhstan	95,5	50,8	44,8

№	Water management basins	River runoff (95 %), km^3		
		Total	including	
			neighboring countries	Kazakhstan
1	Aral-Syrdariya	20,25	18,3	1,95
2	Balkash-Alakol	20,9	10,1	10,8
3	Yertis	21,496	3,869	17,627
4	Yesil	0,252	-	0,252
5	Zhayik-Caspian	5,921	3,345	2,576
6	Nura-Sarysu	0,167	-	0,167
7	Tobyl-Torgai	0,335	0,068	0,267
8	Shu-Talas	3,61	2,97	0,64
	Kazakhstan	**72,9**	**38,7**	**34,3**
Note: forecast values of water resources for 2020 and 2030 formed on the territory of Kazakhstan and neighboring countries, were adopted in accordance with the percentage of those values obtained in the period of 2007 from the forecast values of total natural resources for the same periods.				

Conclusion. Thus, water resources of eight WMBs on the territory of Kazakhstan as a whole were assessed on the basis of almost all accumulated hydrometric information, using modern methodologies and statistical techniques, in the following variants: household (observed) and natural (climatic) runoff, total and local runoff; all this was obtained for the calculation periods: long-term (from early to late 30-ies), modern (mostly 1974-2007) and the period preceding it, much of which is characterized by a quasi-natural runoff. These materials can be considered as the updated data of the published " Resources of surface water..." of the 50-70-ies. They take into account the information accumulated over 40-50-year period and the changes occurred due to climatic and anthropogenic factors. The data will be applied in the solving of strategic and current issues related to the use of water resources, their quantitative and qualitative management.

Forecast characteristics will also be useful when designing the appropriate measures.

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ASSESSMENT OF RENEWABLE WATER RESOURCES OF THE KAZAKHSTAN'S PART OF THE SYRDARIYA RIVER BASIN

В данной статье оценены суммарные ресурсы поверхностных вод Казахстанской части бассейна р. Сырдария на основе всей имеющейся гидрологической информации с учетом климатических изменений и антропогенных воздействий на водные объекты и их водосборы, а также, произведена оценка временных изменений и территориального распределения стока рек и суммарных водных ресурсов исследуемого региона. Приведены характеристики годового стока (норма, сток различной обеспеченности), необходимые при решении стратегических и текущих задач отраслей экономики республики. С учетом глобальных и региональных климатических изменений, антропогенных нагрузок на водные объекты и их водосборы, характеристики стока приведены в разных вариантах, в частности, для многолетнего периода, для периода, характеризующего современное гидроклиматическое условия, для предшествующего ему периода, в значительной части которого режим рек был «условно естественным».

Бұл мақалада климаттық өзгерістер мен антропогендік әсерлердің су объектілері мен олардың су жинау алаптарына әсерін есепке алынған барлық гидрологиялық мәліметтерге негізделе отырып, Қазақстан аумағындағы Сырдария өзені алабының беткі суларының жалпы ресурстары, сонымен қатар зерттеліп отырған аймақтың жалпы су ресурстарының және өзен ағындыларының аумақтық таралуы және уақытша өзгерістері бағаланды. Республиканың экономика салаларының қазіргі және стратегиялық міндеттерін шешуге қажет жылдық ағындының сипаттамалары келтірілген (қалыпты ағынды, әртүрлі қамтамасыздық жағдайындағы ағынды). Су режимінің едәуір бөлігі «шартты табиғи» болғандағы көпжылдық кезеңде және қазіргі гидроклиматтық жағдайды сипаттайтын кезең үшін, жаһандық және аймақтық климаттық өзгерістерді, су объектілері мен олардың су жинау алаптарына түсетін антропогендік әсерлерді ескере отырып, ағындының сипаттамалары әр түрлі нұсқада келтірілген.

This paper evaluated the total surface water resources of the Kazakhstan part of the basin of the river Syrdarya, based on all available hydrological data, taking into account climate change and human impacts on the water objects and their catchment areas, as well as assessed of temporal changes and the territorial distribution of river runoff and the total water resources the test region. The characteristics of the annual runoff (norm, runoff of different provision) necessary for solving the strategic and current tasks of sectors of the economy. Taking into account the global and regional climate change, anthropogenic pressures on the water objects and their catchment areas, the characteristics of runoff are available in different variants, in particular, for a multi-year period, for the period that characterizes modern hydro-climatic conditions, for prior to him period, a large part of which the regime of rivers It was "relatively natural."

Introduction. Syrdariya river, the major water-way of Central Asia, got its name after the merging of two rivers - Karadariya and Naryn, located far beyond Kazakhstan. They flow from the depths of the Tanirtau mountain system, where they receive abundant feeding from the melting snow and glaciers. Naryn is more abounding in water. Syrdariya reaches a length of almost 2900 km together with this river (Figure 1) [1-4].

Water problems and possible consequences of global climate change in the assessment of water resources are a special priority for Kazakhstan. Assessment of the current state of water resources and their forecast for the future is complicated by the fact that the river runoff is an integral characteristic of interaction of many geophysical processes and physical-geographical conditions of the basins.

Generalizations on river runoff in Kazakhstan, made on the basis of a uniform methodical framework, are related to the 50-70-ies of the last century [1]. Since then, firstly, a significant amount of additional hydrological information is accumulated, and secondly, there was a transformation of the conditions of accumulation and discharge of moisture in river basins due to the intensification of economic activity, which affected both the hydrological regime of water bodies, and the resulting volume of water resources. It was exactly in the 60-70-ies when many reservoirs were created, water-intensive industries were developed. Thirdly, climatic changes were clearly defined; they were particularly evident in the recent decades, which also had an impact on hydrological processes. It should also be noted that in connection with the collapse of the USSR, Syrdariya river became transboundary with the corresponding consequences.

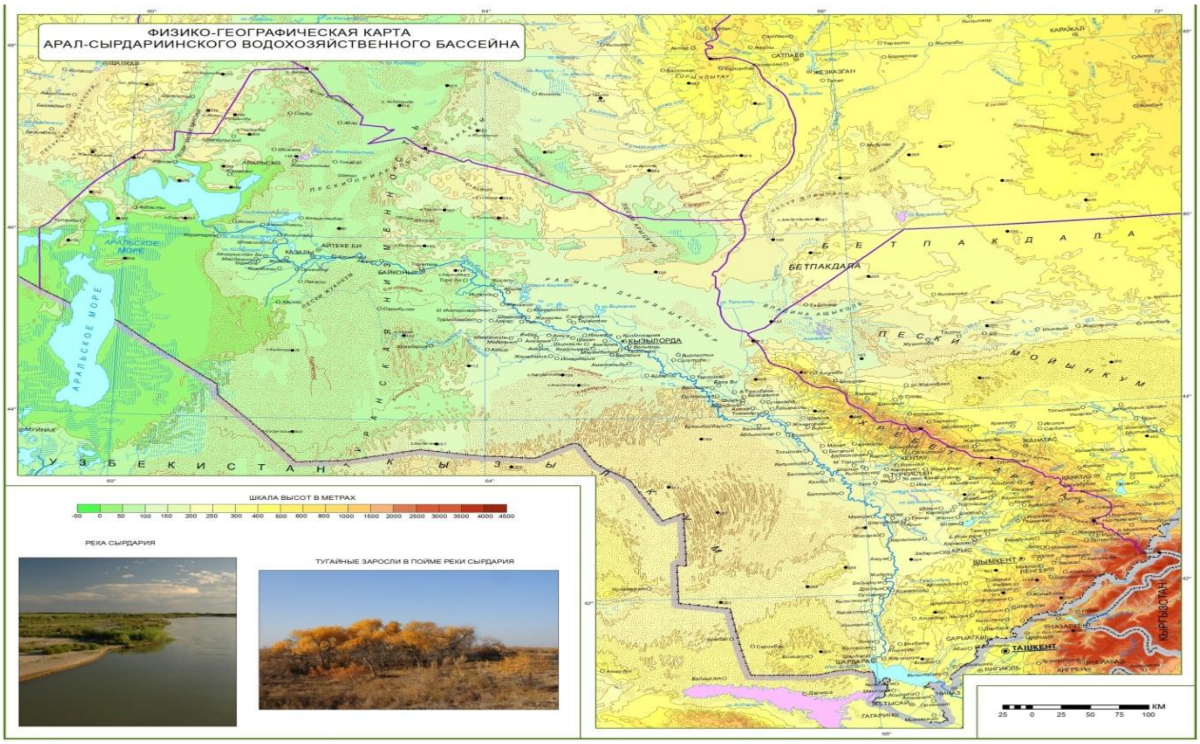


Figure 1 - Physical-geographical schematic map of the study area

As a result, there emerged an urgent task of assessing surface water resources on the basis of all the accumulated information and taking into account the ongoing climate change and anthropogenic impact on water bodies and their basins, as well as geopolitical conditions in the region.

Calculation of the rate and variability of annual runoff. The rate and variability of annual runoff of rivers and temporary watercourses of the basin were, for the first time, identified in the papers before the 70-ies of the last century [1]. These papers on the assessment of the rates of the annual river runoff of the Syrdarya river basin were based on the hydrological information of 10-15 years. 40-50 years passed since that time, and there have been fundamental changes in climatic characteristics and anthropogenic activities in the basin. This shows that there is an objective need for a new assessment of surface water resources, taking into account the mentioned changes.

The estimation of the rate of annual runoff of rivers and temporary watercourses was carried on 172 observation stations, while in the work [1] – on 30 stations. The calculations were made in two versions: for long-term period (1912-2007) and for the contemporary period (1973-2007).

Accuracy of the estimation of the rate in this case is defined by the formula with the autocorrelation coefficient between adjacent members of the series $r < 0{,}5$ [5; 6]

$$\sigma_{Q_0} = \left(\frac{\sigma_Q}{\sqrt{n}}\right)\sqrt{\frac{1+r}{1-r}}, \tag{1}$$

where σ_Q - mean square deviation; n – number of years of observations; r – autocorrelation coefficient between adjacent members of the series.

Thus, the errors in determining the rate of runoff for these stations range from 1,55% to 20,3% over the long-term period, and from 0,92% to 19,0% for the current period. The results of calculations on the main stations are shown in Table 1.

Table 1 - Main hydrological characteristics of the major rivers of the Syrdariya river basin

№	River-station	Long-term period (1912-2007)				Contemporary period (1973-2007)			
		Q, m^3/s	σ_Q, %	Cv	σ_{Cv}, %	Q, m^3/s	σ_Q, %	Cv	σ_{Cv}, %
1	2	3	4	5	6	7	8	9	10
1	Syrdariya river – above the estuary of Keles river	841	0,23	0,78	3,4	859	4,54	0,22	12,7
5	Syrdariya river – Tomenaryk r/w station	717	0,25	0,78	3,1	734	2,16	0,24	12,7
6	Keles river – Zhanabazar village	1,99	0,40	0,99	2,5	1,93	2,61	0,34	13,2
7	Keles river – Akzhar village (Stepnoye village)	5,80	0,32	1,02	3,2	5,60	3,92	0,28	13,3
8	Keles river – Gornyy township	4,73	0,23	1,02	4,4	4,61	9,06	0,20	34,0
9	Keles river - estuary	12,3	0,33	1,02	3,1	11,8	3,01	0,29	12,8
10	Arys river – Zhaskeshu aul	5,99	0,20	1,27	6,4	5,87	2,47	0,16	12,4
11	Arys river - Arys r/w station	45,5	0,28	1,27	4,5	44,2	2,67	0,23	12,6
12	Arys river – Shaulder village	38,4	0,29	1,27	4,4	37,2	1,79	0,24	13,0
13	Zhabagylysu river – Zhabagaly village	2,39	0,26	0,99	3,9	2,28	3,93	0,22	12,7

The stations of observation over the runoff with the duration of the series of less than 6 years dominate in the study area. The definition of the rate of annual runoff for these stations was carried out by the most developed and theoretically justified method of relations. As is known, the method is based on the assumption of the approximate equality of the module coefficients at the station with short-term observations and at the analogue-stations according to the formula [1]:

$$\overline{Q} = Q_i(\overline{Q}_a / Q_{ia}), \tag{2}$$

where Q_i and Q_{ia} - the observed values of the river runoff, respectively, at the station with short-term observations and at the analog-stations; $\overline{Q}$ and $\overline{Q_a}$ - rates of the runoff, respectively, at the estimation station and at the analog-stations.

An issue of the relative accuracy of the obtained results primarily arises, when estimating the rate by this method. In other words, the justification of the selection of the analog or the group of analogs in such cases is determined exactly by estimation accuracy. It is not possible to solve this issue theoretically without additional information. Usually, the problem is solved experimentally. Mean-square error in determining the rate of runoff according to the one-year observation data is calculated by the formula [7]:

$$\sigma_{Q_0} = \sqrt{\sum\left(\bar{y}_i - \bar{\bar{y}}\right)^2 / (n-1)}, \tag{3}$$

where $\bar{y}_i$ - the rate of runoff obtained according to the data of the i-th year of observations; $\bar{\bar{y}}$ - rate of runoff for all the years of observation.

Certainly, it is not possible to determine the standard error by the formula (3) with observational data for only one year. It is necessary to select two observation stations for that, with a rather lengthy series in homogeneous area in terms of hydrology, and one of them is conditionally taken as the station with short-term observations. Further is calculated the deviation of the rate of the estimated series calculated according to the data of individual years, from the rate determined for the entire observation period. It is clear that the accuracy of the estimate obtained in this way depends on the effectiveness of the selection of the analog-station. Therefore, the researchers select not one, but a group of analogs. The effectiveness of this method based on group analysis, is examined in the work in details [8].

Rates of runoff for 30 stations were determined by the method of relations in the Syrdariya river basin. Both weighted average altitudes, and the distance between the catchment areas have been considered in the selection of the analogs.

In order to estimate the runoff rate of the unstudied rivers and stations with disturbed regime, there was used the method of regional curves M_0=f (H_{av}), somewhat adjusted on the basis of the new results obtained in comparison with earlier generalizations.

With the help of the curves of dependence M_0=f (H_{av}), there were determined the rates of runoff for 48 stations, where the natural runoff regime was disturbed, as well as for 20 unstudied stations.

The error of the rate of annual runoff obtained by reducing the short series of observations to the long-term period on the graph of relation, consists of the errors of the average value of the long-term series of observations at the reference station on the analog-river and correlation error caused by dispersion of the points on the graph of relation [8; 9].

The error of the rate in this case is defined by the formula

$$\sigma_{Q_0} = \sqrt{\sigma_1^2 + \sigma_2^2 + \sigma_3^2} \; . \tag{4}$$

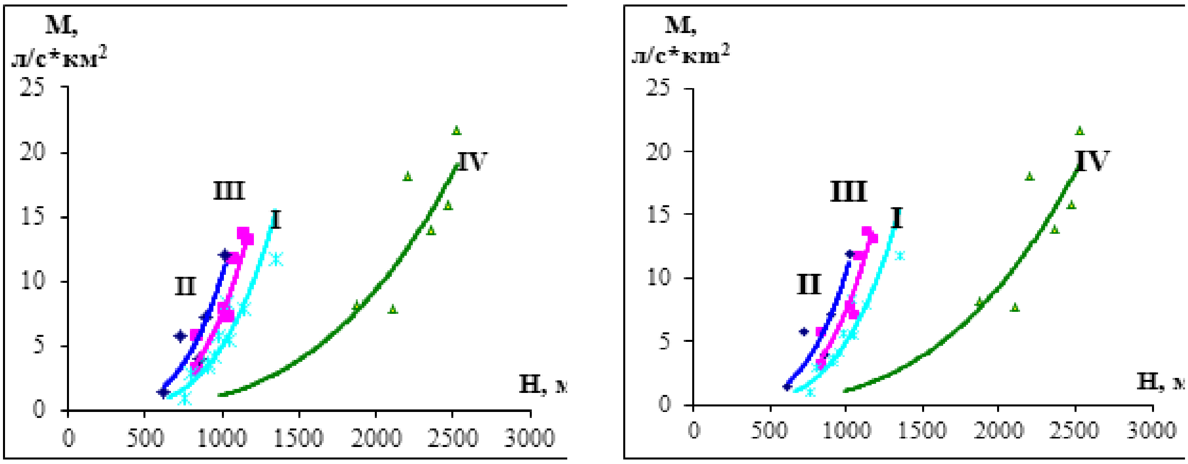
Here, σ_1 - error of the determining of the runoff rate with the short series of observations; σ_2 - error of assessment of the rate of the annual runoff of the reference stations, the data of which were used to construct a curve of dependence M_0 = f (H_{av}); σ_3 - error of the curve of dependence M_0 = f (H_{av}).

Thus, based on the data of 77 observation stations, there was obtained a series of regional dependencies M_0=f (H_{av}), characterizing the state of water content of the individual four areas of the study basin (Figure 2). Due to the adjusted data, the authors identified 4 areas, whereas 2 areas were selected in this catchment area previously in the sound generalization [1]. In addition, it should be noted that the dependencies were constructed separately for the long-term and modern periods.

Detailing the regional dependencies M_0=f (H_{av}), in this work is exhaustive in the present state of knowledge of the problem and quite accurately describes the state of water content of the individual regions of the basin. The curves of dependence M_0=f (H_{av}) in this case are constructed separately for the long-term and modern periods.

The curve of dependence I characterizes the runoff regime of the basins of the rivers of the western part of the south-western slopes of the Karatau ridge. The dependence covers the average altitudes of the catchment areas from 760 to 1350 m. The standard deviation of the points from the curves was 22,0 and 20,6%, maximum – 28 and 33,7% respectively, for the long-term and modern periods.

The curve of dependence II characterizes the runoff regime of the average catchment areas within the altitudes from 620 to 1020 m of the southern part of the south-western slopes of the Karatau ridge (basins of the rivers Bogen, Kattabogen, Almaly, Shayan, Aktas, Arystandy). Previously [1], the area was characterized by a common curve of dependence together with the catchments areas of the south-western slope of the Karatau ridge. The standard deviation of the points from the curve M_0=f (H_{av}) was 26,3% for long-term period and 33,3% for the modern period, maximum –42,9 and 46,0 %, respectively



a) b)

I – river basins of the western part of the south-western slopes of the Karatau ridge; II – river basins of the southern part of the south-western slopes of the Karatau ridge; III – river basins of the south-western slopes of the Boraldaitau ridge; IV – river basins of the north-western slopes of the Karzhantau ridge

Figure 2 - Dependencies of the annual runoff rate: a – for long-term period (1912-2007), b – for the modern period (1973-2007) and from the weighted average altitude of the catchment areas of the rivers of the Syrdariya river basin.

Curve of dependence III covers the average altitudes of the river basins of the south-western slopes of Boraldaitau ridge from 840 to 1140 m. Standard deviation of the points from the curves constructed during two estimation periods (long-term and modern), 20,3 and 17,5 %.

Curve of dependence IV characterizes the runoff regime of the basins of the rivers of the north-western slopes of the Karzhantau ridge at average altitudes from 1870 to 2530 m. In the work [1], the area was characterized by the common curve of dependence together with the catchment areas of the south-western slope of the Boraldaitau ridge. Standard deviation of the points from the curves was 18,6 and 20,1 %, the maximum – 33,9 and 46,4 % respectively, for the long-term and modern periods.

The curves of dependence $M_0=f\ (H_{av})$, obtained for the four regions of the Kazakhstan's part of the Syrdariya river basin, were used to determine the rate of runoff for 48 stations, where the natural regime of runoff was disturbed. Also, on the basis of regional curves, the rates of the annual runoff of 20 unstudied stations were determined.

The accuracy of the determination of the rate in this case consists of the sums of errors of the rates of the stations, the data of which were used for the construction of the curve and the error of the method.

The variability of annual runoff of the rivers of the region was determined by two different calculation periods. The relative characteristic of variability – the coefficient of variation (C_v) for the observation stations fairly lengthy actual or reconstructed series, is determined by the method of the moments:

$$C_v = \frac{\sigma_Q}{\overline{Q}} = \sqrt{\frac{\Sigma(K-1)^2}{n}}, \tag{5}$$

where σ_Q - the standard deviation of annual runoff, m^3/s; Q_0 – long-term average value of the annual runoff, m^3/s; K – modular coefficient; n – the number of the runoff series.

The values of the coefficient of variation in the observation stations range from 0,15-0,33 (closing stations of major rivers) to 0,45-1,93 (small rivers).

The error of the coefficient of variations σ_{C_v} when $C_s=2C_v$ is estimated by the formula of Kritsky-Menkel:

$$\sigma_{C_v} = \frac{C_v}{n+4C_v^2}\sqrt{\frac{n(1+C_v^2)}{2}(1+\frac{3C_v r^2}{1+r})} \,. \tag{6}$$

When $C_s \neq 2C_v$, the formula of A.V. Rozhdestvenskiy, obtained on the basis of statistical modeling, was used:

$$\sigma_{\overline{\overline{C_v}}} = \frac{E_{C_{v\overline{\overline{C_v}}}}\overline{\overline{C_v}}}{\sqrt{n}} \,. \tag{7}$$

The values of the coefficient $E_{C_{v\overline{\overline{C_v}}}}$, which depends on the values of r, C_s/C_v, n, are given in the paper of Rozhdestvenskiy A.V. [7].

As a result of reducing of the series of runoff to the long-term one, the errors of the coefficient of variation were 7,8 - 24,7 % for long-term period and 7,8 - 38,6 % for the modern period.

Results of the estimations of the coefficient of variation for the main stations are given in Table 1, main hydrological characteristics for total 172 hydrological stations were obtained in the study basin.

As a result of the calculations done, values of annual runoff rates and their variability were obtained. More detailed information on the assessment of the rate and variability is presented in [10].

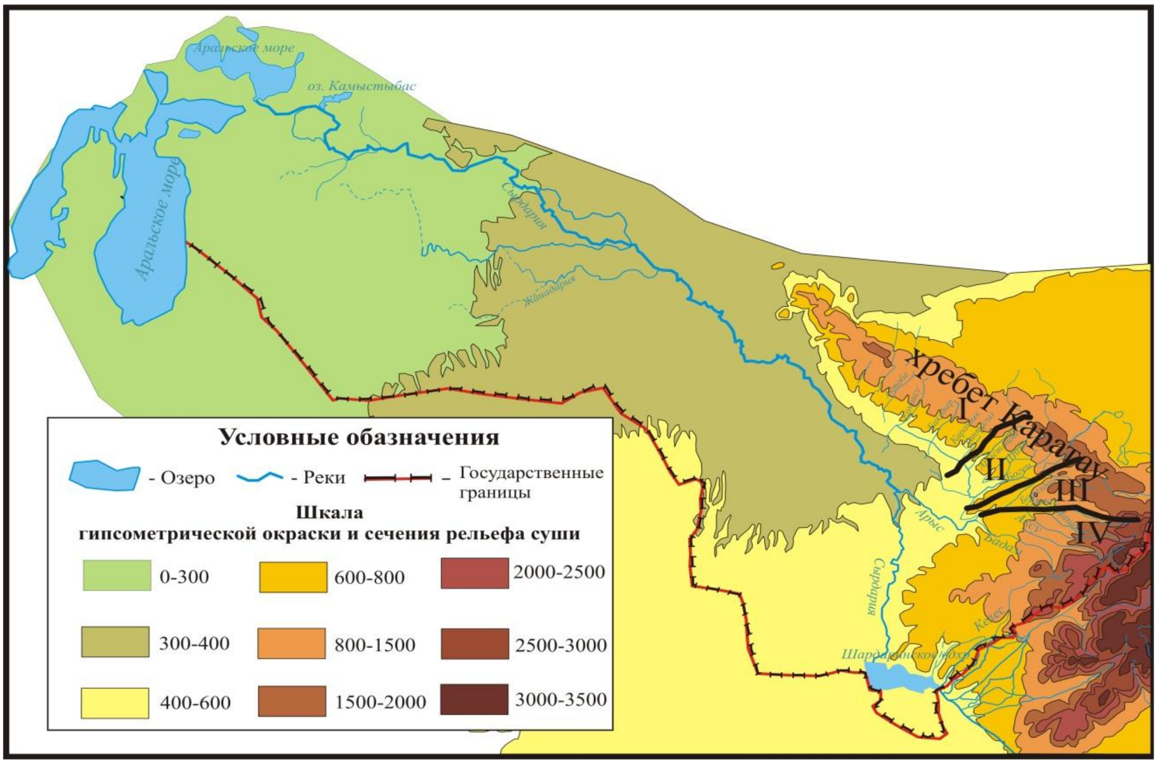
Patterns of spatial distribution of river runoff. Spatial changes of such dynamic natural process as the river runoff, in the conditions of variety of orography and landscapes are very complicated. As it is known, the Earth's surface is characterized by zonal distribution of natural climatic components. One of the most common and major physical and geographical patterns of mountain areas is their altitude-zonal system distribution.

Two major hydrologically homogeneous areas can be distinguished in the Kazakhstan’s part of the Syrdariya river basin: catchment areas of the rivers of the south-western slopes of the Karatau ridge and catchment areas of the rivers of the south-western slopes of the Boraldaitau ridge and the north-western slopes of the Karzhantau ridge. As it is known, allocation of homogeneous areas in the mountainous catchments is rather relative and depends on the hydrological study. Based on the analysis and calculations of data of 77 stations of observations, the study territory is divided into 4 districts (Figure 3), which are well characterized by common features of runoff distribution on the territory of the Syrdariya river basin.

Spatial patterns of the distribution of runoff of rivers in the region are to a large extent related to the azonal factors - mountain elevations. Geographic zonality of the increase in favorable conditions for the formation of water from south to north is completely disturbed.

The runoff for all areas gradually increases with altitude of the terrain, peaking at the most elevated catchment areas and at the same time to the west, where there are the most favorable conditions for the formation of runoff. The runoff of the rivers in the region naturally decreases from east to west of the Karatau ridge.

The rivers of the north-western slopes of the Karzhantau ridge are characterized by maximum water content in the region; the rivers of the southern part of the south-western slopes of the Karatau ridge are characterized by the least water content. The catchment areas of the rivers of the western part of the south-western slopes of the Karatau ridge and south-western slopes of the Boraldaitau ridge have larger surface water resources, than the catchment areas of the rivers of the southern part of the south-western slopes of the Karatau ridge.



I – the basins of the rivers of the western part of the south-western slopes of the Karatau ridge;
II – the basins of the rivers of the southern part of the south-western slopes of the Karatau ridge;
III - the basins of the rivers of the south-western slopes of the Boraldaitau ridge;
IV – the basins of the rivers of the north-western slopes of the Karzhantau ridge

Figure 3 - Scheme of the regionalization of the Syrdariya river basin by the nature of dependence of the runoff modulus on the weighted average altitude

River water resources. The major part of water resources of the Kazakhstan's part of the Syrdariya river basin is focused in the upper reaches of the catchment areas of the Arys, Keles, Shayan, Bogen rivers. The resources of the lowest north-western part of the Karatau ridge are insignificant and are mostly lost at the outlet from the mountains, not reaching the channel of Syrdariya river. The discharges of water of various probability of rivers and temporary watercourses were calculated to assess the surface water resources of the study basin [13,14].

The permanent watercourses defining the surface water resources in the study basin in the territory of Kazakhstan originate in the mountainous areas of the north-western slopes of the Karzhantau ridge, south-western slopes of the Karatau and Boraldaitau ridges. Small rivers of the south-western slopes of the Karatau ridge, entirely used for irrigation, do not reach Syrdariya river.

Assessment of water resources of the basin (Y km^3) through the indicators of the runoff of its individual rivers was carried out by the method of linear equations of the runoff [11,12].

The coefficients k_1, k_2 ... k_n, taking into account the fact that these stations usually close not the entire catchment area, are included into the rate of runoff at the stations of major rivers of the territories (Y_1, Y_2 ... Y_n)

$$Y=3,154\times10^{-2}(k_1Y_1 + k_2Y_2 + \ldots\ldots + k_nY_n) \tag{8}$$

It is recommended to use one of the following examples when determining the coefficients of linear equations: the interpolation of the river runoff rate along its length, the estimation of the runoff rate from the unrecorded territory on the map of isolines, the estimation of the runoff rate of this territory by the method of hydrological analogy.

According to present estimates, the surface water resources in the Kazakhstan’s part of the Aral-Syrdariya basin make up 3,28 km^3 (Table 2).

Table 2 – Water resources of the Aral-Syrdariya basin for the long-term period (1912-2007), km^3/year.

Water resources	Water resources of the RK			
	Average annual	Probability, %		
		25	75	95
Keles river basin	0,39	0,47	0,30	0,21
Basins of the rivers of the western part of the south-western slopes of the Karatau ridge	0,42	0,53	0,28	0,17
Basins of the rivers of the southern part of the south-western slopes of the Karatau ridge	0,26	0,32	0,19	0,12
Basins of the rivers of the south-western slopes of the Boraldaitau ridge	0,79	0,97	0,58	0,38
Basins of the rivers of the north-western slopes of the Karzhantau ridge	1,41	1,59	1,22	0,97
Total	**3,28**	**3,88**	**2,57**	**1,85**

About 91% of the resources of the basin are formed on Syrdariya and Keles rivers, of them 89% come from the Republic of Uzbekistan. However, the actual inflow from the territory of Uzbekistan in recent years is 18,4 km^3. Surface water resources for other rivers are distributed as follows: the basins of the rivers of the western part of the south-western slopes of the Karatau ridge – 1,4 %, the basins of the rivers of the southern part of the south-western slopes of the Karatau ridge – 0,9 %, the basins of the rivers of the south-western slopes of the Boraldaitau ridge – 2,6 %, the basins of the rivers of the north-western slopes of the Karzhantau ridge – 5 %.

Transboundary location of the Syrdariya river basin is the reason of the importance of water allocation disputes between neighboring Republic of Uzbekistan and Kazakhstan. The water resources calculations obtained in the present research show that 26,5 km^3 of water are formed in the catchment area outside the RK, but the actual runoff at the border in recent years is 18,4 km^3. The inflow to the RK through the channels of Zakh, Khanym, which bring their waters to the Keles river basin – 0,39 km^3 per year (1,0 km^3/year according to the agreement). Water resources formed in the basin in the territory of the Republic of Kazakhstan – 3,28 km^3 per year. Total actual water resources - 21,6 km^3 per year.

Conclusions. The rate and variability of annual river runoff of the Kazakhstan's part of the Syrdariya river basin are assessed. The rate of annual runoff was determined by the most developed and theoretically justified method of relations. The calculations were made in two versions: for the long-term period (since the beginning of instrumental measurements from 1912 to 2007) and for the modern period (from 1973 to 2007).

The mean-square error of the determination of the rate of annual runoff according to the observations of one year is calculated by the A.V. Rozhdestvenskiy's formula in assessing the rate using this method.

In order to estimate the runoff rate of the unstudied rivers and stations with disturbed regime, there was used the method of regional curves $M_0 = f\,(\mathrm{H_{av}})$, somewhat adjusted on the basis of the new results obtained in comparison with earlier generalizations.

With the help of the curves of dependence $M_0 = f\,(\mathrm{H_{av}})$, there were determined the rates of runoff for 48 stations, where the natural runoff regime was disturbed, as well as for 20 unstudied stations.

The error of the rate of annual runoff obtained by reducing the short series of observations to the long-term period on the graph of relation consists of the errors of the average value of the long-term series of observations at the reference station on the analog-river and correlation error caused by dispersion of the points on the graph of relation.

It became possible to identify 4 areas after the adjustment of the rates of runoff at the hydrological stations, while 2 areas were identified in this catchment area earlier in the sound generalization of the Surface water resources in the USSR.

The values of variability of annual runoff at the observation stations range from 0,15-0,33 (closing stations of major rivers) to 0,45-1,93 (small rivers).

The spatial distribution patterns of river runoff are analyzed. In general, the water content of the region is reduced from north to south, according to the pattern of geographical zonality, as well as from west to east, depending on the reach of moisture-bearing western air masses. At the same time, the high-altitude, typical of mountain areas, zoning, or the so-called high-altitude zonality, is fully manifested.

Assessment of water resources of the basin (W km^3) through the indicators of the runoff of its individual rivers was carried out by the method of linear equations of the runoff.

According to the research results, surface water resources in the territories of the Kazakhstan's part of the Aral-Syrdariya basin for long-term period (from 1912 to 2007) amount to 3,28 km^3/year.

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S. GEVINIAN

UNESCO, Paris, France

GROUNDWATER COOPERATION

The presentation will demonstrate UNESCO's role in promoting and straightening groundwater cooperation. The audience will learn about the Thematic session 2 of the IHPVIII, development of the international legal framework including Draft articles as well as about the existing groundwater agreements. Given the fact the groundwater resources are still unknown to us, the presentation will demonstrate the elocution of knowledge and information gathering, specifically referring to ISARM Programme and Atlas of Transboundary Aquifers. UNESCO and UNECE have jointly developed a methodology for SDG6 target 6.5.2 which is currently being further developed and tested. The newly created maps will visually demonstrate to the 4(5) indicator.

The presentation will end with two project (GGRETA and DUKTAS) implemented by UNESCO which are aimed at straightening the cooperation between riparians.

N. R. HARSHADEEP, D. FIELDS

The World Bank, Washington, USA

MODERNIZING INFORMATION, INSTITUTIONS, AND INVESTMENTS FOR WATER RESOURCES MANAGEMENT: GLOBAL GOOD PRACTICES

В презентации рассказывается о новых возможностях модернизации процессов управления водными ресурсами в регионе Центральной Азии с использованием передовых методов мировой практики. Будут приведены примеры из опыта работы Всемирного банка в бассейнах национального и трансграничного уровня разных регионов. Также будет представлена информация о растущем массиве современных общедоступных данных, инструментов и подходов к совершенствованию процессов управления водными ресурсами и наращиванию институционального потенциала. В частности, будет рассказано о совершенствовании процессов мониторинга объектов в реальных условиях («восходящие» данные), новых способах использования продуктов спутникового наблюдения Земли («нисходящие» данные), расширении доступа, инновационных аналитических системах, инструментах визуализации и коммуникации (включая порталы и приложения), программах стажировок и прикладных исследований и возможностях дистанционного обучения в дополнение к более традиционным способам получения образования.

The presentation will focus on emerging opportunities to modernize water resources management in the Central Asia region based on emerging global good practice. The presentation will highlight examples from basins at national and trans-boundary level across the world based on World Bank experience, and showcase an emerging array of modern public-domain data, tools, and approaches to improve water resources management and build institutional capacity. This will include improved “bottom-up” in-situ monitoring, improved use of “top-down” satellite earth observation products, public access, innovative analytical, visualization and outreach systems (including portals and Apps), internship and applied research programs, and e-learning opportunities to complement more traditional approaches.

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WATER RESOURCES MANAGEMENT IN THE REPUBLIC OF UZBEKISTAN IN ORDER TO INCREASE THEIR PRODUCTIVITY

Исследованы проблемы управления водными ресурсами Республики Узбекистан, которыми были определены совершенствование организационной структуры управления водными ресурсами республики, меры по повышению эффективности управления водными ресурсами, использования принципов интегрированного управления водными ресурсами и водосберегающих технологий орошения, а также улучшения мелиоративного состояния орошаемых земель, что повышает продуктивность водных ресурсов при их использовании.

The paper examines the issues related to water management in the Republic of Uzbekistan, among which are improvement of institutional framework of national water governance, enhancement of water management efficiency, implementation of integrated water resources management, adoption of irrigation water conservation technologies, and reclamation of irrigated land, with an ultimate aim to improve productivity of water use.

The Republic of Uzbekistan is an agrarian-industrial country with a predominant share of agriculture in the economy, which is based on irrigated farming.

The total area of irrigated lands of the country is 4,3 mln. ha. Cotton, grains, vegetables, potatoes, fruits, grapes and rice are grown on irrigated lands. Uzbekistan is also specialized in the production of silk cocoons, karakul wool. Transhumance is developed in the country.

Aridity of the Uzbekistan's climate requires the availability of water in all types of economic and industrial activity. The main feature of Uzbekistan is the use of more than 90% of all available water resources for irrigation.

The main sources of water resources in Central Asia are Amu Darya and Syr Darya transboundary rivers, which flow through the territories of all states in the region.

Average long-term consumption of water resources in the basins of Amu Darya and Syr Darya rivers is 144 km^3, of which in the basin of Amu Darya – 78,34 km^3, and in the basin of Syr Darya - 36,06 km^3. Average long-term consumption of water resources in the states of the basins of Amu Darya river is as follows: Uzbekistan – 38,94 km^3 (49,8%), Turkmenistan – 21,76 km^3 (27,7%), Tajikistan –9,8 km^3 (12,5%), Afghanistan –7,44 km^3 (9,5%) and Kyrgyzstan –0,4 km^3 (0,5%). For the basin of Syr Darya river – Uzbekistan –17,28 km^3 (48%), Kazakhstan – 12,29 km^3 (34 %), Tajikistan –2,46 km^3 (7%) and Kyrgyzstan –4,03 km^3 (11%).

According to the "Schemes of complex use of water resources of Amu Darya and Syr Darya rivers", the limit of Uzbekistan in general for the basins of the rivers is 63,02 km^3 /year, including for the basin of Amu Darya river –37,53 km^3/year and for the basin of Syr Darya river – 25,49 km^3/year, totaling 63,02 km^3/year [1].

The water resources used in Uzbekistan consist of external water resources inflowing through the rivers from Tajikistan and Kyrgyzstan and internal water resources formed on the territory of Uzbekistan itself. In other words, about 80% of water resources used in Uzbekistan flow from neighboring Kyrgyzstan and Tajikistan, only about 20% of water resources are formed on the territory of Uzbekistan itself.

Water in arid Uzbekistan is a very valuable resource, and the stability of the country's development mostly depends on the degree of provision of drinking water for the population of nearly 30 million people and irrigation water to more than 4,3 mln. ha of agricultural land.

Currently, total annual volume of the use of water resources in the sectors of the economy of Uzbekistan is about 51 - 52 km^3, of which about 46,8 km^3 (90%) are used in agriculture, in power engineering -3,12 km^3 (6%), in public utilities -1,6 km^3 (3%), industry - 0,4 km^3 (0,4%) and fisheries -0,1 km^3 (0,2 %).

One of the most powerful water management systems in the world is built and operated in order to ensure the secure and continuous water supply to all sectors of the economy in Uzbekistan.

Measures for the efficient use of water and land resources are consistently implemented since gaining the independence in the Republic of Uzbekistan:

1. According to the Decree of the President of the Republic of Uzbekistan "On the most important directions of deepening reforms in agriculture № PD-3226 from 24 March 2003, the measures for deepening economic reforms in agriculture, improvement of production relations in villages were fulfilled, the relevant market principles of organizational structure of management of agricultural production were introduced, independence of the agricultural producers and their reliable legal protection were provided.

The use of land resources, which were transmitted to farmers on a long-term basis, was fundamentally changed.

2. According to the Resolution of the Cabinet of Ministers “On improvement of the organization of water management” №320 from 21.07.2003, the transition from the administrative - territorial to the basin principle of water resources management was carried out [2] .

The Naryn-Karadarya (Andijan region), the Naryn-Syrdarya (Namangan region), the Syrdarya - Sokh (Ferghana region), the Lower–Syrdarya (Syrdarya region and some districts of Dzhizak region), the Chirchik–Akhangaran (Tashkent region), the Amu-Surkhan (Surkhandarya region), the Amu–Kashkadarya (Kashkadarya region), the Amu–Bukhara (Bukhara region), the Lower-Amudarya (Republic of Karakalpakstan and Khorezm region), the Zarafshan (Samarkand region, Navai region and some districts of Dzhizak and Kashkadarya regions) Departments for Basin Management of irrigation systems, as well as the Department of the Main Canal Systems in the Ferghana region with a unified dispatch center were created.

The main objectives of the Departments of basin management of irrigation systems are:

- organization of targeted and efficient use of water resources on the basis of the introduction of market principles and mechanisms of water use and consumption;
- implementation of a unified technical policy in the water sector on the basis of the introduction of advanced technologies;
- organization of uninterrupted and timely water supply to consumers;
- sustainable management of water resources in the territory of the basin and improvement of its efficiency;
- ensuring reliable accounting and reporting of water resources use in the context of water users and consumers.

3. Development of Water Users Associations and supporting them. Water Users Associations (WUAs), members of which private and peasant farms became, got the development and support. Currently, 1503WUAs are functioning successfully, providing water-related services to farmers, peasants and other water users.

4. Using the principles of integrated water resources management. Progressive principles of water resources management, including integrated management, are widely introduced Uzbekistan.

As a result of the introduction of the principles of integrated water resources management in the territory of South Fergana Main Canal (irrigated area of 120 thousand hectares), reduction in specific water supply per 1 hectare of irrigated land by 32% was achieved.

Currently, the demonstration areas of integrated water resources management are introduced in seven districts of the country: Alat, Pastdargom, Mirishkor, Bayavut, Buka, Ulugnor and Yazyavan with irrigated area of over 250 thous. ha, and the principles of integrated water resources management are also being introduced on 4,3 mln. ha of the entire irrigated land of the country that will help to improve the efficiency of water management, to introduce systems of modern automated control of water allocation and to improve the efficiency of water use in different sectors of the economy.

5.International cooperation. Uzbekistan, adhering to and respecting the norms and principles of international water law, in accordance with the Decree of the President of the Republic of Uzbekistan "On accession to international treaties" №ПП-683 of August 9, 2007, has joined the "Convention on the Protection and Use of Transboundary Watercourses and International Lakes" (Helsinki, 17 March 1992) and the Convention on the Law of Non-navigational uses of international Watercourses "(New York, 21 May 1997).

Also, we are members of the World Water Council of the International Commission on Irrigation and Drainage, the International Commission on Large Dams, the Islamic inter-state network of development and management of water resources, the Global Water Partnership states of the countries of the Caucasus and Central Asia, the Network of water management organizations of the countries of Southern Europe and Central Asia and other international organizations.

6. Attracting foreign investments. An extensive work on the development of energy saving technologies based on the attraction of foreign investments for the development of water facilities is being conducted by the Government of the Republic of Uzbekistan. Currently, the following projects are being implemented for the modernization of water infrastructure:

- Project on the rehabilitation of the System of Amu Zang machine channel - in the amount of 112,6 mln. US dollars (Asian Development Bank);
- Project "Sector project. Water resources management in the Fergana and Zarafshan valleys"- in the amount of 144,05 mln. US dollars (Asian Development Bank);
- Project on the "Restoration of irrigation network and drainage system in Dzhizak and Syrdarya regions" – in the amount of 94,3 mln. US dollars (the Kuwait Fund for Arab Economic Development, the Islamic Development Bank, the OPEC Fund for International Development);
- Project on "Water resources management in the Fergana valley. Phase-1"- in the amount of 81,85 mln. US dollars (International Bank for Reconstruction and Development).
- Project on "Rehabilitation of the Amu–Bukhara irrigation system" for 406,29 mln. US dollars (Asian Development Bank and the Japan Agency for International Cooperation);
- Project on "Improvement of water resources management in South Karakalpakstan" – for 376,7 mln. US dollars (International Bank for Reconstruction and Development);
- Project on "Rehabilitation of the main irrigation channels of the Tashsaka system of Khorezm region" – 144,2 mln. US dollars (Islamic Development Bank);
- Project on "Improvement of water resources management in Surkhandarya region (reconstruction of the Hazarbag - Akkanchigai canal system)" – for 122,42 mln. US dollars (Islamic Development Bank);
- Project to improve ameliorative condition of irrigated lands in Kashkadarya, Bukhara and Navoi regions – in the amount of 60,2 mln. US dollars. (Asian Development Bank).
- Project on "Rehabilitation of the "Kuyu-Mazar" pump station in Bukhara region" – in the amount of 18,47 mln. US dollars (OPEC Development Fund).
- Project on "Rehabilitation of the "Alat" pumping station in Bukhara region" – in the amount of 17,01 mln. US dollars. (Saudi Development Fund).

In general, more than 20 large water-related investment projects for the total amount of more than 1 billion US dollars are currently being implemented in the country.

7. Improvement of irrigation facilities. The following facilities operate in the sector of water management of the Republic of Uzbekistan:

- 180 thous. km of irrigation networks;
- 160 thous. water management facilities;
- 800 large structures;
- 1496 pumping stations consume more than 8,2 billion kWh of electricity per year;
- 55 reservoirs with a total volume of 19,1 bln. m^3;
- 4124 vertical drainage wells for irrigation;
- 102,8 thous. km of open drainage networks;
- 38,3 thous. km of closed drainage networks;
- 3451 vertical drainage wells;
- 153 reclamation pumping stations;
- 24839 observation wells.

A series of measures is carried out by the Government of the Republic of Uzbekistan, Ministry of Agriculture and Water Resources and a number of other agencies; the following construction and reconstruction works were conducted in irrigation facilities at the expenses of the state budget of the country, foreign investments and grants, as well as other funds during the period of 2013-2015:

- 890,2 km of channels;
- 192,9 km of trough networks;
- 42 waterworks;
- pumping stations with capacity of 32,9 m3/s;
- 48,3 km of pressure pipelines;
- 25,4 km of bank protection works;
- reservoirs with capacity of 325 mln.m^3.

8.Complex measures for irrigated lands reclamation. In order to create the necessary conditions for the further sustainable development of agricultural production, improvement of soil fertility and, on this basis, increasing crop yields, a special attention is paid to the improving of reclamation state of irrigated lands.

In accordance with the Decree of the President of the Republic of Uzbekistan "On measures to radically improve the system of land reclamation" PD-3932 of 20 October 2007, an effective mechanism for the organization of complex measures to improve ameliorative state of irrigated lands was launched.

In accordance with this Decree, the Fund of reclamation of irrigated lands and the structure of its management, as well as the Department for its management, were created.

State Program for Irrigated Land Reclamation provided for works on the further construction and reconstruction of drainage collectors, the collector-drainage open and closed networks, reclamation pumping stations, vertical drainage wells, repair and restoration works of the operated drainage systems and structures and the completion of the complex of the State unitary enterprises engaged in the fulfillment of works on irrigated land reclamation using necessary excavation and auxiliary machinery and equipment.

1 trillion 370 billion of Uzbek sums were spent on measures to improve ameliorative condition of irrigated lands for the period 2008-2015 within the framework of the State Program.

During the period of 2008-2015, in accordance with the State Program:

Reconstructed and built:

- 5759 km of open collectors;

- 942 km of closed horizontal drainage;
- 167 reclamation pumping stations;
- 1254 vertical drainage wells;
- 193 waterworks.

Repairs and restoration:

- 99976 km of open collectors;
- 6066 km of closed horizontal drainage networks;
- 246 reclamation pumping stations;
- 6741 vertical drainage wells;
- More than 10 000 waterworks.

The optimal level of subsoil waters for normal growth and development of crops was ensured in the project zones with an area of 2 mln. 44 thous. ha of irrigated lands during this period. In addition, the area of irrigated land with the level of groundwater occurrence to 2,0 decreased by 244,9 thous. ha; desalinization to slightly saline and non-saline lands was provided in the area of 186,3 thous. ha of strongly and medium saline lands.

Cotton yields increased by an average of 3-4 quintals and crops increased by 4-5 quintals in irrigated areas, where land reclamation activities were carried out.

Currently, the lands are transferred to the long-term rent to farmers, and agricultural crops are grown on the basis of scientifically sound agro-technical rules, and most importantly, the lands have their real owner, that is, in turn, an important factor.

In order to promote the renewal of the existing and the formation of a multipurpose fleet of reclamation machinery, to ensure the supply to the construction and operating water management organizations conducting activities on irrigated land reclamation, to provide modern reclamation machinery and equipment, the "Uzmeliomashlizing" leasing company was created by the Resolution of the Cabinet of Ministers №266 from December 21, 2007. During the period of 2008-2015, the "Uzmeliomashlizing" company carried out the delivery of 1950 units of modern reclamation equipment in the amount of 240,0 bln. UZS.

In 2013, the State program on the rational use of water resources and improvement of ameliorative state of irrigated lands for the period 2013 – 2017 was adopted [3], according to which the following activities were provided:

1. Construction and reconstruction of irrigation facilities:

– different channels – 1744 km;
– trough network – 359 km;
– waterworks – 96 pcs.;
– pressure pipelines –75 km;
– water and debris basins – 40 mln. m^3;
–pumping plants with capacity of 97 m^3/s ;
– bank protection works – 36 km.

• repairs and restoration:

– of different channels – 29258 km;
–trough network– 498 km;
– waterworks – 45549 pcs.;
– pumps – 13293 pcs.;
–irrigation wells – 6598 pcs.

•repairs and restoration of the irrigation network of the WUA:

– channels – 492645 km;
– trough network – 65926 km;
– waterworks – 174110 pcs.;

– pumps – 11533 pcs.;
–sites of water intakes of farms – 252650 pcs.;

2. Construction and reconstruction of reclamation facilities:

–open collectors – 3852 km;
– closed horizontal drainages – 1257 km;
– vertical drainage wells –907 pcs.;
–reclamation pumping plants– 35 pcs.;
–observation network–5012 pcs.;
– waterworks –226 pcs.;

- **repairs and restoration:**

– open collectors – 75507 km;
– closed horizontal drainages – 8082 km;
– vertical drainage wells –3639 pcs.;
– reclamation pumping plants – 126 pcs.;
– waterworks – 881 pcs.;
– pipe crossings– 6685 pcs.

According to this State program, during the period of 2013-2016, the country is carrying out the course of consistent development and implementation, modern water-saving irrigation technologies, such as:

– drip irrigation is effectively used for watering crops on a total area of over 22,6 thous. ha, providing savings of up to 50% of irrigation water and helping to improve crop yields two-three times.

The table below shows the effectiveness of the use of drip irrigation systems in Uzbekistan in recent years, from which you can see that the comparison of furrow irrigation and drip irrigation shows the effect of water-saving of drip irrigation from 24% to 60%, and a comparison of agricultural productivity shows that there is from 1,4 to 3,2 times increase in yields in quintals per hectare under drip irrigation (Table).

In order to widely introduce drip irrigation systems in agriculture of the country, the Government of Uzbekistan issued the Decree № 176 "On measures for the effective organization of the implementation and financing of the system of drip irrigation and other water-saving irrigation technologies" of June 21, 2013, which approved the regulations on the procedure of formation of the state program of implementation of the system of drip irrigation and other water-saving irrigation technologies and their financing by the Fund of reclamation of irrigated lands under the Ministry of Finance.

With a view to a number of benefits for the agricultural commodity producers, who establish and implement the systems of drip irrigation, which are as follows:

1. In accordance with the Presidential Decree PD 4478 of 22 October 2012, agricultural producers, who have implemented the system of drip irrigation, are also exempt from paying land tax for 5 years.

2. Crediting to agricultural producers for the implementation of drip irrigation system at the expense of the Fund's line of credit is carried out up to 1000 times the minimum wage, with a 6-month grace period, for a period not less than three years at a reduced interest rate of 6% per annum (including bank margin - 3%). The government also recommended commercial banks to issue loans for the projects included in the State program of implementation of the system of drip irrigation and other water-saving irrigation technologies, at the rate of refinancing of the Central Bank of the Republic of Uzbekistan (currently 10-12% per annum).

Table – Efficiency of using drip irrigation systems in Uzbekistan in recent years

Place of the use of drip irrigation system	Year	Crops	Irrigation norm, m³/ha		Water-saving effect, %	Yield, q/ha		Increase in yields, times
			Furrow irrigation	Drip irrigation		Furrow irrigation	Drip irrigation	
Samarkand region Samarkand district (Оғалик олтин боғи меваси)	2014	Gardens (apple)	4730	2984	37	125	400	3,2
Tashkent region Akhangaron district (Эйвалик)	2013-2014	Vegetables (onion)	18951	14357	24	540	1040	2,0
Namangan region Uychi district (Жамолиддин Сардор Хамкор)	2010	Cotton	4260	1856	56	20	38	2,9
	2011	Cotton	3905	1622	58	18	46	2,6
Pap district (Narin-Sirdarya BAIS site)	2014	Gardens * (young)	3860	1560	60	-	-	-
Surkhandarya region Zharkurgan district (Сурхон олтин мевалари)	2014	Gardens (peaches)	4680	2893	38	90	125	1,4
Ferghana region Ferghana district (Миндонобод агросаноат)	2014	Vineyard	4140	1690	59	102	145	1,4
Kuva district (Илёсбой Исломали угли)	2014	Gardens (peaches)	3870	1580	59	56	92	1,5
Kashkadarya region Kitab district (Хусам ноз неъматлари МЧЖ)	2011	Grapes	2960	1382	53	80	125	1,6
Karshi district (Саид Ахмад набираси Анвар)	2011	Cotton	6930	2840	59	24	32	1,3

*The gardens of the first year of planting were cultivated on the site, the feature of the site, along with irrigation water savings, is 100% saving on electricity costs, due to the use of natural water pressure created when the water is delivered to the field from the reservoir through the pipeline

3. According to the same Decree, the farmers who implement drip irrigation system are granted polyethylene granules at the declared price that is more than 4 times lower than the stock exchange price of granules.

4. According to the Degree № 176, the agricultural producers, who implemented the systems of drip irrigation and other water saving irrigation technologies, have the right to use the saved water resources to grow crops in the areas freed from grain crops cultures.

– irrigation along shielded with plastic wrap furrows is implemented on irrigated area of 28,7 thous. ha, which provided savings of around 30% of irrigation water at field level;

– irrigation using flexible portable irrigation pipelines in the area of 118,4 thous. ha of cotton, winter wheat and other crops, which allowed reducing the volume of water used up to 20 %;

– the improved furrow irrigation technology is used on more than 400 thous. ha and provide irrigation water savings of up to 15 %;

– sub-irrigation is used on land with depth of ground water level of up to 2,0 m and mineralization of up to 3 g/l, which is more than 1000 hectares and with a saving of at least 20% of irrigation water.

The results of the measures implemented are pushing for further development of works on the implementation of water-saving irrigation technologies. At the same time, it is planned that the areas using water-saving technologies will be increased by 2020:

– drip irrigation additionally on the area of 46,3 thous. ha, which will provide savings of irrigation water (net) in the volume of more than 110 mln. m^3;

– irrigation along shielded with plastic wrap furrows on the area of 48,0 thous. ha, which will provide water savings in the volume of more than 75 mln. m^3;

– irrigation using flexible portable irrigation pipes over an area of 400 thous. ha with irrigation water savings in the volume of over 240 mln. m^3;

–the improved methods of furrow irrigation (irrigation along shortened furrows, irrigation through furrow, irrigation with variable stream, tier irrigation with intra-contour use of discharges, counter irrigation on lands with small slope, irrigation by mulching, irrigation with the use of siphons and mobile prefabricated irrigation troughs, etc.) allowing water savings in the volume of more than 300 mln. m^3;

– sprinkler irrigation of grain, vegetables and other crops of the continuous planting on the area of 1000 hectares;

– non-traditional methods of irrigation (the use of polymer hydrogels, sub-irrigation, etc.), which will save up to 20% of irrigation water.

By 2020, it is expected to achieve irrigation water savings of more than 800 mln. m^3/year with the introduction of water-saving irrigation technology, and more than 1,5 bln. m^3 per year taking into account the losses in water delivery to the consumer. This will increase water supply to irrigated land on the area of about 1,5 mln. ha.

9. The development of research and design works on the rational use of water resources and irrigated land reclamation

It is no doubt that the most important task is to prepare highly qualified personnel and skills development for the water economy of the country in order to develop scientific research on the rational use of water resources and irrigated land reclamation.

As part of the Ministry, Tashkent Institute of Irrigation and Land Reclamation, the Tashkent State Agrarian University, Samarkand and Andijan Agricultural Institute, Agricultural Institute are functioning and working on the training and professional development of highly qualified professionals for the industry of the Ministry.

As part of the Ministry, there are also the Research Institute of Irrigation and Water Problems at the Tashkent Irrigation and Melioration Institute (RIIWP at TIMI), the Republican Association "Vodproject", design institutes UZGIP and "Uzsuvloyiha" that provide a scientific-methodical substantiation of developments for the rational use of water resources and irrigated land reclamation.

The head research organization of the Ministry to address water-related issues is at the RIIWP at TIMI, including 10 doctors, 30 candidates of sciences and 80 researchers. This team carries out research in the following areas together with the auxiliary units of the Institute:

1. Improvement of Water Management of the Republic [4].
2. Conducting research on hydrology and hydro-ecology of water bodies [5].
3. Studies of hydraulics of irrigation transboundary and domestic water facilities of the systems and irrigation networks.
4. Ensuring the sustainability and safety of operation of water management structures.
5. All-round use of modern water-saving technologies.
6. Use of metering of water discharge and modern information technologies in waterworks facilities.
7. Improving the efficiency of repair, reconstruction and construction of waterworks facilities, using building materials, land reclamation machinery and mechanisms.

As a result of the implementation of measures to improve the efficiency of water resource management, replacing the water-loving crops with less water-intensive, the introduction of water-saving irrigation technologies, improvement of ameliorative condition of irrigated lands, the annual volume of water resources used in Uzbekistan decreased from 64 km^3 (mid-1980s) to 51 km^3 (average for 2011-2015) in the last 25 years.

The specific volume of water used per capita of the population decreased from 3193 m^3 in 1990 to 1890 m^3 in 2015, that is, specific water consumption has declined about twice over 25 years.

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METHOD OF SIMULATION FOR A DYNAMIC-STOCHASTIC MODELING OF KAZAKHSTAN'S WATER SUPPLY SYSTEM

The study justifies an application the methodology of simulation dynamic-stochastic modeling for a strategic planning of Kazakhstan's water supply systems. Particularly, a basin water supply system of the Republic is characterized by uncertainty and stochastic features. The research develops a structure of simulation models on the Aral-Syrdarya, Ile-Balkash as well as Ertis basins as a basis for creation of Kazakhstan's Unified Water Supply System. In addition, the study carried out a translation of the model to C # programming language as well as developed the technique of two-dimensional visualization of the simulation process.

Introduction. Simulation modeling of the Water Supply Systems (WSS) is revealed as a numerical method of computational experiments with mathematical models simulating the behavior of real objects in time within a specified period. Thus, functioning of such objects is described as a set of algorithms simulating the probabilistic nature of river flow [1].

The basin WSS are characterized by features of complex systems. Furthermore, uncertainty and stochasticity are caused by the unpredictability of water-related activities in neighboring countries and the probabilistic nature of hydrometeorological processes to determine the amount of water available. The dynamic-stochastic modeling (Monte Carlo method) is a method of study on complex systems subject to random perturbations with the use of simulation models.

The Monte Carlo method was used previously for a calculation of water regulation as well as for water and energy calculations [2, 3]. The proposed method is one of the most vital instruments of studying the complex systems in mathematics, physics, and natural sciences. In this regard, the method was applied at this study for the first time to solve the issue of National Water Complex, including water supply of natural and technogenic systems.

Formulating the issue of water supply systems (WSS) in the Aral-Syrdarya, Ile-Balkash and Ertis basins is a key component of the national water complex. Particularly, the indicated basin systems are a set of water sources and water users with uniting them water regulation and water allocation (NWC) (Figure 1).

Within the basin WSS is formed up to 80% renewable resources of river runoff, concentrated 73% of proven reserves of groundwater. Thus the Aral-Syrdarya and Ile-Balkash basins are the most water consumptive systems in the vast territory of the republic. In addition, integrated water demand of population as well as a production of natural objects is half of republican. The Aral-Syrdarya and Ile-Balkash basins are strongly dependant on the transboundary flow: A to C - 89%, and, B - 44% that triggers them to the real and potential 'water crisis'. Both basins are potential 'recipients' of the Ertis River flow, which is a "donor" basin [4, 5].

Figure 2 shows a diagram of the potential inter-basin water management and transboundary links of Kazakhstan's Unified Water Supply System (UWSS).

Figure 1 - Schematic map of the basin's water supply systems in Kazakhstan

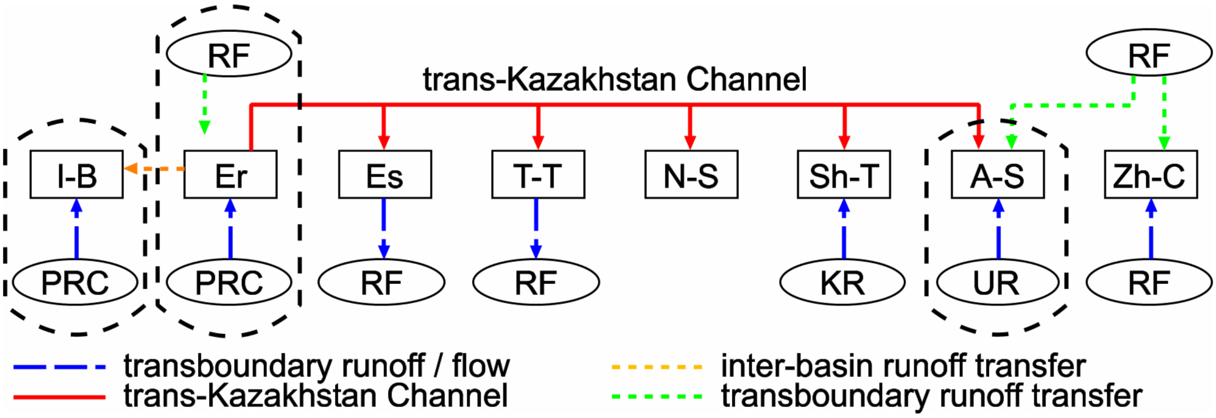


Figure 2 - Scheme of the potential transboundary and inter-basin water relations of UWSS. Countries: PRC - People's Republic of China; KR – Republic of Kyrgyzstan; UR - Republic of Uzbekistan; RF - Russian Federation. River basins: A to C - Aral-Syrdarya; AND-B - Ile-Balkash; Er - Ertis; Es - Esil; Zh-C - Zhaiyk Caspian; N-S - Nur-Sarysu; T-T - Tobol-Turgai; SH-T - Shu-Talas.

Trans-Kazakhstan Channel (TKC) will serve as a basis of forming a single water system, bringing together existing and future inter-basin water management communication with efficient use of water resources in order to achieve social, environmental and economic objectives of the country's development [5, 6].

Research methodology. Methods of dynamic-stochastic modeling consists of the following steps:

1. Computer modeling for pseudo-random sequences of annual runoff with a given law of probability distribution (Monte Carlo method);
2. Using the obtained numerical sequences in dynamic simulation for mathematical models of regulation and water distribution in natural and economic systems;
3. Statistical analysis of simulation results with the water system evaluation according to the criteria of reliability and risk.

The process of progressive development towards the simulation model of water system begins with the creation of a simple model, which gradually becomes more complicated in accordance with the requirements of the issue solving.

Firstly, it is become evident to formulate and define the initial problem. Second stage begins with constructing a model of system under study, including statistical and dynamic description. In statistical descriptions of the system are determined the major characteristics of its elements. However, dynamic description focuses on interaction of the system elements that result in a change of status in time.

The process of formulating the model in many ways is revealed as complex issue to understand the structure of the system, to identify the rules of its operation as well as release them into the most significant details. The model is formed easy to understand and at the same time quite difficult to adequately reflect characteristics of the real system.

The most important are decisions taken regarding the reliability of simplifications and assumptions that determine composition of elements and interactions between them. The model's level of detail depends on the objective of its creation. The elements of the system those are essential for solution of the problem under investigation could be taken under consideration. "The first sketch" of the model is subject to analysis and discussion. At the stages of defining the problems and modeling is carried out a tight cooperation between developers of the model and its users, which helps to ensure a successful implementation of the simulation studies.

At the stage of model development are determined the requirements for input data. Typically such input data values are defined based on some preliminary hypotheses or analysis. In some cases, the exact values of one (or more) of input parameters have little effect on the results of the model. Sensitivity of the results to changes in the input data can be evaluated through a series of simulation modeling for various input parameters. The simulation model can therefore be used to reduce the time and cost outlays to update the input data.

The next challenge is to translate the model into a form available for computers. The main criterion at choosing a programming language for computer implementation of the model is an object orientation. This language paradigm is based on the representing the form of objects as a whole, which are instances of a particular class, and embodies the use of the abstraction concept.

On verification and validation steps are carried out an assessment of the simulation model functioning. The verification stage determines whether the programmed computer model comply with the developer's plan. In this regard, it is usually done by manual inspection of calculations, and can also be used a number of statistical methods [7].

Establishing the adequacy of the system's simulation model under study is carried out on the validation stage. Validation of the model is usually performed at the level of input data, the model elements, subsystems and their interconnections. Checking out the adequacy of the developed model includes a comparison of its structure with the structure of the system, as well as a comparison of results for implementing the elementary functions and solutions in the model and system as a whole.

Terms of the machine runs on the model are determined by stages of strategic and tactical planning. In addition, strategic planning challenge is to develop an effective plan of the experiment, in which either turns out the relationship between controlled variables, or is managed by a combination of variables, minimizing or maximizing response of the simulation model. In contrast to a strategic, the tactical planning solves the issue of how in the framework of a plan experiment to carry out each simulation run, to get the most information from the output. The important place in the tactical planning occupies a defining the initial conditions of simulation runs and methods to reduce the dispersion of model's response at the average value [7].

The next steps in the process of a simulation research are a carrying out for a computer simulation and analysis of the obtained results, including a run of simulation models on a computer and the interpretation of the output data. By using the results of simulation experiments statistical methods are applied to draw conclusions or verification on the actual functioning of the system.

The last step in the process of a simulation research is a realization of solutions and documentation of the simulation model and its use. *Results of the study*. Figure 3 shows the structure of initial version of the model - "a rough prognosis", where we use aggregated intervals of the UWSS (T), the aggregated parameters of water (W) and water demand (the V) as well as an enlarged spatial units (i) that are estimated by a set of statistical water security criteria (F). The status of the object management UWSS at any time (T) is in the context of NTS basins (i) and uniquely determined by the following multidimensional vector:

- Available water resources of NTS in general,
- Distribution of water resources between the components (WT i, m),
- Water demand (VTi, n).

As a result of certain effects the system can change from one state to another with a certain degree of efficiency in terms of the criteria adopted. These impacts are presented as a multidimensional vector (YTi, y), where its components are a set of tools for regulation and distribution of water resources. The processes that are takes place in the system are influenced by a number of random factors, forming the vector of disturbance (ZTi, b). The components of such a vector are uniquely unpredictable regime of the NTS water sources [1].

Water supply systems of the researched water basins have the following structure (Figure 4, Table.):

- Renewable resources of basins runoff are composed of local and cross-border flow (from the territory of the PRC and the Republic of Uzbekistan);

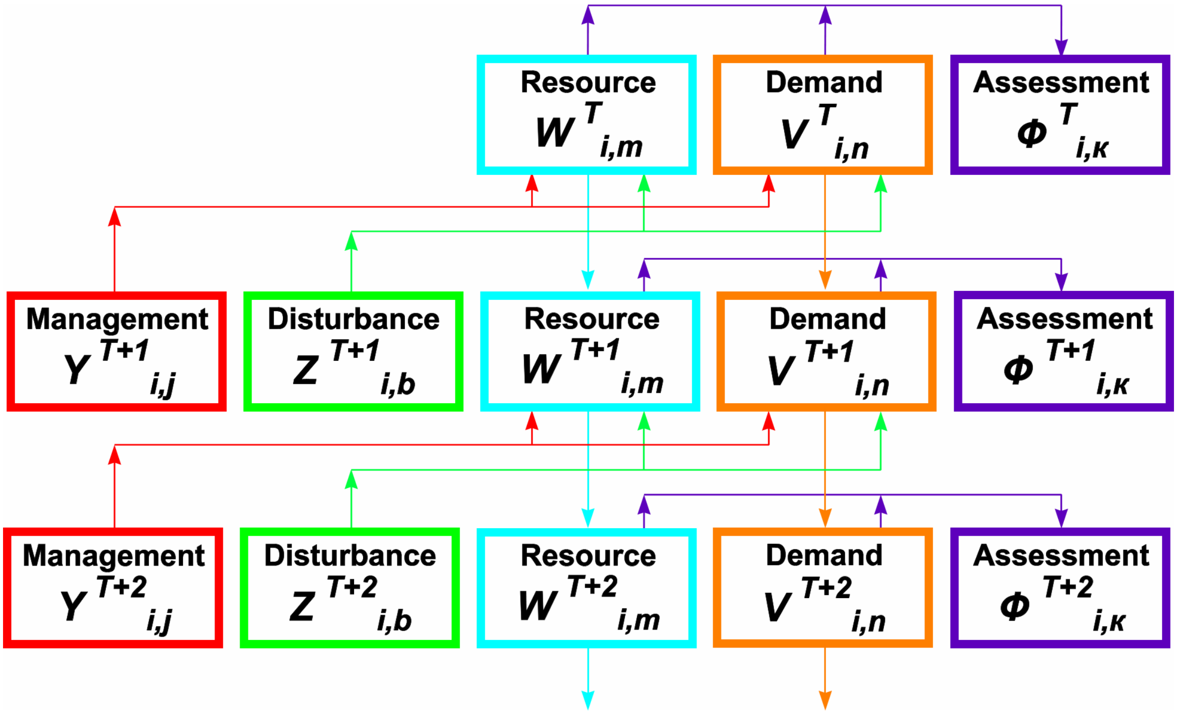
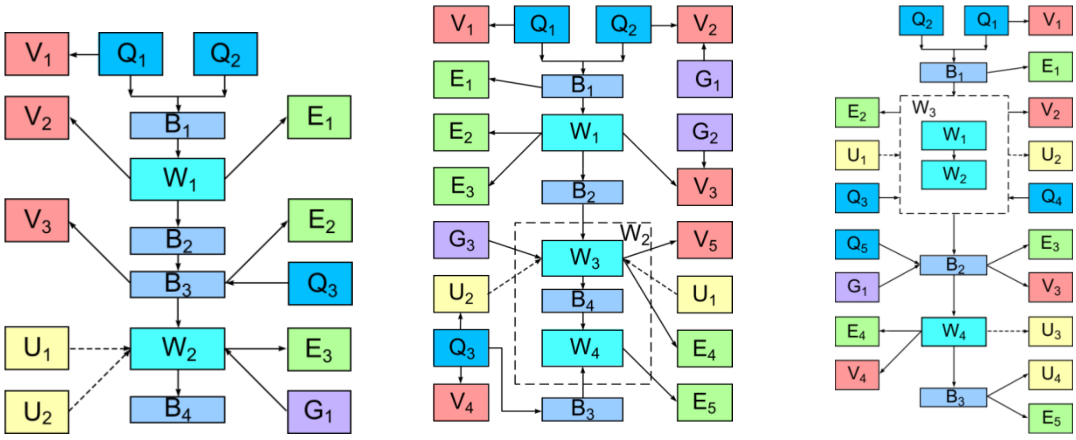


Figure 3 - Simulation dynamic-stochastic model for scenarios of NTS water supply.

Table - Structure of the simulation dynamic-stochastic model for water supply systems

Designation	Water Supply system		
	Aral -Syrdarya	Ile-Balkhash	Ertis
1	2	3	4
Surface water resources			
Q1	Transboundary flow of the Syrdarya River	Transboundary flow of the Ile River	Transboundary flow of the Kara Ertis River
Q2	Local flow (the Keles River)	Local flow of the Ile tributaries	Local flow of the Kaldzhir River
Q3	Local flow (the Aris River)	Flow of the eastern rivers	Local flow of the Bukhtirma River, Kurchum River and others
Q4			Local flow of the Bazark River, Kenderlik River and others
Q5			Local flow of the Uba River, Ulba River
Groundwater sources			
G1	Tributaries of groundwater into the North Aral Sea	The Kopa-Ile basin	Groundwater tributaries
G2		The South Balkhash basin	
G3		Groundwater tributaries into the Lake Balkhash	
Domestic, industrial and agricultural water users			
V1	Uzbek part of the Syrdarya River	Chinese part of the Ile River	Chinese part of the Ertis River
V2	Upper reach of the Shardari Reservoir	Upper of the Ile basin	Upper basin
V3	Lower reach of Shardari Reservoir	Lower reach of Ile River	Average part of the basin
V4		Basin of the eastern rivers	Lower reach of the basin
V5		West Balkhash	
Redistribution of river flow			
U1	Ertis-Syrdarya	Bukhtyrma-Balkhash	Upper-Katun transfer
U2	Volga-Syrdarya	Karatal-Ile	Water abstraction in Ile-Balkhash basin
U3			Water abstraction in TKC

1	2	3	4
U4			Water abstraction in Kanysh Satbaev Channel
Filling the reservoirs			
W1	Shardari Reservoir	Kapshagay reservoir	Zhaisan part of Bukhtyrma Reservoir
W2	The North Aral sea	The Lake Balkhash	Bukhtyrma Reservoir
W3		The West Balkhash	Bukhtyrma Res., the Lake Zhaisan
W4		The East Balkhash	Shulba Reservoir
Streamflow			
B1	Syrdarya tributary in Shardari reservoir	Ile tributary in Kapshagay Reserv.	Tributary in Bukhtyrma Reservoir
B2	Shardari reservoir release	Ile tributary in the West Balkhash	Water inflow in Shulba Reservoir
B3	Water inflow in the North Aral Sea (NAS)	Tributary of eastern rivers in the Eastern Balkhash	Streaflows in RF
Environmental water users			
E1	Water losses in Shardari Reservoir	Upper reach	Channels losses
E2	Channel’s water costs	Kapshagay Reservoir	Bukhtyrma reservoir
E3	The North Aral Sea	Lower reach	Channels losses
E4		The West Balkhash	Shulba Reservoir
E5		The East Balkhash	Channels losses



a b c

Figure 4 - Structure of simulation dynamic-stochastic model for the water system of : a) the Aral-Syrdarya; b) Ile-Balkash; c) Ertis.

- System unit management are hydro reservoirs with a long flow regulation: Kapshagai, Buktyrma (long-term) and Shardara, Shulba (seasonal);
- The main natural water users in the basin are river deltas and floodplains;
- Major industrial water users are industry, municipal and agriculture with water intakes (existing and potential) from the river channel and regulating reservoir;

- explored reserves of groundwater are taken into account in fluid communication with the surface water;
- Discussing the options of future water transfer from the Basin of the Ertis River (Trans-Kazakhstan Channel, Buktyrma- Balkhash channel) and existing (Canal KISatpaev.), as well as a possible transfer of Russian rivers (Upper Katun) into the Ertis river runoff.

Computer implementing the simulation models of Ile-Balkash, Aral-Syrdarya, Ertis water supply systems is carried out on object-oriented programming language C #. Furthermore, developed software package includes a set of modules: a graphical interface, mathematical functions, interactive analysis, and interaction with the operating system (Figure 5). [8-10].

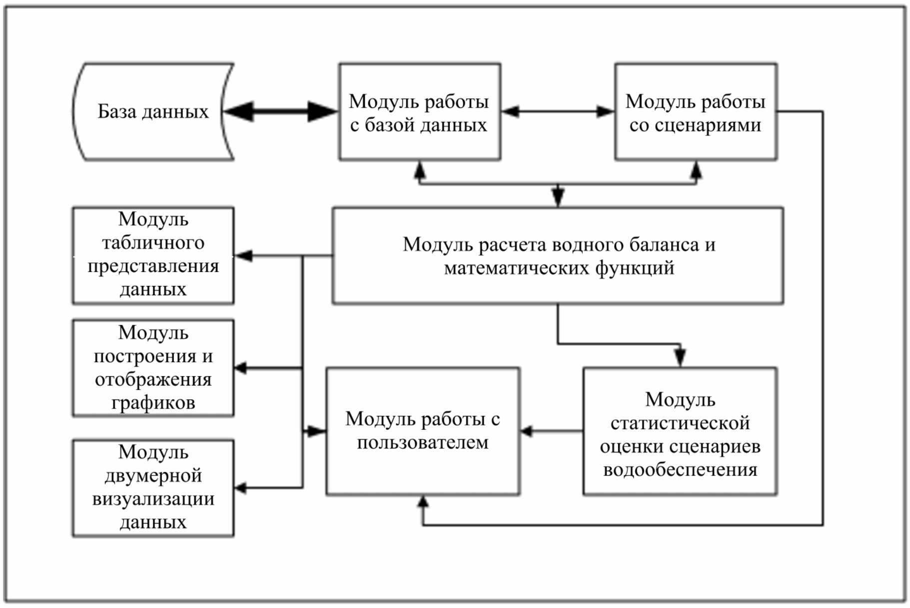


Figure 5 - Diagram of modules and connections between them

The study assessed the adequacy of the simulation model for the system under study by means of manual motion (validation and verification procedures) [11-13]. In addition, the research develops a two-dimensional model visualization of simulation process for water systems with animation of its dynamics on the basis of schematic symbols of objects, their relationships and design parameters (Fig. 6-a, b, c). The study specially designed modules that include the following:

- algorithm of parameters for changing of polygonal objects depending on the model included in the design;
- algorithm for determining the thickness of lines that characterize the relationship of water bodies;
- algorithm for changing the color visualization of objects, based on a tabular format color communication and object parameters.

Conclusions. The major focus of study is a developing of the simulation method for a dynamic-stochastic modeling of Kazakhstan’s water supply systems. For the first time was developed a tool (the first model of sketch) of decision support in strategic planning of National water sector development, including reconstruction of water infrastructure, conservation and restoration of natural water bodies and improving of interstate water allocation.

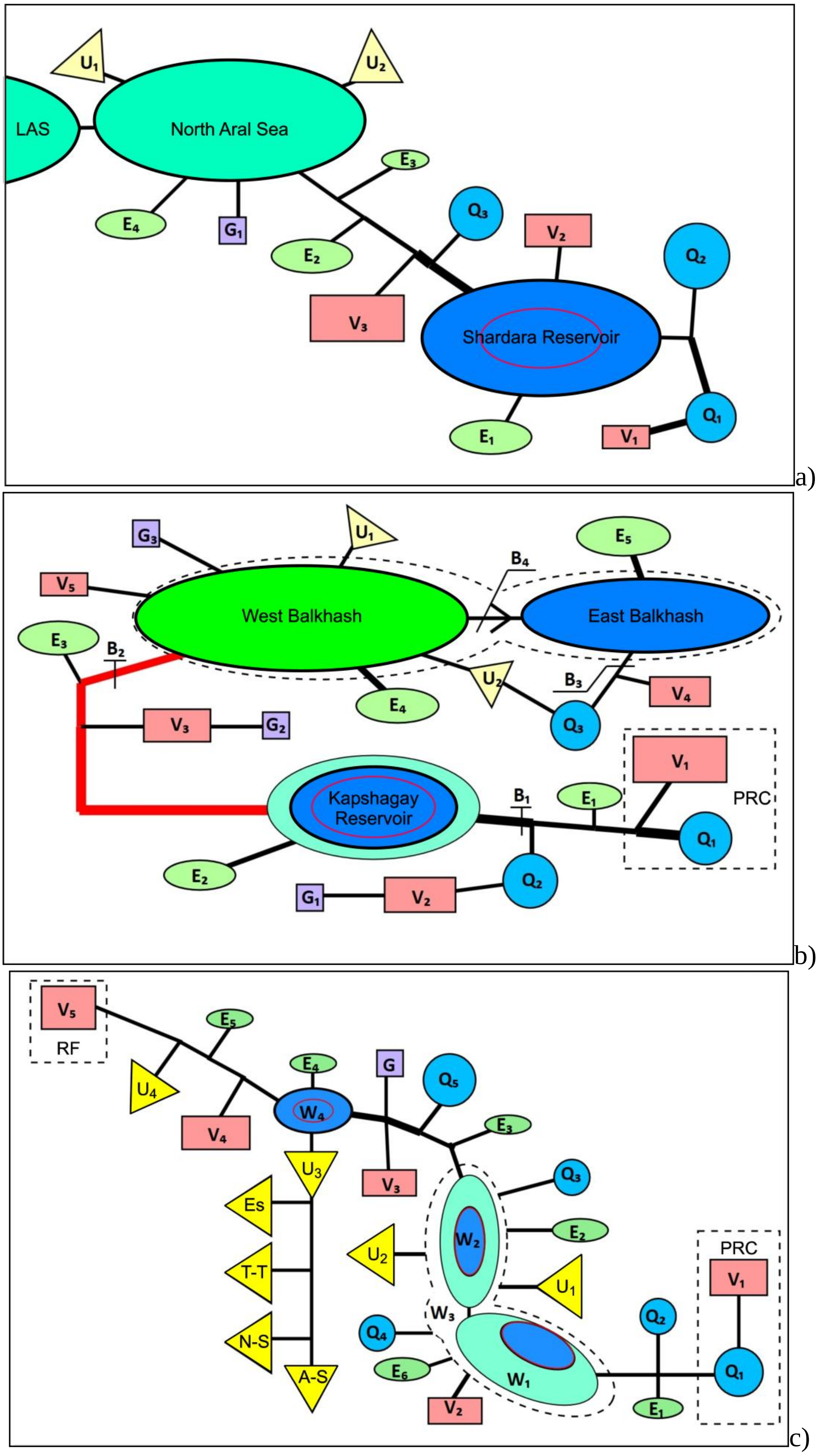


Figure 6 - A two-dimensional computer visualization of simulation model for the WSS Development: a) Aral-Syrdarya river basin; b) Ile-Balkash basin;c) Ertis basin

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CLIMATIC CHANGES AND WATER RESOURSES OF SOUTHERN CAUCASUS

Introduction. Nature and humanity have always been in discrepant relations with each other, i.e. there was a time when nature threatened man, but now man threatens nature. Concerning the water resources consumption by people, the same is going on: uncontrolled exhaustion of natural water resources and disorderly feeding of sewage by people to the water objects, further the water shortage, the water pollution, unclean foodstuffs production, increase and spread of different diseases, environment depletion and oppression. One of such regions of the world is the Caucasian region, especially its southern part, where vital activity of people and economic sectors fully depend on quality and quantity of water resources. The water resources originate in the territory of one country, but they are used in the territory of others, i.e. side by side with natural factors, the anthropogenic impact on water resources make one country to some extent dependent from another one.

The South Caucasus have been identified by Conservation International (CI) as one of the world's 25 biodiversity hotspot, and the area identified by CI corresponds closely to the Kura-Aras river system. This demonstrates the ecological importance and fragility of this area. Notably, the Aras is home to one of the last natural sturgeon breeding grounds, there are important and unique dry-land riparian forests along the Kura, and the delta where the Aras and Kura rivers flow into Caspian contains many important wetland sites. The Caucasus region is also well known for its diversity of natural landscapes, climate, unique and ancient cultural heritage, archaeology and ethnography.

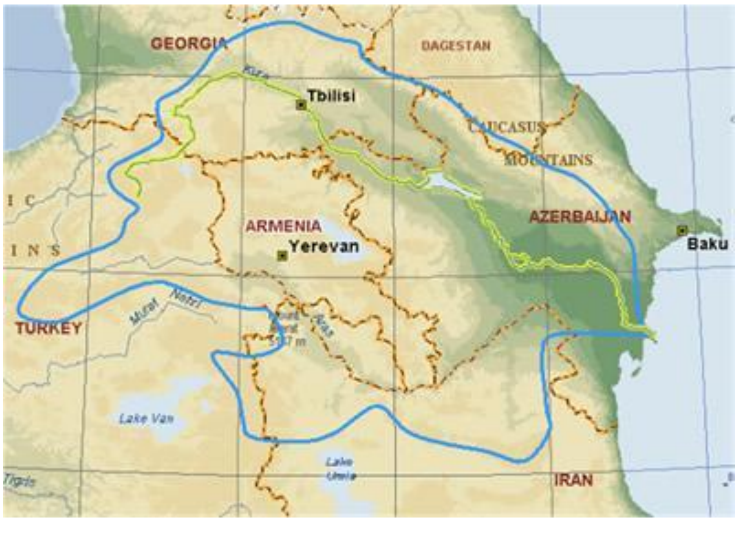

Figure 1 – South Caucasus region

On the biodiversity ecosystem of Southern Caucasus is one of the first places in northern hemisphere. 6000 thousand different kinds of plants take place in Southern Caucasus and this fact allows estimating region as the centre global biodiversity. The region differs in high density endemic; quarter existing here a fauna and flora are endemic. For this territory is character.

For this territory relic types are characteristic. Southern Caucasus also differs landscape biodiversity. The region territory makes only 0,5 % Earth, but 10 % of landscapes Earth here are presented.

The one tenth part of territorycovers small change or the absolutely not changed landscapes. Various landscapes of Southern Caucasian countries have similar economic and environmental problems.

Caucasus is located in the middle of the Eastern Europe, Central Asia and the North Africa. Traditionally Caucasus from the north Kuma-Manychskoj depression, from the West Black and the Azov seas, from the south Turkey and Iran, and from the east to be bordered by Caspian sea (Fig.1). In such representation into its structure enters four states, the territory makes 400 thousand km^2, the population is 30 million persons, density the population 68 people in km^2.

The biggest settlement is on intermountain plains, the channel of the rivers and foundation ditches of mountains of Small Caucasus and it creates the greatest anthropogenous loading on these territories.

The countries of the South Caucasus are Azerbaijan, Georgia and Armenia. The rivers Kur and Aras are transboundary for these countries as well as for Turkey and Iran to a certain extent. The area of territory and the population of these countries the following: Armenia - 29,7 thousand км^2 territory, 2,9 million population; Azerbaijan - 86,6 thousand км^2 territory, 9,7 million population; Georgia - 69,7 thousand км^2 territory, the 3,7 million population.

Climate change in the region. Together with above mentioned importance in this ecosystem also take place climate change processes as in whole earth. For example according Climate Centre South Caucasus countries for period 1880-2015 years temperature was increased in Armenia, Azerbaijan and Georgia accordingly 0,7; 0.7 and 0,8 ^{0}C. The Azerbaijan is more big country of South Caucasus and its territory cover as Lesser also GreaterCaucasus. On this we will consider climate change in this region as example of Azerbaijan territory.

The main conclusion of The Second International Conference On “Climate and Water”, which had taken place in Finland in 1998, and where I made a report (Мамедов et al., 1998), was concluded as following: In the future, the quantity of humidity will diminish in arid zones of the planet/earth/world and it will increase in damp regions. If we take into account that 60 % of the territory of Azerbaijan is part of the arid zone and already suffers an acute shortage of water today, it is not difficult imagine the water problems which this country has to expect. Unfortunately, as mentioned above, the conclusion and the forecast already starts to slow down it step-by-step concerning to the water amount of the rivers of Azerbaijan. As was marked above the natural flow has decreased about 25-30% during the last 6 years. So, the little water still decreases, the situation is aggravated because of anthropogenic and natural causes.

For period 1880-2010 years change of temperature of air in Azerbaijan was from 0,2 to 1,5 ^{0}C and last 40 years are the warmest period. The greatest rise in temperature is observed on the Kura-Aras lowland (0,4-0,9 ^{0}C), the Kazakh-Gjandzhinsky zone (0,6-1,1 ^{0}C), the Southern Slope of the Big Caucasus (0,5-0,8 ^{0}C), Northeast (0,6-1,5 ^{0}C) and Northern slope (0,4-0,6 ^{0}C) Lesser Caucasus (fig. 2).

In many regions of the country have occurred reductions of an atmospheric precipitation from 3 to 15 %. Changes of an amount of precipitation on territory and on seasons are not uniform. According to Institute of Geography of National Academy of Sciences Azerbajdzhna in such areas of the country as Gedebek, Nakhichevan, Lenkoran, Shusha and Akstafф for last hundred five years an amount of precipitation has decreased for 70, 24, 160, 30 and 20 mm/year, accordingly ((Мамедов et al., 2008).

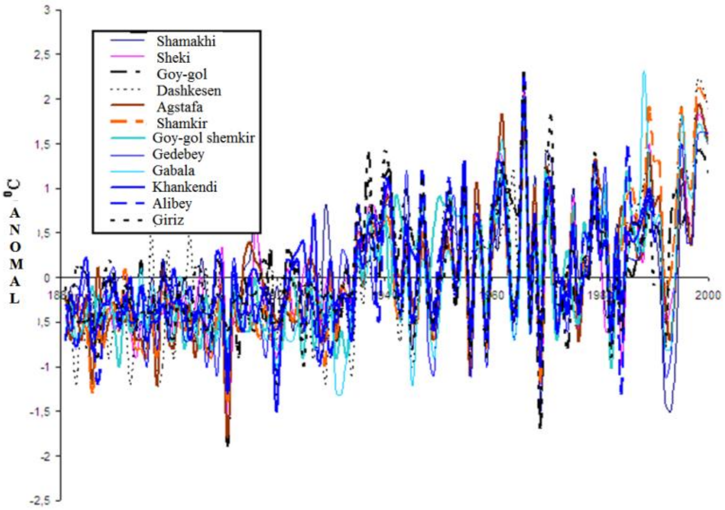

Figure 2 – Anomalies of temperature in various areas of Azerbaijan

The river Kur with its tributaries cover almost all of Armenia and Azerbaijan, and a sizeable part of the populated and urbanized parts of Georgia. The waters in the rivers are therefore essential to sustainable development of these three countries. Whereas they are less crucial, at a national level, to Iran and Turkey, they are nevertheless important to the economy and communities living in the catchment areas.

Regional Importance of the Waters. Kura is the largest river of the South Caucasus (fig 3), its source is in Turkey (area Ardagan) at the altitude of 2740 m., and the estuary is in Azerbaijan on -27m. The length of Kura is 1515км^2, and the drainage basin 188 thousand км^2 (Fig. 1) and is arranged in territories of 5 states. It is arranged as follows: Azerbaijan - 52,9 thousand км^2, Iran - 40 thousand км^2, Georgia - 36,4 thousand км^2, Armenia - 29,8 thousand км^2, Turkey - 28,9 thousand km^2. The longest part of the stream course flows through Georgia (37,7%), Armenia (23,4%) and Azerbaijan (21,5%) as well as 13,6% in the territory of Turkey and 3,8% in Iran.

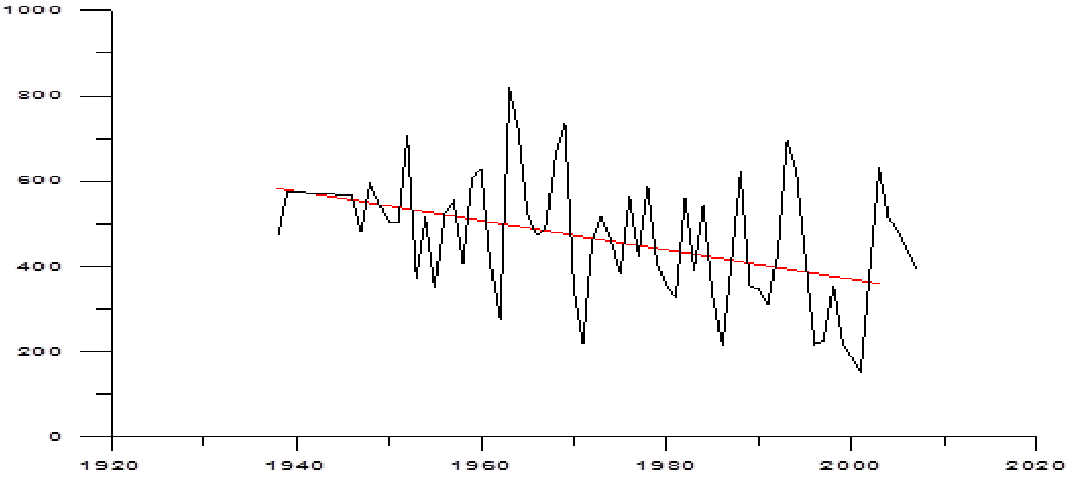

Figure 3 – ManyyearsannualflowriverKura

The basin of the river Kur covers 64 % of the territories of the countries of Southern Caucasus. More than 65 % of terrain of basin of the river Kura (122,2 thousand км^2) is in an altitude of more than 500 meters above the sea level and introduces the area of a supply and transit of flow, and 35 % of the area are rearrangements and losses. The common slope of the river makes 2,03$\%_0$(Rustamov S., Kashkay R., 1989).

The largest influx of the river Kur is the river Aras with a drainage basin of about 102000 кm^2, which is 54,2 % of the basin-area of the river Kura. The source of the Aras also is in Turkey at the altitude of 2990 m. (spine Bingel). It’s length is 1072 km, the mean slope 2,8$\%_0$. Below the estuary of Aras, for almost 210 km, the Kura has no other influx.

The long term average volume of water resources of the Kura river basin is 26,6кm^3. The total amount of water use in the countries of the basin of the river is about 23 кm^3, that means 86 % of water resources are used for the needs of population and economics. 20 million persons are living at the river basin. The enormous water use exhausts the rivers in the basin and decreases the flow at its estuary. The decrease of water amount of the river Kur has been observed and became obviously during the last 60 years.

Figure 4 – Breakthrough and Flooding village in mouth area of river Kura in 2006.

Figure 5 – Kura flooded several administrative regions in 2010 year in Azerbaijan.

The analysis of water consumption structure in countries situated in the Kura river basin is approximately as follows in the following way: irrigation – 68%, heat-power engineering – 11,0%, industry – 6,9%, communal economy – 6,3%, agricultural water-supply – 5,2%, forestry – 2,6%. Water consumption increase is observed in Azerbaijan for the last 30 years (7,0%), East Georgia (7,0%), Armenia (8,5%), and Iran (4,1%).

The existing condition has even more aggravated in the last years with the reduction of the natural flow in the river basins, in connection with climatic changes. In the last 6 years

(1995-2011) the natural flowing diminished about 25-30%, in alpine regions the solid precipitations diminished and the seasonal snow-line rose to 500-800 m. beyond usual. Thus, it is necessary to note that especially in 2003 and 2010 years (fig. 4 and 5), the water amount of the Kura exceeded the long term norm and flooded large territories in the southern flow. These years, the Kura has caused many social and ecological problems in Azerbaijan: About 31 administrative regions with a population of 1,5 million people were affected.

In Azerbaijan, 980 м^3/sec., or 30,9кm^3 of water arise from the river resources. The considerable portion of flow in Azerbaijan comes from contiguous territories by the transit rivers. The mean volume of this influx to the liquid water content per year makes 652 m^3/sec or 20,6км^3. The stream course, directly reshaped within the limits of the country (local flow), is 328 m^3/sec or 10,3кm^3. As a whole, from the local resources of fluvial waters the portion of surface flow averages 58 %, and underground flow 42 %. The resources of fluvial waters of the country for a rainy year are 735 m^3/sec, or 23,2кm^3, and for a year with little rain 228 m^3/sec or 7,2 кm^3. It is necessary to note that 80 % of the counties water resources consist of the river Kur and its inflow, of which 70 %, is reshaped in terrains of neighboring states. The water resources of the republic are limited extremely and contrasting to neighboring states, their specific weight per unit of territory and per capita accounts less according to Georgia 7.7 and 8.3 times, and to Armenia 2.2 and 1.7 times.

The Kura-Aras river system is an internationally significant river system, which is seriously degraded and continues to be threatened. Water scarcity is an issue at many points in the river system. Water quality and quantity constraints are already leading to use conflicts, and the trans-border aspects of these conflicts are likely to increase in the baseline scenario. Integrated, multi-country, trans-boundary responses are necessary to address the threats to the river system, and to address their underlying causes. Many years flow of river Kura are given in figure 3. As we can see is observed some decreasing trend in many years flow of river.

Ecological condition and regional security. The problem of rational use and protection of water resources is very actual for the region countries. Until 1990, the water use and water resources quality control realized on the base of legislative acts of the former USSR and agreements between the USSR and Turkey and Iran. At the same time the state system of regular observations, water quality control and sewage and drainage waters cleaning and draining system were agreed. The scientific-research organizations of the country conducted the scientific-research and engineer-prospecting activities for rational use of water resources.

However, in the last 25-30 years not any seriously fundamental investigation on the assessment of water quality formation and transformation, and the natural facilities of self-cleaning and the renewal of water quality characteristics has been studied in order to develop the scientific-based measures on transboundary rivers quality management. Due to economic difficulties and the lack of programs and acts between countries on rational water resources use, and also the lack of understanding water capacity and quality formation regularities, water resources consumption and distribution at present time, the situation in the region is confusing.

Also the lack of a regional data collection and exchange system in the last 10-20 years makes it impossible for administrative bodies to make timely and objective decisions. There is no regional system of beforehand water capacity and quality prevention.

Azerbaijan faced such a situation in the period of 1999-2000 when it was impossible to plan the actions schedule of Azerbaijan big reservoirs timely. The levels of Mingechevir, Shamkir and Nakhchivan were below the dead capacity most part of the year. Accordingly, in lower reaches of the Kura and Aras rivers, the flowing was two times below the sanitary norm, but the degree of pollution on separate elements was above the utmost permissible norm. This process is going on up to present, and in spite of all kinds of cleanings, the drinking water for Mngechevir, Yevlakh, Ali-Bayramli, Baku and other towns is still polluted.

The water flow to Kura and Aras river-beds below the sanitary norm leads to the increasing of underground waters flow, polluted with pesticides from agricultural lands to the river-beds. Due to unprofitable flowing regulations, the intensive obstruction and silting of Kura and Aras river-beds can be observed. The rivers lost their unique flora and fauna which are relic for these places (rare species of fish, crayfish, forest plant attached to river-beds, etc.).

For the last years, , the disposal of polluted sewage was realized only irregular, and all small and large river basins on the lower reaches of the river lost their natural self-cleaning-abilities The pollution of the separate rivers exceed the permissible concentration many times. The agricultural pesticides aggravated the situation. So, in 2012, the data of water-security offices of Azerbaijan, Armenia and Georgia concerning the basin of the river Kur indicated about 575 million кm^3 of sewages too little, including within the limits of Armenia 300 million. km^3 (52 % from all volume), in Georgia - 250 million km^3 (43 %) and in Azerbaijan - 25 million km^3 (5 %). And in 1998, in connection with economical changes, these parameters were a little lowered again when common sewage disposal in the basin of the river Kura were 453 million кm^3. For Armenia, this volume has gone down to 212 million km^3 (47 %) from all volume, Georgia up to 229 million кm^3 (51%) and Azerbaijan up to 12 million кm^3. As a result of this, the annual water flow of these rivers in their lower limits brings 7662 thousand tons of dissolved chemical combinations, 6060 thousand tons of suspended matters, 4-5 thousand tons of petroleum, 350 tons of phenol and up to 300 tons of compounds of metals. More than 60 % of these matters are on the share of the river Kura, 25 % on the share of Aras and the remaining 15 % - on a lobe of the rivers Alazani, Iori, Akstafacay and Oxchuchay. The extremely unfavorable ecological situation was culminated by undercurrents of the rivers, first of all in the terrain of Azerbaijan, where already the flow from the terrain of Georgia was contaminated by industrial and municipal sewages and from the terrain of Armenia by cities of Yerevan, Kafan, kadzaran, Alaverdi. 80 % of the population, 90 % of the agriculture and 100 % of the industry and other branches of economics use water resources from the river Kur.

Table 1 – Concentrationofsomepollutantsinthe lower reaches oftheriverKur, Mg/l

Years	Phenols	Suspended fragments	Petroleum	Heavymetals, Copper	Azote, ammonium
1970	0,005	675	0,06	0,012	5,2
1975	0,010	576	0,05	0,012	4,3
1980	0,011	834	0,025	0,012	8,3
1985	0,024	1050	0,11	0,010	4,8
1990	0,024	940	0,95	0,020	2,8
1995	0,045	1023	0,20	0,012	8,0
2005	0,036	994	0,18	0,028	5,0

Unfortunately, the pollution of the rivers and reservoirs is continuing in the territory of the Azerbaijan Republic. The main contaminants of the rivers Kura and Aras within the limits of the republic are the industrial enterprises and municipal services of cites like Dashkesan, Ganja, Nakhchivan and MingecevirThe sewages enter the flow after having passed one single sewage plant where only 30-40% from the total amount have been cleaned.

During the last time, the river Koshkarcay has been polluted daily by firms of the city Dashkesan, mainly an ore dressing factory, with another 46 thousand m^3 of sewages. This river runs into the river Kura almost at the tailpiece of the water storage basin at Mingecevir. Everyday about 300 thousand m^3 of sewages from the city Gandci is dumped in the river Gandcacay, which runs into Mingecevir water storage basin after 25 km. In the table 1 are given the concentrations of some pollutants in the undercurrent of the river Kura (The ministry of ecology and natural resources of Azerbaijan, Annual report, 2000).

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ECONOMIC ASSESSMENT OF WATER RESOURCES IN THE CONTEXT OF WATER CHARGING

The value of water resources is based on a compromise between the water subjects within a water deficit. The market mechanism of the water charging gives an opportunity to identify the most rational and efficient water users. The Government should play an active role in harmonizing the water demand and supply model to ensure social responsibility and environmental protection.

Relevance. Water throughout the human history has been considered as one of the most vital resources for economic development as well as the source of human well-being. Availability, adequacy and an abundance of fresh water contribute to its insufficient use. Water is a public good except for some regions in the earth. In this regard, water as economic resource is viewed only on a limited scale. Currently, acute shortage of fresh water resources has become tangible due to the intensification of human activity and significant population growth around the globe. Extension of cultivated areas as well as industrial and energy potential annually reduces the number of available fresh water sources, which is an essential resource for the human development. Water use is a critical human activity criterion on the certain territory. The amount of water used for domestic and industrial needs is directly proportional to the human economic activity. Primarily, water must ensure a stable water supply for cities and settlements as well as favorable living conditions for the human well-being. Secondly, water should be in sufficient amount to carry out the economic activities, preservation of the environment to ensure comfortable conditions for human existence and society as well. Thus, all the ancient civilizations have arisen in the deltas of the great rivers: the Tigris and Euphrates, Nile, Ganges, Yangtze, Mekong. Currently more than 80% of the world population lives in coastal or adjacent to large water sources.

Water is indispensable for providing almost all kinds of human activities. Thus, during a long period of water use have formed the following key sectors of water management:

- the water supply for cities and settlements, industrial, agricultural, transport and energy (thermal and nuclear power plants);
- reclamation, use of water for irrigation and water supply as well as drainage of excess water from the territory(drainage);
- hydropower (water use of energy);
- water transport (use of water for navigation);
- Fisheries (farming and fishing).

In this regard, water users can be divided into four large groups:

- Municipal services - drinking and domestic water supply;
- Industry and energy;
- Agriculture;
- Environment.

Competition between the water stakeholders arises in the context of water scarcity. Market pricing methods will naturally adjust the water demand and allow to find an optimal compromise in the best use of resources, both for society and the state, and at the level of each individual.

Water in the economic dimension. Water is a natural resource, such as the earth, air, sun. In the context of abundant water resources, it is not necessary to use water charging as an effective water management tool. However, in terms of water scarcity the effective water management based on the use of market-based pricing mechanism should be of crucial importance. According to the Constitution of Kazakhstan, water cannot be privately owned from the natural surface sources and is not subject to bargaining. The Article 3 emphasizes that "The land and underground resources, waters, flora and fauna, and other natural resources are state-owned. The land may also be privately owned on terms, conditions and within the limits established by the law." Furthermore, historically man did not contributed to water replenishment, so water from surface water reservoirs, rivers and underground sources is a public good, and the property of the whole society in the face of the state. The state's major priorities are the social security of population and environmental safety. Accordingly, the water pricing under state regulation can be influenced by social and ecological indicators.

Due to the dualistic nature of water use, it can be argued that a sufficient amount of fresh water sources for all the water subjects is a public good and is not subject to economic assessment. In the context of acute water shortage, the water acquires its value. In this regard, due to lack of natural resources, it's become essential for the rationale water use regulation. In this case, water acquires it's "value" within the framework of the "nature-society" system and is formed in the mind of each person individually. The set of individual assessments will determine the average value of water to society and the state as a whole and within a certain territory. Although, it should be noted that there is no common understanding among the economists on definition of the water ownership form [1].

The value of water - is a ratio (a compromise) between the subjects of water use and water consumption during its distribution, expressed in quantitative terms.

Water pricing. The amount of available fresh water in general is equal. In this regard, man does not consume water in literal sense, and uses the properties of fresh water in such manner with not having effects on quantity of available water resources. However, due to both the natural and human factors not all of water resources can be consumed.

Natural factors include:

- The seasonal nature of river flow;
- Water infiltration into groundwater sources;
- Long-term fluctuations in the level of surface waters;
- surface evaporation;
- The number of depositors,
- Natural hazards associated with water - flood, floods, high water, salinity, water logging.

The human factor includes:

- water losses during transportation
- hydropower;
- water pollution.

Due to the acute water shortage, it should be noted that the above factors determine the need for water regulation. Regulation of water volume suggests a temporary mechanism for water accumulation and distribution, which would have economic viability, and could be achieved by effective water management with the use of existing market mechanisms. The fluctuation of the river flow can be synchronized with fluctuations of water consumption volume due to the maximum volume of investments in the regulation of river flow. Depending on the river basins, this will increase the available water volume from 3 to 10 times (Figure 1, 2). Moreover, the river flow regulation has a different economic effect that will significantly reduce the number of natural water disasters and the risks of natural hazards for human life by reducing damage to natural and economic systems from floods and flooding.

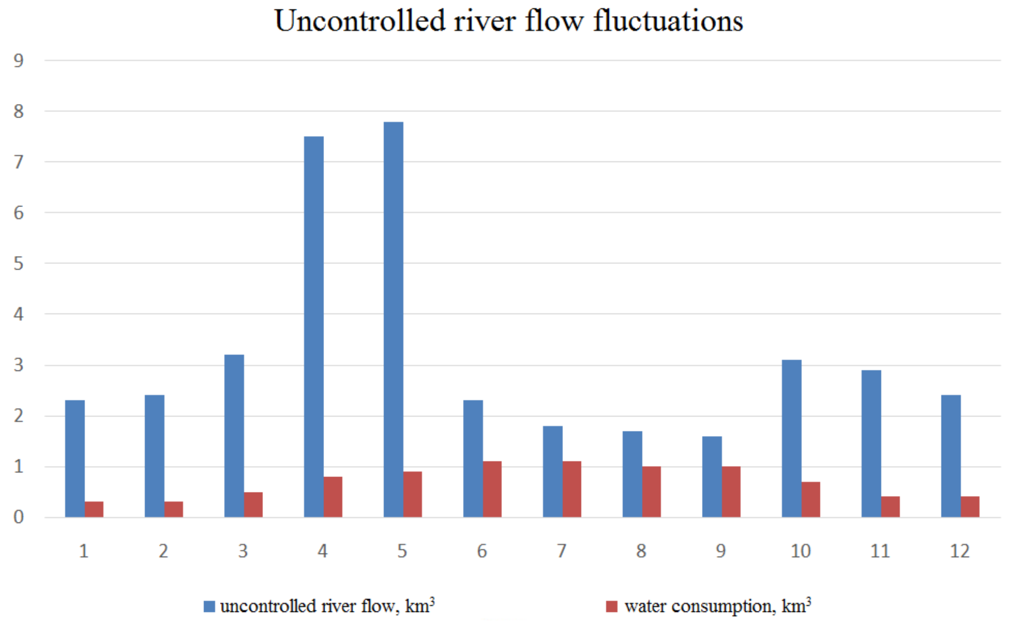

Figure 1 – Water consumption under the uncontrolled river flow.

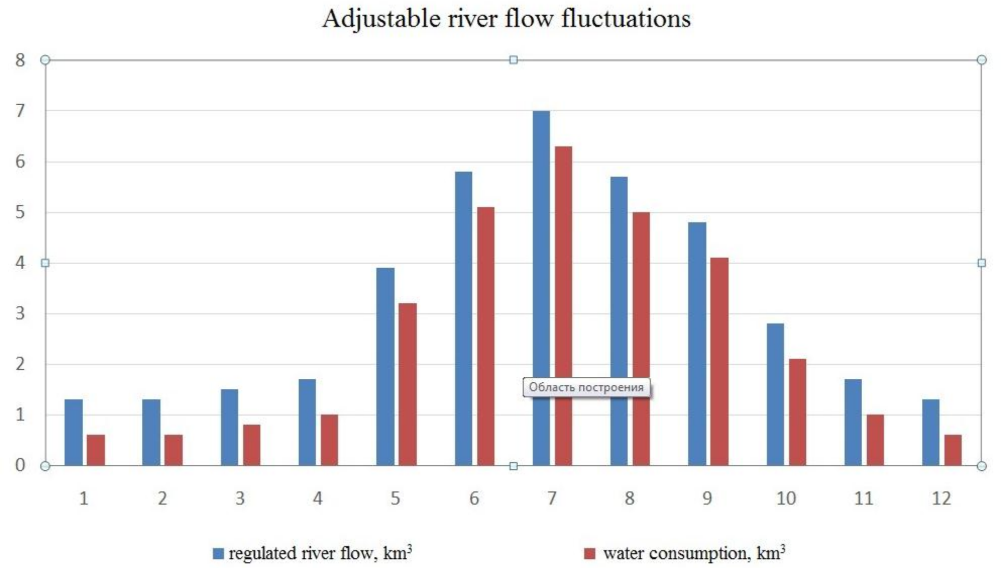

Figure 2 – Water consumption under the adjustable river flow.

The cost of river flow regulation have a possibility to extend the acreage significantly to ensure the reliability of water use, to increase productivity of crops, as well as impact positively on the environment as well. Such costs refer to infrastructural, which in most cases are carried out by the State and involve the following:

- Construction and maintenance of reservoirs as well as hydro-schemes of different types (underground, lake, perennial, seasonal, weekly);
- dredging operations;
- Alignment of the river channels and strengthening of the shoreline;
- Construction of sewage treatment facilities in the river beds;
- Monitoring the qualitative composition and volume of river flow, etc.

The river flow regulation allows economic subjects to double water intake downstream of the Ile River on the basis of Kapchagai reservoir (Figure 3). Under these conditions, the correct economic assessment of water resources allows:

- to create the desired amount of water to meet the needs of water charging from a source that is a kind of tax for water users;
- To finance the construction cost and maintenance of infrastructure to regulate the river flow volumes.

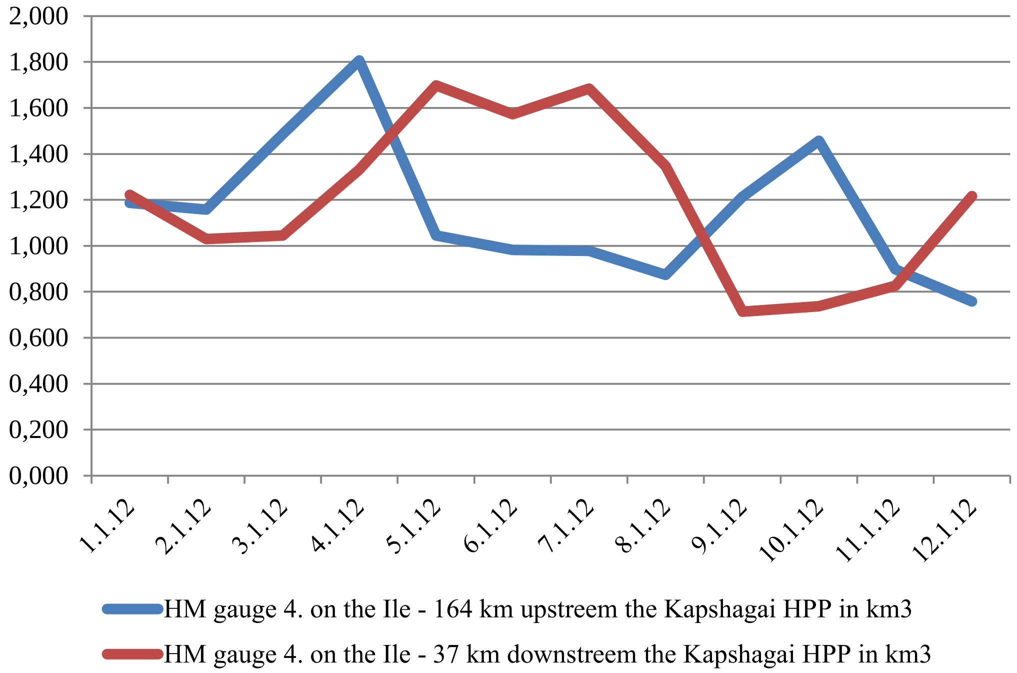

Figure 3 – Fluctuation of the river flow volume on the Ile River upstream and downstream of the Kapchagai reservoir (according to the Kazhydromet)

However, the water cost should meet the market-based mechanisms for its forming. For example, at absence of necessity to carry out the high cost of river flow regulation, where there is no corresponding water demand (Figure 4). The water cost should be acceptable for the economic development of specific territories, and at the same time high enough to cause careful attitude to the resource as well as encourage the most efficient ways of water use.

The water pricing mechanism. Available water consumption depends primarily on the quantity of available natural resources. Fresh water from surface sources: rivers, ponds, lakes are relatively inexpensive. Lifting sources are more expensive, but the best in terms of quality (if not salty), however, has limitations in terms of water consumption. The sea and ocean water are virtually unlimited resource, but requires a very high costs for desalination process, so it is often used only for drinking water. Thus, with increasing the water costs are growing the volume of available fresh water resources. The special landlocked location of Kazakhstan without access to the unlimited water supplies, envisages close interaction with the natural environment. In this regard, increasing in the amount of available fresh water can be possible due to the river flow regulation as well as water production from underground resources.

The curve of water demand in the long run to certain point (the maximum amount available from natural water sources) is elastic. The curve reflects amount of water available for consumption from surface sources. Relying entirely on market pricing methods, if we suppose that water is a commercial kind of goods, it becomes the product of a natural monopoly, which in a certain area will dictates the price and maximize the profit at minimum cost. Under these conditions, the value (PMK) is a result of matching the marginal cost of water extraction (MC) and the marginal water utility (MR) at the point K (Figure 5).

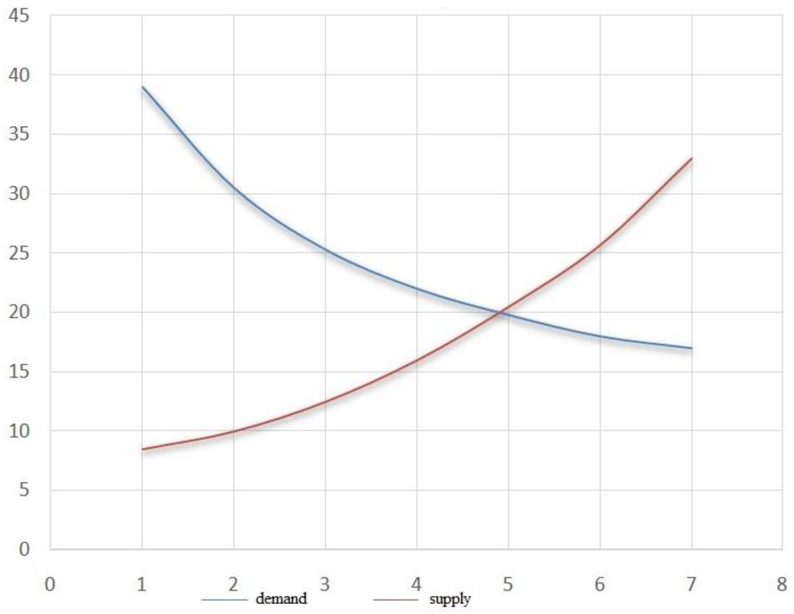

Figure 4 – Compliance of supply and demand for water resources.

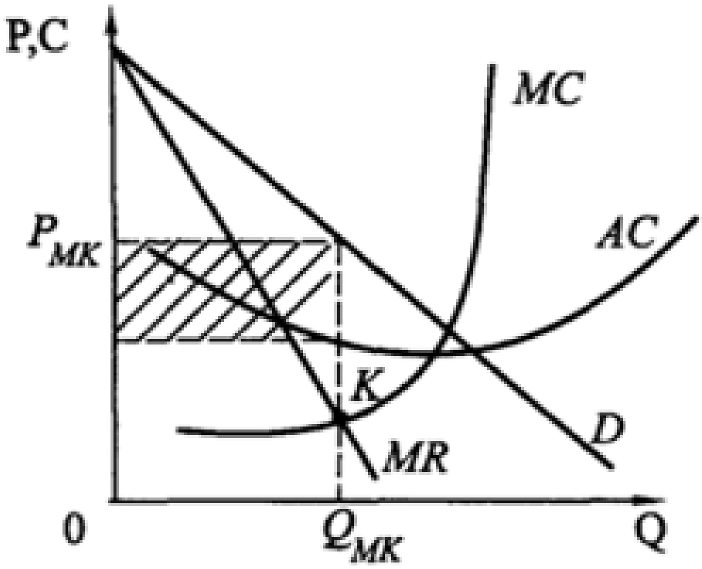

Figure 5 – Pricing in the monopoly market

However, water from the surface sources cannot be in private capital ownership, vice a versa is a public good and owned by the state. Consequently, social justice is a basic water distribution principle. The principle of social justice in the market economy towards the water resources allocation assumes that every person has the right to it. However, as water is a public good it should be distributed to society in the most useful manner in a way that does not impair the needs of the other water users.

Market water allocation mechanism that responds to the principles of social justice can only be in perfect competition model, which is characterized by (Figure 6.):

- Unlimited number of independent buyers and sellers of goods at a competitive industry (a few hundred or thousand), each seller has a limited market share;
- The absolute product uniformity, which means that the goods offered for sale have the same standard features in terms of quality, packaging and appearance;

- Absolutely free access for new enterprises to the market and the free exit from the existing companies;
- Absolute mobility, that is a freedom of movement for all production factors, the ability to get rid of extra resources or raise additional factors;
- Market transparency means that sellers and buyers are aware of the prices, quality goods, the volume of supply and demand, as they make decisions under certainty;
- Equal conditions of competition for all market participants. Restriction on setting up in competition for someone benefits due to friendship or differences in the timing of goods delivery.

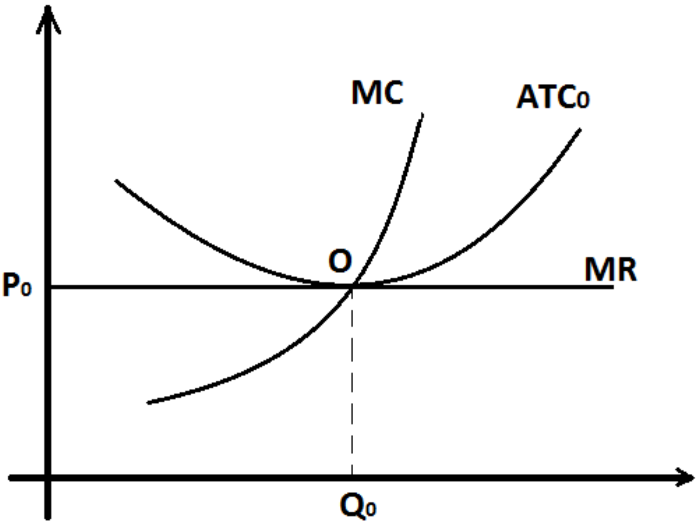

Figure 6 – Pricing in the perfect competition market

Water as a commodity is a relatively homogeneous product that complies with the model's conditions. The consumers, being diverse and sufficiently numerous groups, have an opportunity to be to some extent a serious competitor in the final water distribution market. The presence of only one major supplier does not meet similar pricing models. However, the state has unique capabilities in simulating the behavior of multiple vendors to correct the market pricing: P = MR = MC = ATC (price is equal to the marginal utility, marginal cost, average total costs at the point O)

Thus, in the perfect competition market, the long term water price will be equal to:

(1)

Where P –is the water price, the ATC - the average total cost, TC - total costs for the river flow regulation (including depreciation expense), Qp - the amount of water allocated for consumption use. These estimates will regulate the market by the volume of water consumed and its price, as well as to take into account the water demand fluctuations on the part of consumers, and natural water fluctuations, which may vary significantly every year.

Due to the limited and unevenly distributed water resources, it is clear that with increasing water demand in the market economy, will raise the price (Figure 4), but the exact behavior of consumers is difficult to be reflected in the mathematical model. Since the water in the short term is inelastic commodity, then in the case of shift at the demand curve (increasing the demand for water), the equilibrium price will be determined by similar cobweb model for supply and demand matching (Figure 7).

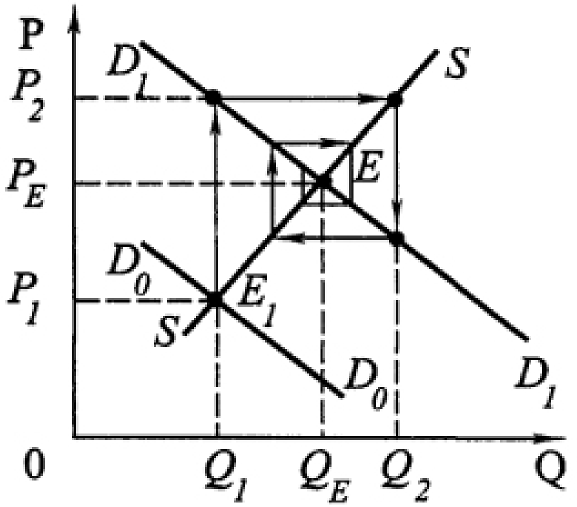

Figure 7 – The cobweb model of equilibrium in the market.

The given pricing model with some variations is characteristic for the real market economy in the context of competition. However, it should be taken into account that water is not an exchange commodity and not a market product. In this context, the State is only responsible for the sustainable water management and rational water consumption with the of use market-based pricing mechanism. Therefore, the water price should be oriented towards the largest water users in the face of agriculture and it's the seasonal cycle operation, and should be adjusted accordingly by the state for planning the sowing season once at the beginning of the year.

The state is also aggravated by a number of social functions for the water distribution, and cannot allow sharp fluctuations in prices for agricultural products. On the other hand, the state policy is aimed at long-term investment projects to improve the effectiveness of the river flow regulation in the long term and is not interested in a sharp jump in water prices.

$$I_1 = P_1 – TC_1, \quad I_2 = P_2 – TC_2 , \quad ….. \quad , \quad I_n = P_n – TC_n,$$

Where $I_1 \geq I_2 \geq ….. \geq I_n$ –investments made in 1, 2, ..., n years. In the n - year will be reached a new equilibrium point, where In = 0. Then the total cost of the projects for the flow regulation, which is corresponding to one shift of the demand curve, should be equal to:

(2)

Where r – is an accounting rate of the National Bank.

However, the market environment neither theoretically nor in real life do not allow to reach a point of equilibrium (P1 → PE) in the case of demand curve's shift for a single iteration. Therefore, in our case, the water pricing model should be provided for softer vibrations, focused on the long-term financing for the construction of hydraulic structures, which weaken the sharp rise in prices in the secondary markets.

The objective environmental factors make high degree of uncertainty in the pricing model that are difficult to predict in the long term, such as the annual fluctuations in the river flow, rainfall, annual temperature regime and other factors that affect the water demand and ultimately crops productivity and efficiency.

The first constraint for price regulation of the river flow: water price within the river basin should not exceed the cost of its regulation for maximum water consumption.

(3)

The second constraint is a water availability and adequacy for consumers needs, which will be expressed in probabilistic terms, and reflected in the amount of the required investments,

(4)

Where, pj - reliability (probability) of ensuring Qj - all of the water subjects in the j-th year.

(5)

Where Pj - the water price for the source in the j - year set at the beginning of the year, TSj - the total cost of the river flow regulation in the j-th year, Ij (1-pj) - the total amount of investment for the development, pj - probability of ensuring all water consumers in the j-the year.

For example, if it is possible to provide the volume Qj at the expense of existing infrastructure to regulate the river flow, for example in the high water, the pj = 1, respectively, while investment I_j (1-p_j) = 0, the price remains at the same level or will even be reduced.

If the actual volume of water consumption (QJ) QJ is different from the potential demand at the beginning of the year, then

$$Q_J+1 = QR_J + \Delta Q_J \qquad (6)$$

Where QJ + 1- the potential water demand for the next year, ΔQJ – the water shortage in the j - year.

The described pricing mechanism will improve the water use efficiency, without significant administration costs. Moreover, the pricing mechanism will promote satisfying the water management objects as well as the most effectively to meet the individual, population and enterprises needs.

The water pricing under the state regulation. Despite the general basis for the water pricing, there are certain restrictions in the pricing model that should be corrected by the state. Thus, the basic water cost, in spite of it's uniformity, varies depending on qualitative composition, contamination, temperature and other parameters of water resources. In addition, the main water users are: the communal services, hydropower, industrial complex, agriculture, recreation and national parks, natural environment as well. Differentiation of water use subjects brings to the fore the social obligations of the state for guaranteed ensuring the drinking water supply. Communal networks for the water supply regulations should be provided with a reliability of the 99% (0.99). The second priority of the state implies ensuring a certain level of social welfare, i.e. a certain level of employment. Reliable supply for large industrial facilities with a large number of the working population - a power plant, large mining and processing industries should be carried out to maintain the economic activity of the urban population.

In this regard, the required level of reliability for water supply should be at least 95% (0.95) for successful functioning of such facilities. Agriculture, fisheries, water transport, and the environment are in remainder. Based on the principles of social justice, the priority in water use should be directly reflected in the price for water resources. As a result, depending on the consumer’s priority level, the correction factor is introduced in the base assessed value for water resources:

(7)

Where pw – is the level of reliability, i.e. value of the State's obligations under a guaranteed water supply, pj – is a probability of satisfying the potential water demand in the j-th year.

The ecological status of surface water resources is one of the most important criteria that require state regulation. Namely, the irrational water use is a major source of water pollution. The level of water pollution should be reflected in the final cost for water resources. The water pollution index (WPI) is the most convenient factor to water pollution calculation, which is already an integral indicator characterizing the quality and status of water resources:

– extremely clean (<0.25)
– clean (0.25 .. 0.75)
– moderately polluted (0.75 .. 1.25)
– polluted (1.25 .. 1.75)
– dirty (1.75 .. 3.00)
– very dirty (3.0 .. 5.0)
– extremely dirty (> 5.0).

Accordingly, water use with the best quality indicators should be more expensive than water with the worst. Thus, the water cost for the consumers can be adjusted due to quality of the intake water.

(8)

Dependence is an inversely proportional, as the less water polluted, so the higher price is, and thus the water of good quality does not require additional costs for water treatment procedures. Despite the high cost for clean water, the cost of its acquisition justified at the expense of significant reduction in its additional cleaning costs.

Moreover, it should be taken into account that the return runoffs play an important role in maintenance of the water quality in terms of affecting the downstream countries. Guided by the experience of foreign countries, we must increase the water use efficiency and to minimize the amount of return water fed back into the surface water sources and to take it into account in the calculation of water tariffs.

Thus, the water cost for consumers needs is established depending on the amount of intake and return water:

(9)

Where, Qt, Qr - the volume of the return and intake water respectively; Pj - the base water price; WC - the total water cost, which is determined for each water subject.

The differentiation of tariffs on water users and qualitative composition of water have adjusted our pricing model with perfect competition model to a model of monopolistic competition, as de jure and de facto state in the face of market entity, in essence, is a socially-oriented monopoly.

The basin approach to the water assessment is a second constraint of the model, i.e. water cost will vary depending on the basin. Accordingly, the water assessment model requires the basin water management principle. In Kazakhstan, as in most countries of the world, the water management is carried out within the basin feature that speaks in favor of the proposed model.

The third constraint of the model assumes that the total cost for maintenance of the hydraulic structures and the total investment in the basic model must be distributed equally on all of the water subjects, regardless of their territorial localization: in the upper or the lower reaches of the river or its tributaries. The principle of social justice in this case provides: the upstream water users reduce the amount of water available to the downstream users, respectively; they have to pay the same water cost, despite the fact that upstream users have considerably less hydraulic structures requiring maintenance than downstream.

The fourth constraint in the model is market volatility of the water price, which is changed at least once a year. However, with regard to the economic actors, especially in the field of agriculture is inconvenient for business planning longer than a year. This moment could easily be overcome by public investments in updating, upgrading and construction of new hydraulic structures. As a result, the annual payments on investment from this sum may serve as buffer to maintain the water price stability for a decade. However, it is become possible to assess and forecast the water demand, volume of water supply as well the volume of required investments due to well-coordinated work of economists, water engineers and hydro- geologists.

Furthermore, the model can include environment as a subject of water use and to facilitate a search for compromise in implementation of the human economic activity and nature as well. Firstly, since the assessment of water resources is carried out at natural source, the natural environment becomes a full-fledged subject of natural management in the river flow regulation. This fact gives an opportunity to operate with a concept of "sanitary" flow - flow for maintaining the ecological status of natural landscapes, which can be used for household needs at a pinch. The ‘sanitary” flow can be calculated on the basis of environmental damage to the natural environment from the lack of water resources:

$$ED = P_j O_{sf} \rightarrow O_{sf} = ED/P_j \qquad (10)$$

Where ED - amount of environmental damage to the natural environment from the lack of water, Pj - the base water cost in the j-th year, Osf – “sanitary” flow.

Consequently, the water pricing model is based primarily on the market mechanism with the state regulatory components, aimed at addressing the socio-economic problems. Such a model of the market water pricing does not require significant investments in its implementation and will directly contribute to the improvement of water use efficiency, water saving and improving the surface water quality.

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MUDFLOWS IN ILE ALATAU DURING RECENT 25 YEARS

В статье приводятся данные о селевых явлениях в хребте Иле Алатау в Казахстане за период с 1990 по 2015 годы. Всего было зафиксировано 235 селевых явлений. Из них 30 селей были крупными с объемом более 10 тыс. м^3. Среди крупных селей 23 селя были дождевыми, а 7 селей – гляциальными.

Мақалада Қазақстандағы Іле Алатауы жотасындағы 1990 және 2015 жылдар аралығында болған сел құбылыстары туралы мәліметтер берілген.Барлығы 235 сел құбылысы орын алған. Оның 30-ы көлемі 10 мың м^3-ден асатын ірі селдерге жатады. іре селдердің 23-і жаңбырлық, ал 7-еуі гляциалдық болып табылады.

The article presents data on the of mudflow phenomenon in the Ile Alatau range in Kazakhstan for the period from 1990 to 2015. Total 235 mudflows were reported. Of these, 30 ones were large mudflows with a volume of more than 10 thousand m^3. Among the large mudflows mudflow 23 ones were caused by rainfalls and 7 ones – by glacial lakes outbursts.

Introduction. Ile-Alatau mountain range stands out among the mudflow-prone areas of Kazakhstan for the number of mudflows and the amount of damage caused by them. This is explained not only by intensity of mudflows, but also by the degree of development of high valleys and foothills. There are large settlements almost at all the debris cones, including Almaty metropolis with a population of nearly 2 million people. The first information about mudflows in Ile Alatau appeared in I.V. Mushketov's proceedings [1], which describes the seismogenic mudflows in 1887. Then, the description of catastrophic mudflows in 1921 was published [2]. Systematic collection of data about mudflows and their publication began in the 1930-s, with the formation of mudflow service at Kazhydromet and especially after the establishment of KazSIGMR in 1951 and KazSeleZashchita in 1973 [3-7]. Many publications were dedicated to catastrophic mudflows on Yesik river in 1963, on Malaya Almatinka river in 1973 and on Bolshaya Almatinka river in 1977 [8]. There were few generalizing monographs with historical retrospective until the middle of 19th century [9-12]. However, since the early 1990-s, the amount of mudflow researches sharply decreased, and the number of publications on the facts of the mudflows reduced very much. Therefore, the information on the mudflow activity in the last 25 years is not available to the scientific community.

This article summarizes the data on the mudflows in Ile Alatau collected during the recent quarter of the century.

Data used. Data about mudflows were collected by KazSeleZashchita, Institute of Geography and Kazhydromet. From 1990 to 2015, 235 mudflows, including debris-water floods and small debris emissions, were recorded in Ile Alatau.

By genesis, mudflows are divided into rain and glacial, and by size - into small and large ones. Rain mudflows are formed during heavy rainfall and glacial - with intensive melting of glaciers and breakouts of moraine lakes. The small ones include mudflows with a volume of less than 10 thousand m^3, the discharge of which is not more than 10 m^3/s. Volumes of large mudflows reach 1 mln. m^3 or more, and the discharges exceed 1000 m^3/s.

Results

30 large mudflows were observed in Ile Alatau during the period under review. Among them, 22 mudflows were rain origin mudflows. Rain mudflows also prevail among small mudflows. Out of the 205 small mudflows, 187 ones were rain origin (Table 1).

In the long-term series of mudflows, there is a sharp decline in mudflow activity after 2003. Reducing the number of rain mudflows can be attributed to the decrease in number and intensity of rainfalls, while reducing the amount of glacial mudflows, is explained by preventive emptying of moraine lakes implemented by KazSeleZashchita.

Table 1 - Distribution of the number of mudflows over the years

Year	All mudflows	Small mudflows		Large mudflows	
		rain	glacial	rain	glacial
1990	21	9	9	2	1
1991	11	8	2	1	-
1992	4	3	1	-	-
1993	13	9	-	3	1
1994	8	4	-	3	1
1995	7	4	-	2	1
1996	24	21	1	1	1
1997	13	12	1	-	-
1998	17	16	-	1	-
1999	22	20	-	2	-
2000	2	2	-	-	-
2001	3	3	-	-	-
2002	12	11	-	1	-
2003	25	22	-	3	-
2004	8	8	-	-	-
2005	7	7	-	-	-
2006	8	7	-	1	-
2007	9	8	-	1	-
2008	1	1	-	-	-
2009	4	4	-	-	-
2010	5	4	-	1	-
2011	2	2	-	-	-
2012	-	-	-	-	-
2013	3	2	-	1	-
2014	1	-	-	-	1
2015	5	-	4	-	1
Total	235	187	18	27	7

The earliest mudflows were recorded in mid-March, the latest - in the beginning of September (Table 2). Since early April there is a steady increase in mudflow activity from 3 events in the first decade of April in 25 years to 20 events in the first decade of June in 25 years. The sharp increase in mudflow activity occurs in July, reaching its maximum in the third week of the month. During this period, there were 43 mudflow phenomena for 25 years. Glacial mudflows were observed in the period from the second decade of June to the first decade of August. Over the entire period of observations, the most recent glacial mudflows took place in the third decade of August. In August, there is a sharp decline in mudflow activity, which is associated with a decrease in precipitation and a decrease in temperature in the glacial zone.

Large mudflows slid down starting from the first decade of June until the second decade of August (Table 3). Large rain mudflows were recorded from the first decade of June to the third decade of July, and large glacial mudflows - from the third decade of June to the second decade of August. Most often large mudflows were formed in July (22 of 29). 5 out of 7 large glacial mudflows were accounted for this month. All large rain mudflows, accompanied by damage slid down from the beginning of July to the end of July. The amount of mudflow-forming precipitation always exceed 50 mm, reaching 159 mm. Large glacial mudflows were observed during the period from late June to early August. In most cases, the formation of glacial mudflows occurred as a result of the underground breakout of a moraine lake. Surface breakouts were prevented by preventive emptying of lakes conducted by KazSeleZashchita. High positive air temperatures reaching 15-19 °C in the daytime stayed for several days before the breakout of moraine lakes in the glacial area.

Table 2 - Intra-annual distribution of the number of mudflows

Month and decade	Decade	All mudflows	Small mudflows		Large mudflows	
			rain	glacial	rain	glacial
March	2	4	4	-	-	-
March	3	1	1	-	-	-
April	1	3	3	-	-	-
April	2	8	8	-	-	-
April	3	10	10	-	-	-
May	1	15	15	-	-	-
May	2	12	12	-	-	-
May	3	13	13	-	-	-
June	1	20	19	-	1	-
June	2	14	13	1	1	-
June	3	15	10	1	3	1
July	1	32	22	3	4	3
July	2	37	24	5	7	1
July	3	43	28	8	6	1
August	1	10	6	4	-	-
August	2	6	5	-	-	1
August	3	2	2	-	-	-
September	1	1	1	-	-	-

Table 3 - Large mudflows in Ile Alatau from 1990 to 2015

Data	River basin	Type	Reason	Discharge, m^3/s	Volume, m^3	Material damage
06.07.1993	Mid Talgar	Glacial	Underground breakout of the lake	1340	1400000	significant
21.07.1993	Right Talgar	Rain	Heavy rainfall	-	-	insignificant
03.07.1994	Ulken Almaty	Glacial	Underground breakout of the lake	1000	-	-

21.06.1995	Mid Talgar	Glacial	Underground breakout of the lake	180	-	insignificant
06-07 .07.1995	Mid Talgar	Rain	Heavy rainfall	100	-	insignificant
11.08.1996	Mid Talgar	Glacial	Breakout of intra-glacial reservoir	-	300000	insignificant
19-20.06 1998	Ulken Almaty	Rain	Snow melting and rain	500	-	insignificant
24.06.1998	Kaskelen	Glacial	Underground breakout of the lake	-	-	insignificant
14.07.1999	Bedelbai	Rain	Heavy rainfall	200	40000	significant
30.06.2002	Ulken Almaty	Rain	Heavy rainfall	-	-	insignificant
06.07.2003	Yesik	Rain	Heavy rainfall	-	-	significant
22-25.07.2003	Yesik	Rain	Heavy rainfall	-	-	significant
23-24.07.2003	Akzhar	Rain	Heavy rainfall	30	-	insignificant
23-24.07.2003	Ulken Almaty	Rain	Heavy rainfall	-	-	insignificant
23-24.07.2003	Kishi Almaty	Rain	Heavy rainfall	25	-	insignificant
27.07.2003	Mid Talgar	Rain	Heavy rainfall	500	-	insignificant
15.06.2006	Akzhar	Rain	Heavy rainfall	20	22000	insignificant
06.07.2006	Ulken Almaty	Rain	Heavy rainfall	800	1000000	significant
06.07.2006	Mid Talgar	Rain	Heavy rainfall	-	-	insignificant
26-27.07.2007	Yesik	Rain	Heavy rainfall	30	-	significant
21.07..2013	Sarysai	Rain	Heavy rainfall	-	-	significant
17.07.2014	Mid Talgar	Glacial	Underground breakout of the lake	1340	2000000	significant
23.07.2015	Kargaly	Glacial	Underground breakout of the lake	-	-	significant

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PRINCIPLES OF WATER RESOURCES MANAGEMENT IN KAZAKHSTAN

The major focus of the study is the Concept of water management as set of constructive principles and functions of administrative activities including "planning", "organization", "motivation" and "monitoring" each of which is carried out by means of "procedures" and "operations". The first sketch of an imitation model is developed for an assessment and comparing the alternative scenarios of Kazakhstan's Water Supply System(WSS) development.

Introduction. It's become evident that the fresh water is a finite resource as well as water scarcity will have the most negative consequences on the global level. According to the UN statistics 2 billion people suffer from a regular short-changing of water. According to the forecasts of the Food and Agriculture Organization of the United Nations (FAO), to the middle of third decade of the XXI century, a number of people experiencing permanent water shortages will exceed 4 billion. In the context of an expected global water crisis, the international community pays a great attention to the various aspects of water security, interpreted as a prevention of threats to global stability because of water wars, water terrorism, etc. (Figure 1).

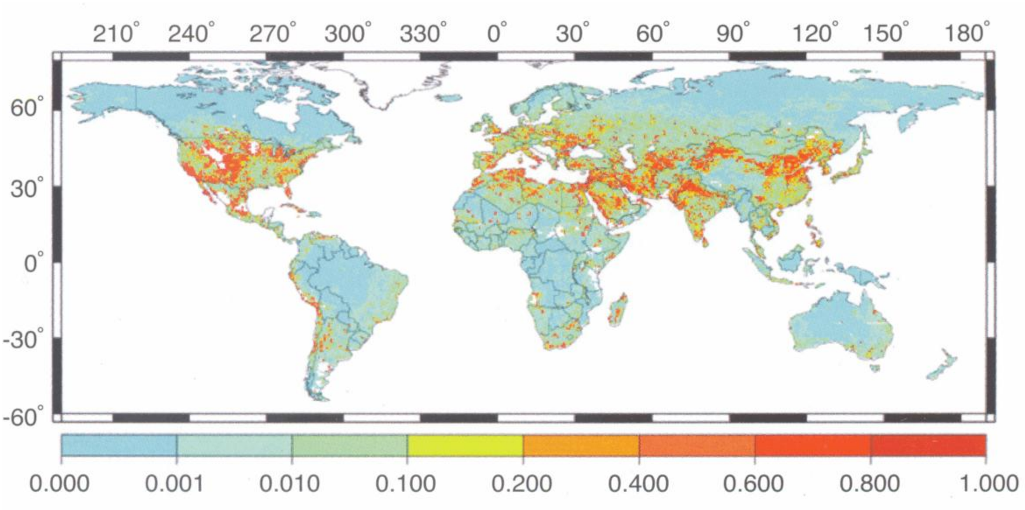


Figure 1 - The expected water stress around the globe (2050).

Acute water shortage is a fourth largest threat that the Republic of Kazakhstan faces in the XXI century. In this regard, ways out of the "water crisis» are formulated by the President of the Republic of Kazakhstan in the Strategy "Kazakhstan-2050" [1], particularly outlines the main vectors of a new policy "once and for all solve the problem of water supply. On behalf of the Head of State was developed the State water resources management program, approved by respective of Presidential Decree № 786 (Figure 2).

Transboundary water resource threats. The severity of water supply issue in Kazakhstan is caused mainly by its unfavorable geographical position in the lower reaches of transboundary basins (Figure 3). Almost half of the country's renewable water resources contain a transboundary uncontrolled runoff. Potential effects on flow change pose a real threat to the sustainable development of the country [2].

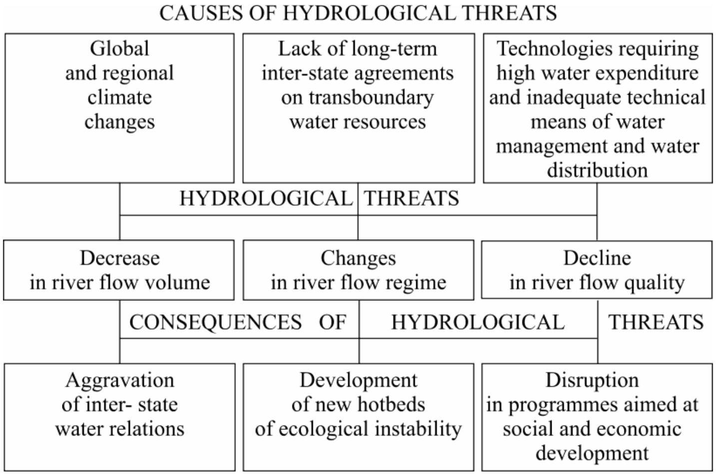


Figure 2 – Hydrological threat: causes and consequences

Water threats. Water basin system of Kazakhstan is classified into energy transport (1), irrigation and energy (1), irrigation (2), transport and fisheries (1), water supply (3) (Figure 4). Current water management system of the country is dominated by technologies with high water consumption both with an imperfect tools of water regulation and water allocation. In the context of an expected reduction of transboundary runoff it will inevitably lead to the aggravation of inter-sectoral and inter-regional conflicts.

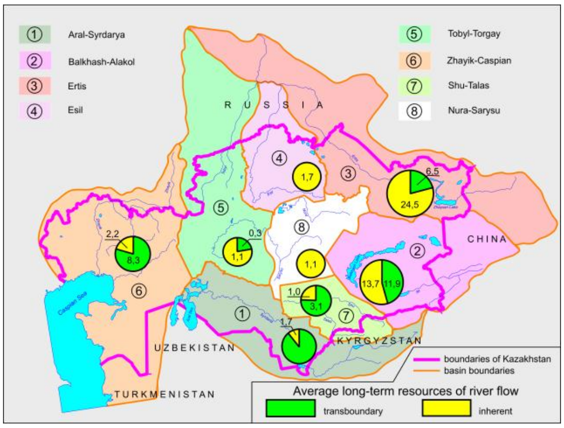


Figure 3 - Transboundary water threats in basins of Kazakhstan

Figure 4 - Water economy threats of Kazakhstan

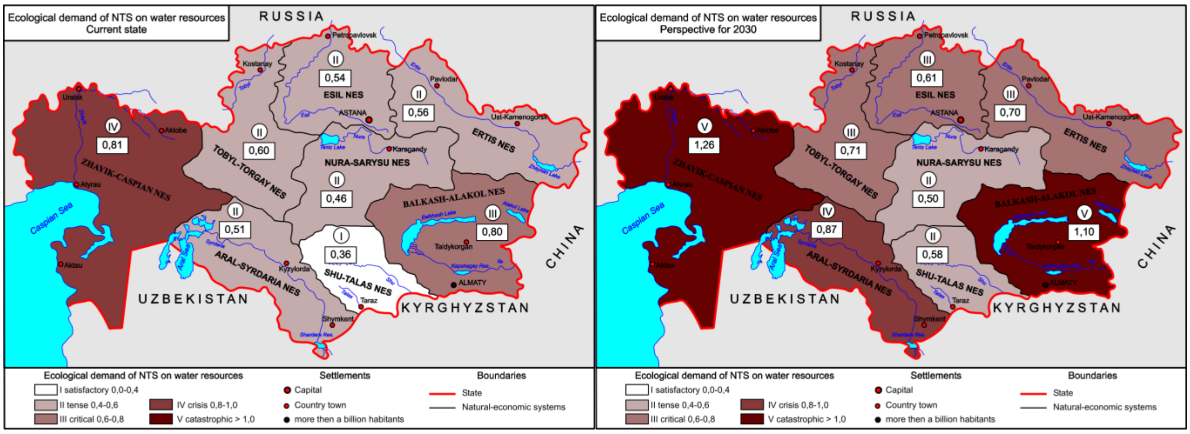
Water and environmental threats. Ecological demand of natural and technogenic systems of the Republic on water resources involves the need of natural objects, mandatory water releases and unproductive losses in natural hydrographic network as a limitation of productive water use (Figure 5).

Norms of ecological water demand are established via a political decision based on the need of balancing environmental, social and economic objectives of the country. Eventually, established constants can be changed in the direction of both with a tightening and easing the threshold of permissible anthropogenic pressure [2].

The concept of water resources management. In the context of worsening water issues around the globe alter significantly the functionality, principles, priorities and water management mechanisms [3].

The new water paradigm in developed countries, along with "resource management" suggests the "demand management" of water through water conservation and water efficiency policies.

Priorities in the use of water resources vary with the development of society. On the one hand, in developing countries, the main priority is a production. On the other hand, economically developed countries focus on the well being of society and the environment.



a) b)

Figure 5 - Water and environmental threats in Kazakhstan

Implementation of the ecosystem approach means considering nature as an equal partner with the use of water resources. Environmental aspects of the WRM are realized in two directions: respecting the requirements of nature towards water resources and prevention of harmful effects regarding the water.

The basin principle of water resources management (WRM) is a widely used practice in the entire world. Water management and environmental management in general, encompasses embedded into each other basins of different sizes, business entities, authorities and population.

Operational and medium-term water resources management (WRM) for the purposes of ecological improvement is implemented in a scale of small river basins. Strategic planning is developed in a large-scale basins.

Water resources are considered (and managed) in unity with the other components of ecosystems, maintaining integrity of the water ecosystem [4]. From all variety of approaches defining the concept of management, in this study the authors accepted interpretation of water management as a purposeful influence of the subject of management on the object of management to transfer it to the state necessary to achieve the target (Figure 6) [5].

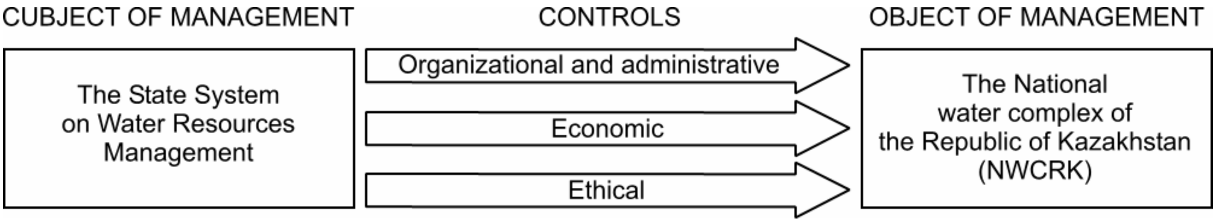


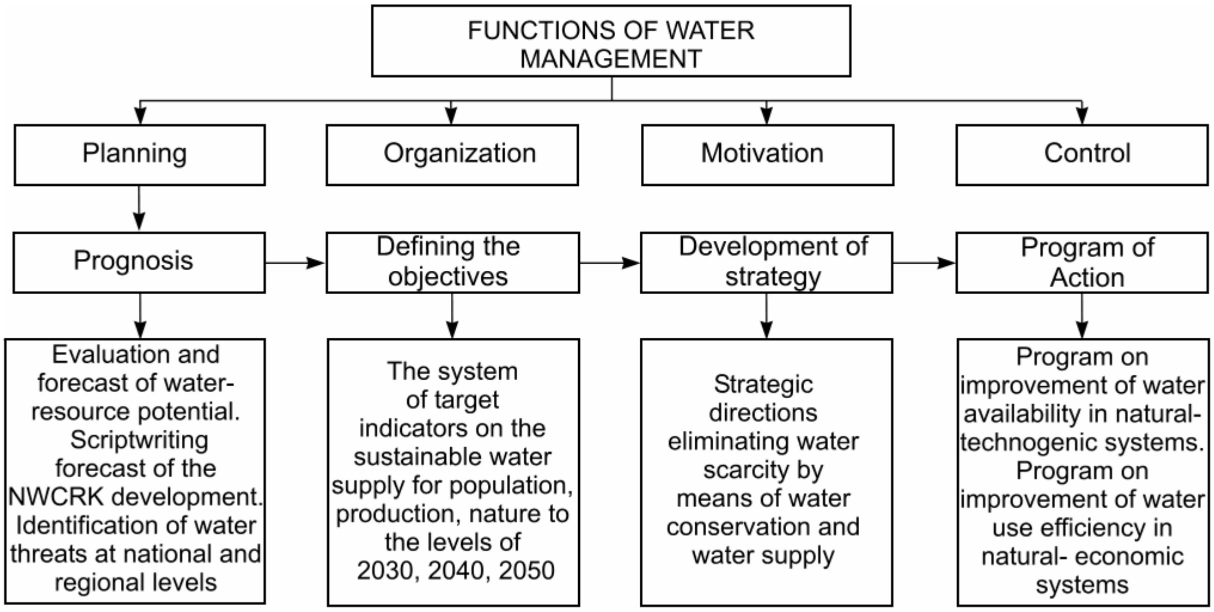
Figure 6 – the concept of water resources management

Subject of the water management is understood as a management structure, divided into levels: intergovernmental, basin and territorial. The power impact of the subject of management is realized in organizational and administrative, economic, moral and ethical levers.

The object of water management is a National water management system with a main focus on the water supply system of the Republic of Kazakhstan as a set of water sources and water users with combining water infrastructure.

In substantive aspect the water resource management consists of a set of functions - specific types of management activity, including planning, organization, promotion and monitoring (Figure 7.). Each management function is performed by a set of actions - management procedures, consisting of specific elements - management operations [5].

Institute of Geography within the framework of scientific and technical programs conducts a research in strategic planning of Kazakhstan’s water supply system with the following basic procedures:



Fugure 7 – Functions of water management

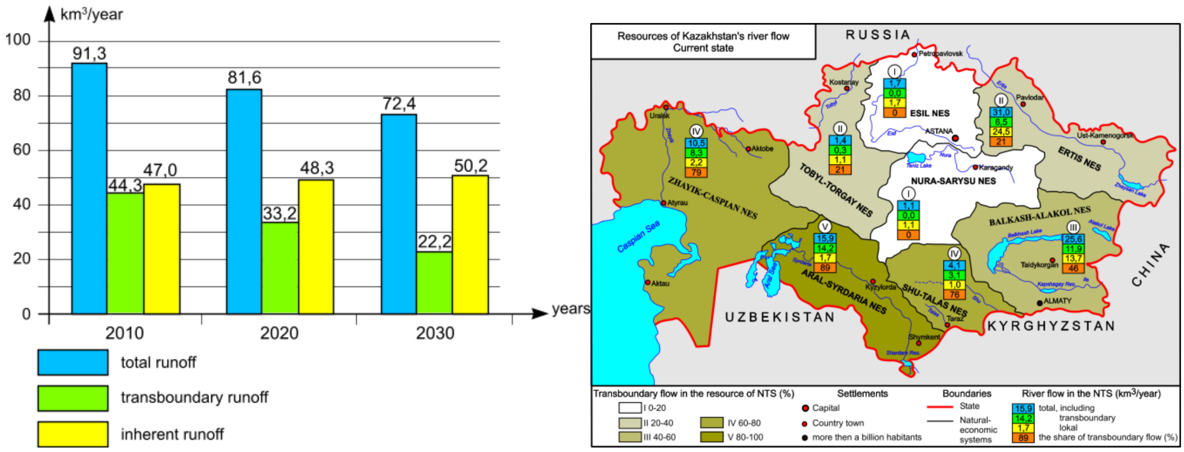
Forecasting includes a researching the prospects of water supply system development, identifying relevant for Kazakhstan's water threats at the global, regional and national levels. Defining the objectives includes justification for the targeted indicators of water supply system development on the estimated levels: political, social, economic, environmental.

Strategy development means to determine the main directions of eliminating a water deficit in Kazakhstan by means of water conservation and water supply. Formation of the plan is a justification for Program of Action by establishing a system of measures and timetables for its implementation.

On specificity of its activities the Institute of Geography under the "Planning" function procedures consider "prediction", "definition of the objectives", "development strategy", "Program of Action".

Forecasting. Resource Forecasting. The total surface water resources of Kazakhstan (domestic waste water during the period of observation 1974-2008 gg.) amount to 91.3 km^3 / year (50% probability). Natural climatic flow (restored) is estimated to 115.1 91.3 km^3 / year [6]. Due to the economic activity the river flow of Kazakhstan decreased by 23.8 km^3 / year (21%), including: transboundary flow - 15.9 km^3 / year (26%), local flow - 7.9 km^3 / year (14%) (Figure 8a.).

The greatest impact of economic activity is evident in the Aral- Syrdarya river basins (47% reduction), the smallest - in the Nura-Sarysu and Ertis rivers (down 8%). Based on the possibility of unfavorable implementation of climatic and transboundary hydrological risks in the long term will inevitably lead to reduction of the river flow in Kazakhstan as a whole in 2020 to 81.6 km^3 / year, including cross-border - up to 33.2, the local - to 48.3 km^3 /year.; 2030 - 72.4, respectively; 22.2 and 50.2 km ^{3} / year (Figure 8a).

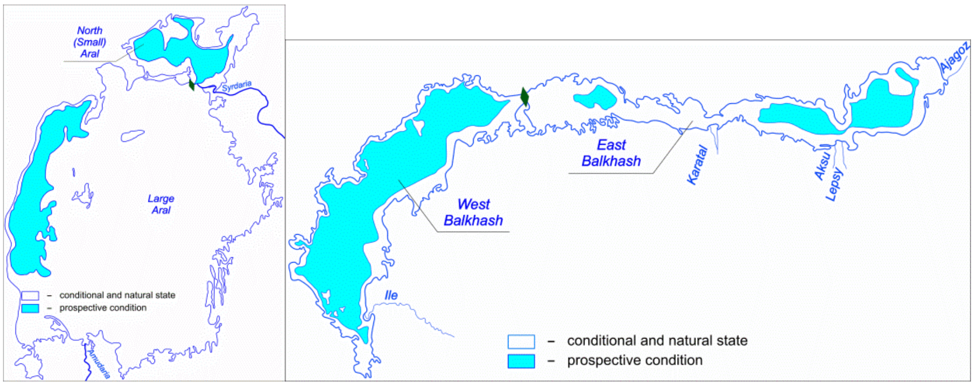


a) b)

Figure 8 - Forecasted scenario of changing in the river flow

The most dependent on the transboundary flow are the Aral-Syrdarya Natural-technogenic system (NTS) (89%), Zhaiyk- Caspian (79%), Shu-Talas (76%). It is assumed that these preconditions should be taken in the framework of Kazakhstan's water security strategy (Figure 8b.).

Due to reduction of the Ile and Syr Darya transboundary river flows on the part of China's territories and Uzbekistan as well, the level of drainless basins the Lake Balkhash and the Small Aral will decrease to the established legal parameters (markers) (Figure 9, Table. 1) [7].



a) b)

Figure 8 - Forecast of the Aral Sea levels (a) and the Lake Balkhash (b)

Table 1 - Current and forecasted status of drainless basins

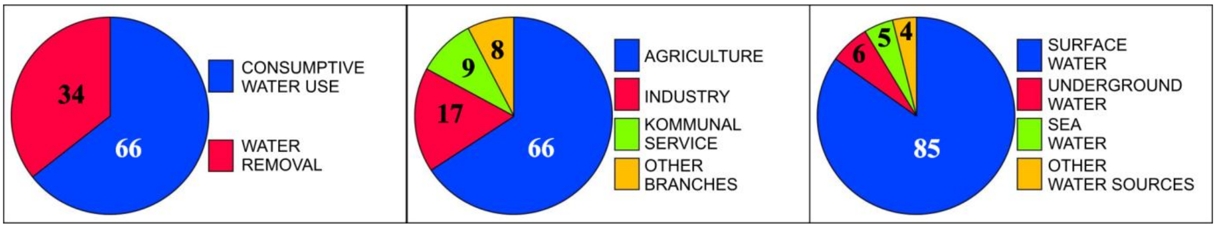
Parameters of reservoir	Unit	The Aral Sea			The Lake Balkhash		
		State of nature	Modified state		State of nature	Modified state	
			Recommended	De facto		Recommended	Expected
River flow	km^3/ year	56,8	40,0	7,6	15,1	12,0	9,0
Benchmark,	m	53,0	43,0	-	342,0	340,0	-
Priority water area		-	-	42,0	-	-	340,0
Residual water area		-	-	30,0	-	-	-
The water surface area,	thousand, km^2	66,0	31,4	8,70	18,21	14,12	10,56
Priority water area		-	-	3,55	-	-	8,44
Residual water area		-	-	5,15	-	-	2,12

Figure 9 - Effect of underground water withdrawal on a surface runoff

The magnitude on reduction of surface runoff during the operation of explored groundwater deposits in a volume of 15.44 km^3 / year will amount 5.05 km^3 / year. The most significant impact on the river flow will have water intakes in a river valleys (a decrease of 2.1 km^3 / year) and river fans (a decrease of 2.2 km^3 / year) (Figure 9). [8]

Forecasting water demand. Expected in the future a rapid growth of production in Kazakhstan is recommended to maximize intensification of water use within the established water withdrawal limits in a volume of 23.3 km^3 / year (consumptive use - 15.3; sanitation - 8.0 km^3 / year), including agriculture - 15.4; industry - 4.0; utilities - 2.2; Other sectors - 1.8 km^3 / year (Fig. 10).

Perspective limits of water intake is planned to be achieved through the surface waters - 19.8 km3 / year (85%); Groundwater - 1.5 (6%); marine waters - 1.1 (5%); other water sources - 0.9 km^3 / year (4%) [8, 9].



a) b) c)

Figure 10 - Forecasted water consumption in economic sectors (%): a) consumptive use and disposal; b) industry; c) water sources

Development of water-intensive production sectors will take place by intensifying the use of water resources. Due to development of groundwater and alternative water sources is planned to decrease proportion of water intake from surface water sources by 10-12% before 2030. Moreover, in terms of implementation of recycling and closed water systems is planned to reduce the share of wastewater industries by 10% before 2030.

Sustainable development of irrigated agriculture in Kazakhstan could be achieved both with a comprehensive reconstruction of irrigation systems (with an increase in efficiency 0.5 to 0.75) and introduction of modern irrigation technology with decreasing irrigation rate from 9250 to 7100 m^3 / ha.

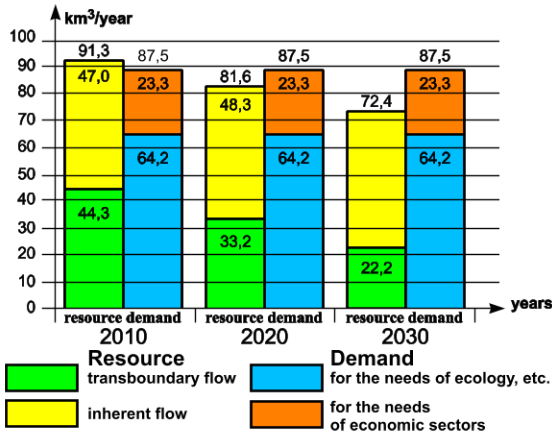


Figure 11 - Dynamics of the river flow and water demand

However, water conservation program does not guarantee a balanced development of the country. Moreover, by reducing a transboundary flow (Fig. 11) Kazakhstan continues to face a shortage of water resources in a volume of 5.9 km^3 / year in 2020 and 15.1 km^3 / year in 2030 in the whole country.

Defining the objectives. The main objective applies to the guaranteed supply of water to population and production, restoration and conservation of natural water bodies to ensure favorable living conditions. Figure 12 implies achieving the following complementary objectives.

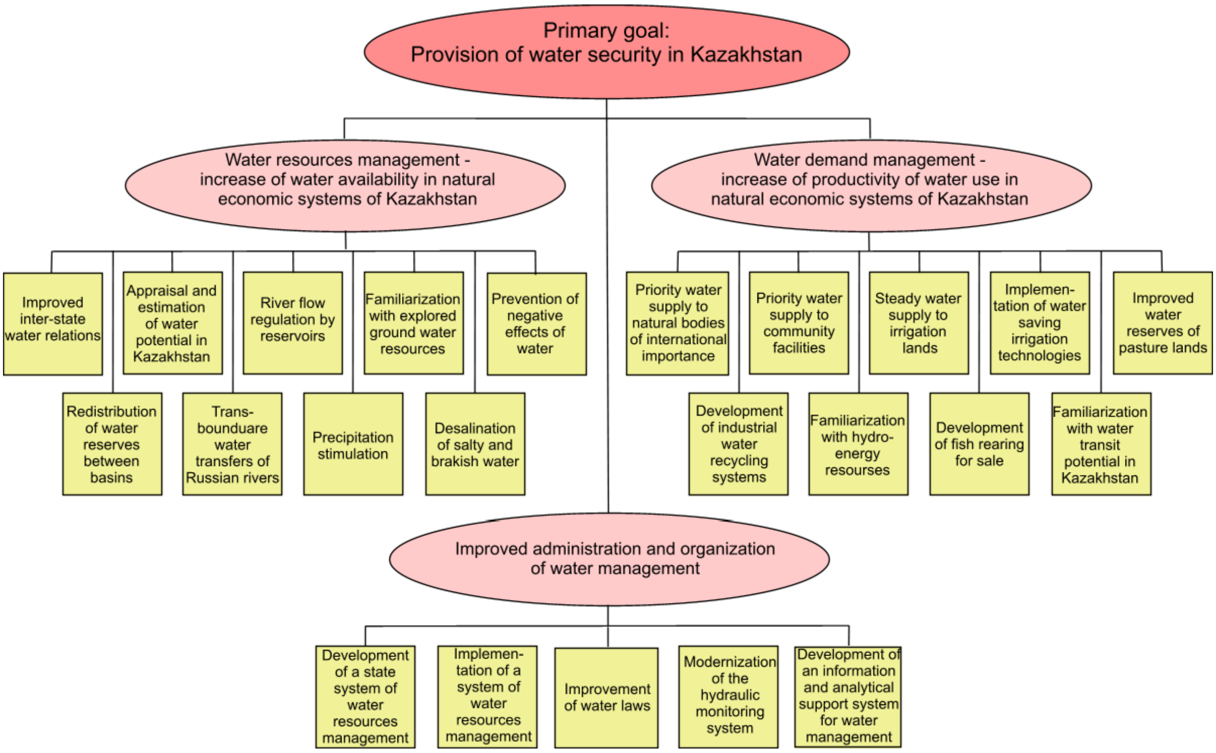


Figure 12 - Defining the objectives

Objective 1. Increasing of water availability in natural- technogenic systems of Kazakhstan (water management).

Objective 2: Increasing the productivity of water used in natural-technogenic systems of Kazakhstan (water demand management).

Objective 3. Improving the state system of water management.

Strategy Development.

Strategic directions to achieve the objectives are:

- "Water supply". Compensation due to anthropogenic and climatic water reduction by improving interstate water relations, reconstruction of the national water infrastructure, development of alternative water sources;
- "Water conservation". Intensification of water use through introduction of water saving technologies in irrigation, development of water recycling in industry, development of hydropower resources and water-transport potential of the country;
- "Improving governance" means improving the efficiency of administrative activity through a creation of information-analytical systems, modernization of monitoring systems, and improvement of water legislation.

The Programof Action. Spatio-temporal redistribution of water resources is a strategic priority for the development of water supply systems in Kazakhstan [10]. Unbiased prerequisite for territorial redistribution of water resources is a pronounced spatial unevenness of distributing the river flow and water demand of the natural- technogenic systems.

The highest volumes of river flow are formed in Ertis natural-technogenic system (up to 33% of total resources and 45% local). The Nur-Sarysu, Esil and Tobol-Torgay natural-technogenic systems are formed by at least 6% of river flow, and in dry year’s local flow less than the average about 10 times (Figure 13).

River flow of the southern and western regions is most vulnerable to uncontrolled anthropogenic changes due to the economic activity in neighboring countries (Russia, China, Uzbekistan, and Kyrgyzstan). At the same time in the region operate the most water-intensive production and large ecologically important water bodies. Taking into account information above, it poses a real threat to formation of deep water shortages in the southern, northern, central and western regions of Kazakhstan, resulting to serious economic losses and unacceptable violations of the environment.

In terms of expected changes in availability of the water resources there is a huge need to form the Unified Water Supply System (UWSS) as a combination of water sources and water user of Kazakhstan with uniting their water infrastructure.

The basis for formation of Kazakhstan's Unified Water Supply System (UWSS) will be the Trans-Kazakhstan Channel (TKC) linking the existing and future inter-basin water management communication with more efficient use of the river flow in order to achieve social, environmental and economic objectives of the country (Figure 14). [11].

Figure 13 - The main directions of interbasin and transboundary water transfer

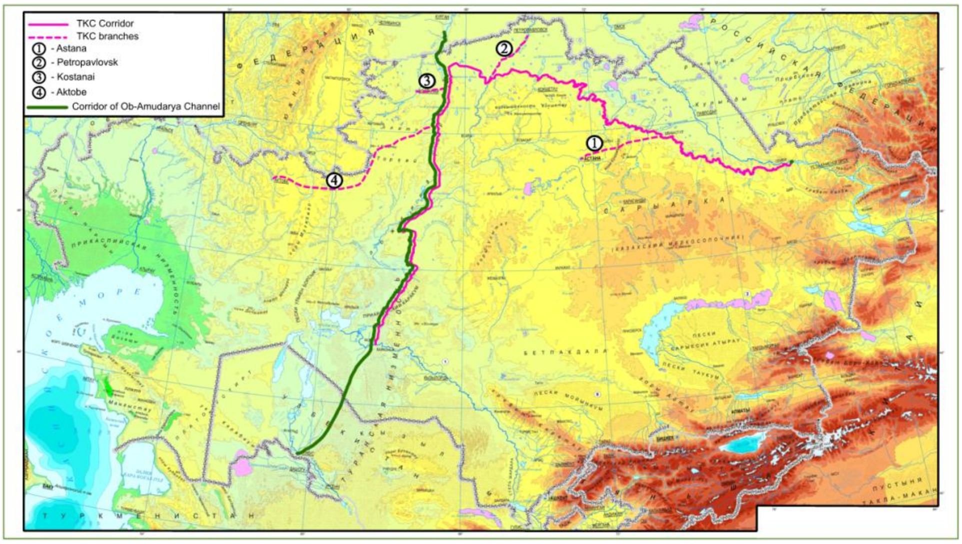


Figure 14 - Trans-Kazakhstan Channel

The Institute of Geography proposed an updated schema on a gravity flow of the Trans-Kazakhstan Channel (TKC) "Ertis - Syrdarya" with an abstraction of the Shulbinsky reservoir (second stage) to improve a water availability of the basins Ishim, river Nura, Tobol, Sirdariya [2]. The advantages of the scheme regarding available alternatives are:

- Lower energy consumption of transporting the Ertis water;

- The ability to use the corridor of the channel on Tobol-Torgay and Aral-Syrdarya areas for the transit of Russian rivers flow to Central Asia;

- The prospect of formation on the basis of the TKC of the Unified Water Supply System (UWSS), bringing together existing and future water-related communications;

- The possibility of using the initial portion of the TKC for immediate construction of " Astana branch" channel;

- The prospect of forming a navigable waterway "Russia - Kazakhstan - Uzbekistan" on the channel "Ob - Amudarya" with respect to the TKC corridor.

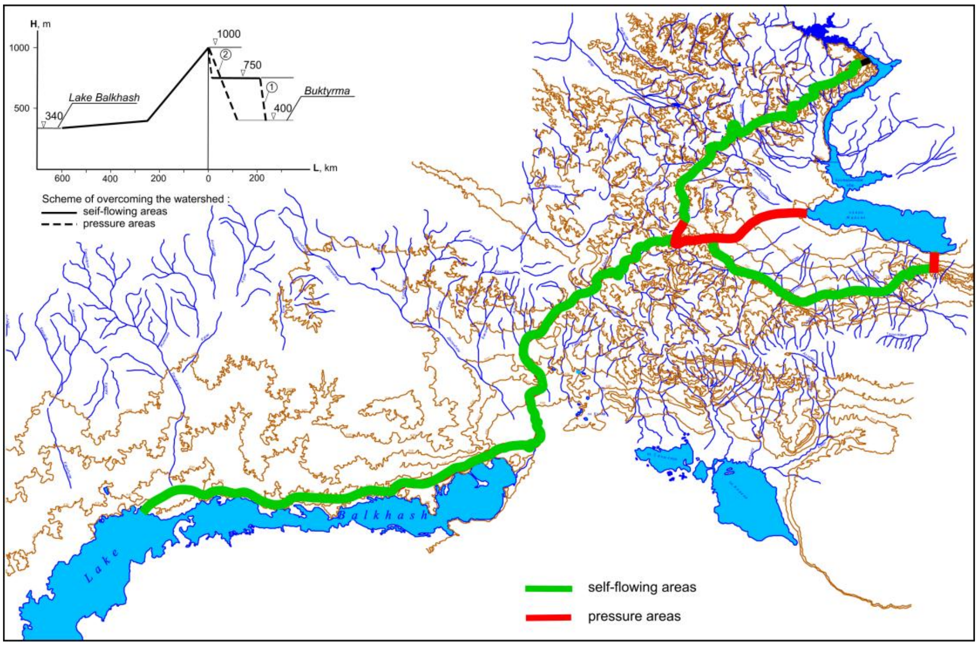


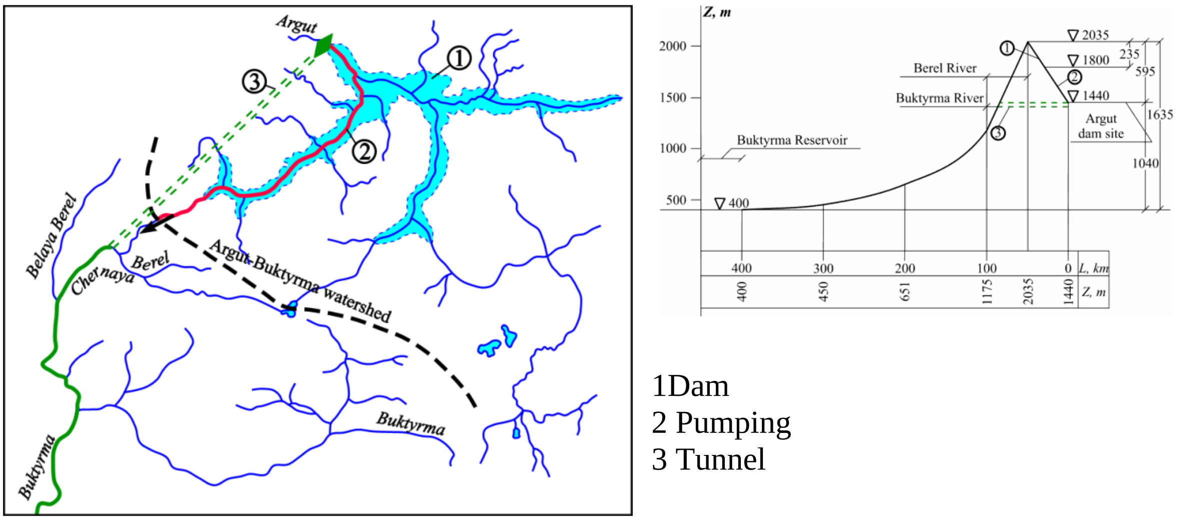
Figure 15 - Water transfer of the Ertis River to the Lake Balkhash

The transfer of the Ertis runoff to the Balkash basin will compensate for a reduction in transboundary flow of the Ile River from the part of China. Subsequently, such a transfer will ensure a preservation of ecological and socio-economic values of the Lake Balkhash being a special object of the national importance (Fig. 17).

In the context of development on the transboundary water cooperation with Russia the study offers an updated scheme of mutually beneficial use of the Russian rivers flow in areas Argut-Buktyrma and Volga-Sirdariya (Fig. 15, 16). [10]

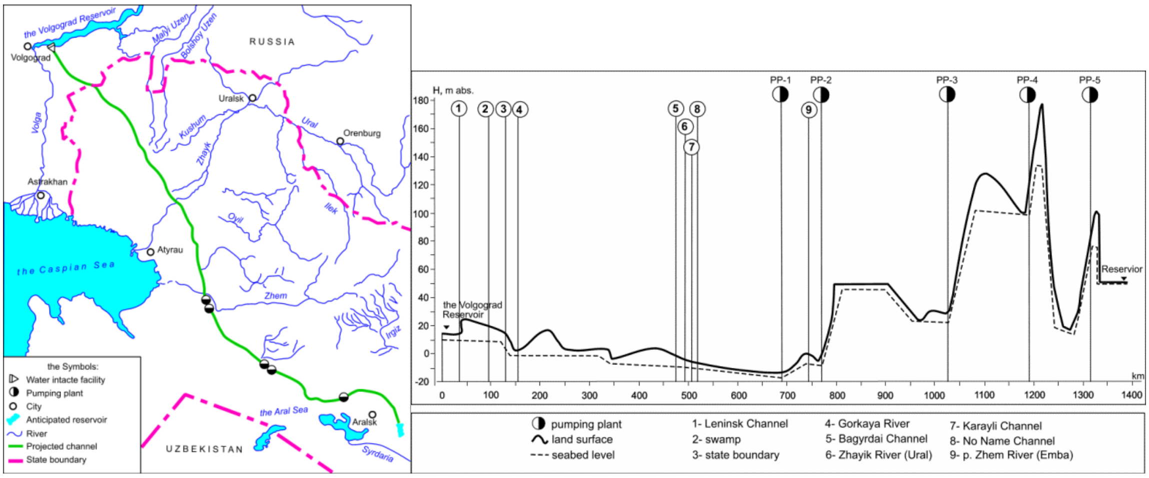
Implementation of strategic activities on the water resources management in Kazakhstan requires a long time: design, construction and putting of facilities take up to 10-15 years. In this regard, this means that the scientific support for strategic actions must begin in advance (about 25 years).

Development and operation of the water supply system Kazakhstan is characterized by properties of complex systems. Regarding, uncertainty caused by the unpredictability of the water-related activities in neighboring countries and the probabilistic nature of hydrometeorological processes and phenomena that determine the amount of water resources available.



a) b)

Figure 16 - Scheme of overcoming the watershed Argut-Buktyrma: a) plan, b) profile



a) b)

Figure 17 - Route of the Volga-Syrdariya Channel: a) plan, b) profile

An effective tool for studying complex systems subject to accidental influences is an imitation modeling. The influence of random factors is taken into account by specifying characteristics of the stochastic processes (the probability distribution laws) [13-15].

Imitating modeling of Water Supply Systems is a method of computational experiments with mathematical models simulating the behavior of real objects in time within a specified period. At the same time functioning of water bodies is described by a set of algorithms that simulate probabilistic nature of river flow and dynamics on water demand of the natural-technogenic systems.

Conclusions. Development of the Concept on water management as a system of constructive principles and functions of management.

Within the framework of function on "strategic planning" are made the test calculations for development of:

- Forecast of water-resource potential and scenario analysis of national water management complex;
- Sustainable water supply System on the basis of population growth forecast and the development of production;

- Strategic directions eliminating the water scarcity of the natural- technogenic systems by means of a water conservation and water supply;

- Program of Action for implementation of Kazakhstan’s Unified Water Supply System.

For the first time was developed an instrument (the first sketch of the model) for the formation of alternative scenarios in strategic planning of water sector development including:

- reconstruction of water infrastructure,
- conservation and restoration of natural water bodies,
- economic justification of water use limits,
- Improving of interstate water allocation (Figure 18).

The inertial scenario assumes implementation of prevailing water use trends in the country as well as the factors determining them. The scenario is fraught with deep deficits of fresh water, severe economic damage and the violation of the natural environment.

The water-saving scenario assumes all possible water saving and stabilization of domestic water consumption that not exclude a possibility of fresh water deficit in the long term.

The innovative scenario assumes an expected reduction in water availability to compensate for transboundary and inter-basin water diversion. The scenario provides a balance of water use at the basins of all of Kazakhstan’s natural-technogenic systems.

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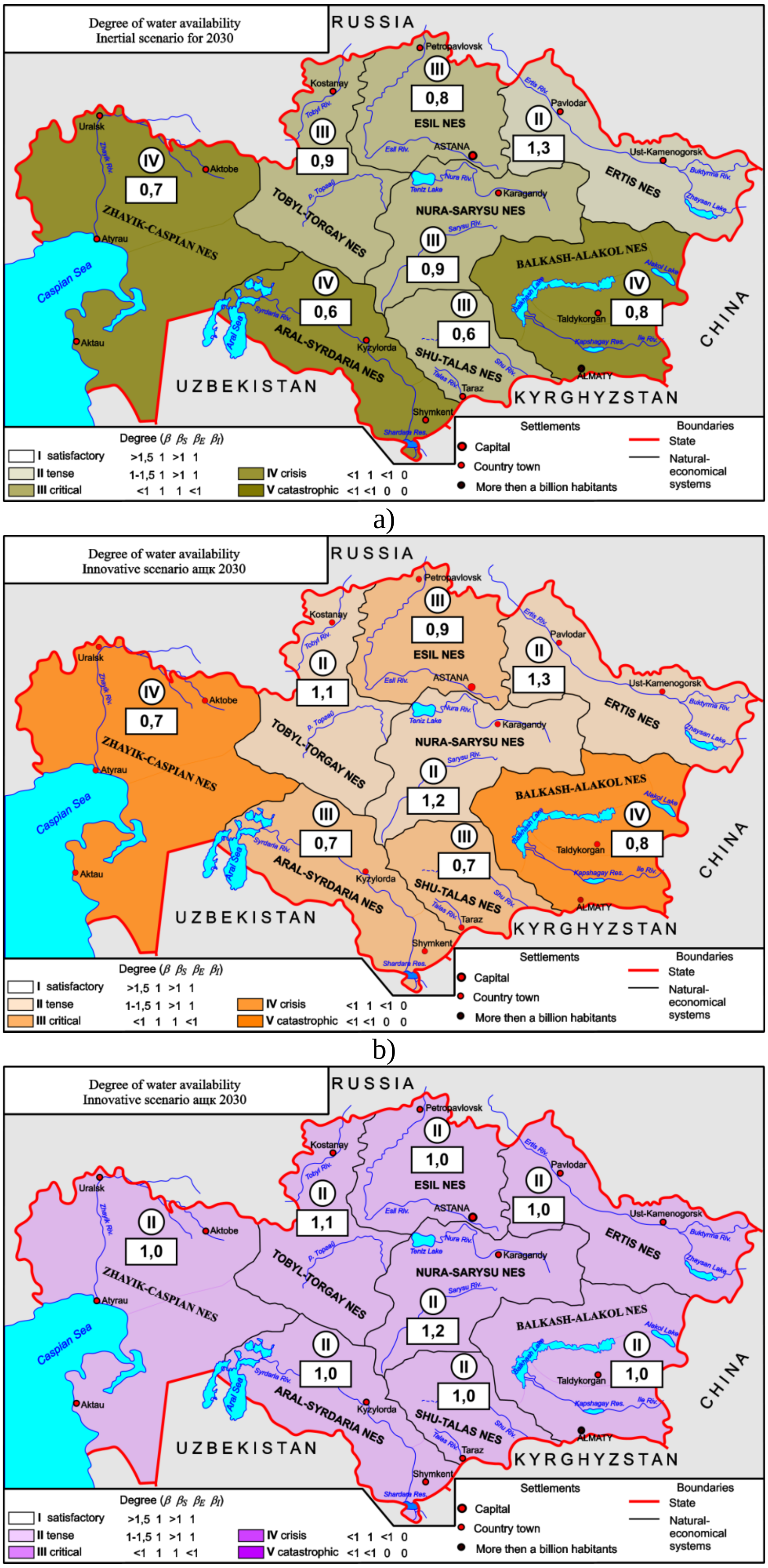

a)

b)

c)

Figure 18 - Scenarios of Kazakhstan’s water supply system:
a) inertial, b) water-saving, c) innovative

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WATER SUPPLY TO AGRICULTURE OF KAZAKHSTAN IN THE CONTEXT OF FOOD SECURITY

Мақалада Қазақстанның азық-түлік қауіпсіздігін анықтайтын екі құрамдас бөлік қарастырылуда, ол ауыл шаруашылығын сумен қамтамасыз ету және халықты азық-түлікпен қамтамасыз ету. Қазақстан аймақтарында ауыл шаруашылығы өндірісінің тұрақты дамуы үшін (суармалы егіншілік пен отарлы-жайылымдық мал шаруашылығы) ауыл шаруашылығын сумен қамтамасыз етуіне талдау жасалынды. Халықтың тіршілік әрекетінің негізі ретінде Қазақстанның оңтүстік аудандарының суармалы егіншілігіне баға берілді.

The article describes two components that determine the food security of Kazakhstan, they are water supply to agriculture and the provision of population with food. The water supply to agriculture of the regions of Kazakhstan is analyzed for sustainable development of agricultural production (irrigated agriculture and distant-pasture livestock breeding). The assessment of irrigated agriculture of the southern regions of Kazakhstan, as the basis of life activity of the population, is made.

Introduction. The main problem in the life of world's population in the XXI century, which requires an immediate solution, is the problem of providing the population with food and sufficient water of good quality. Problems of water supply to agriculture and ensuring food security are related to the most pressing global problems of our time, and they are in the center of the world's attention for several decades. For the first time, the problem of food safety has become a subject of special consideration at the 34th session of the UN General Assembly in 1974. At this United Nations General Assembly, the resolution entitled "International food security commitments in the world" was adopted, in which "Universal Declaration and Action Plan on the elimination of hunger and malnutrition in the world" were approved. The Food and Agriculture Organization of the United Nations (FAO) was responsible for the practical implementation of this document.

Water availability is also recognized as a fundamental human right, and it was recorded in the adopted in July 2010 UN General Assembly Resolution №64/292 on the human right to water. Thus, water security can be defined as the right of everyone to secure access to safe drinking water, and the ability of the population to preserve the ecosystems and save a sufficient amount of water of acceptable quality .

Problems of water supply to agriculture. Global problems of water and food security demand multilateral solutions, a variety of strategic tools and unanimity across borders. However, the severity of the solution to these problems is, finally, the responsibility of the national governments, which must carry out responsible policies within the countries and cooperate with each other. Kazakhstan is aware of the global problem of water supply and the urgency of the political solution to it. Water and food security is an important component of the "Kazakhstan-2050" strategy. Water resources of Kazakhstan are the determining factor in the development of agricultural production (crop production and livestock breeding). The main threats in the field of water supply for agriculture of the country are the global and regional climate changes, lack of coordination of interstate water relations, use of water-intensive technologies and inadequate technical means of water regulation and water allocation. The acuteness of the problem of water supply to the agriculture of Kazakhstan is due to its unfavorable geographical position in the lower reaches of transboundary basins. Almost half of the country's renewable water resources is formed by the uncontrolled transboundary runoff. Potential effects of changes of river runoff resources pose a real threat to the sustainable development of agriculture of the country.

Water supply and food security. Let us consider the surface water resources of Kazakhstan, which are crucial for the development of irrigated agriculture and distant-pastoral livestock breeding, especially in its southern regions (Figure 1).

Figure 1 - River runoff resources in the Republic of Kazakhstan [1]

According to experts of the Institute of Geography of the MES of the RK [2,3], surface water resources of Kazakhstan amount to 91,3 km^3, of which 47,0 km^3 of river runoff are formed on the territory of the country, while the rest comes from neighboring countries. In low-water years, the river runoff is reduced to 55,3 km^3, and the disposable volume is reduced to 30,7 km^3 [2,3] The volume of return water is about 9,0 km^3. Fresh underground water reserves were recorded in the amount of 15,44 km^3. The level of their use is about 11,3% [2,3]. Therefore the agriculture of the country will be developed in conditions of water scarcity in the nearest years, and great dependence of the economy sectors on the water resources of neighboring countries. This situation will cause reduction of cultivated areas and areas of watered pastures, especially in the southern regions of Kazakhstan that will affect the self-provision of the population for a number of staple foods (grains, vegetables, potatoes, milk and meat).

The real pattern of water supply in the Republic of Kazakhstan on the water management complexes is demonstrated in Figure 2, according to which the greatest water scarcity is typical for the Yesil and Nura-Sarysu natural and economic systems [1,4].

Figure 2 – Scheme of water supply in the Republic of Kazakhstan [1]

The low level of water supply to the regions and low culture of agricultural production caused the reduction of water intake for agriculture from 26 km^3 in 1992 to 15,4 km^3 in 2011, and a two times decrease in the area of irrigated land during the same period [1-4]. These circumstances have affected crop areas and total yield of agricultural crops and posed a serious threat to food security of the country. The main user of water resources in Kazakhstan is agriculture, it accounts for about 66% of the total water intake (Figure 3).

Figure 3 - Water consumption by economic sectors in Kazakhstan, % [2]

It is clear that food production is not possible without water, and it cannot be distributed effectively in the interests of large-scale agricultural production without economic intervention, which will ensure its effective and sustainable distribution. Consequently, the price of food in particular, and the economic safety in general, depend on water. Thus, the issues of food security and water availability are inseparably linked to each other, and their relationship should be stable at the different levels of economic development. Water resources are the most important factors contributing to the current changes in the food security of Kazakhstan.

According to the regulations of the UN Food and Agriculture Organization, the country's food security is ensured in the event that about 80% of consumed food is produced in it. Food security is considered to be ensured if there is an additional production in the amount of the renewable safety stock at the level of the developed countries of the world in addition to the production of the necessary amount of food (17%). In the event that certain types of food are not produced in the country or their production is limited, the food security in them is ensured through purchase in other countries. It is important to prevent the occurrence of food, political or other dependence on the exporting countries in terms of deficient food [5,6].

The self-sufficiency of the Republic of Kazakhstan with food is influenced by a number of factors, foremost of which should be considered the following: the rational distribution of agricultural production, taking into account sufficient water supply and creation of specialized food zones on this basis; the use of advanced water-saving technologies for increasing crop yields and livestock productivity.

Table 1 shows the values of indicators characterizing the food security of Kazakhstan, which allow making the following conclusion - there is a problem with food security in the country [5]. It was found that the basis of food security of Kazakhstan is made by agricultural products, manufactured by private part-time farms and peasant farms. Agricultural production in Kazakhstan is small-scale.

Table 1 – Values of indicators of food security in Kazakhstan [6]

Indicators	Norm	Actually for 2013	Deviation from the norm (+,-)
1. The amount of carryover stocks of grain remaining in storage until the next harvest yield, %	not less than 25% of annual consumption (90 days)	27% or 97days	+7 days
2. Production of grain per capita, tons	not less than 1	1,310	+0,310
3. The share of agriculture,% of GDP	not less than 10	10,1	+0,1
4. Import of food products,% of total consumption	not more than 20	+20	0
5. Self-sufficiency in basic foodstuffs,% of physiological needs:			
- milk	not less than 84	82,9	-1,1
- meat in slaughter weight	not less than 84	76,4	-7,6
- eggs	not less than 84	75,8	-8,2
- vegetables and melons	not less than 84	105,9	21,9
- potatoes	not less than 84	180,5	96,5
- horticultural crops	not less than 84	25,9	-58,1

There are 182419 or 96,7% peasant farms out of 188616 agricultural entities of the country. More than 6% of the main crop products and 85% of livestock products are manufactured by private part-time farms accounting for more than 2,2 million units [7]. Most of the agricultural products manufactured in agricultural entities, remains of low quality and uncompetitive due to the inability to use high-quality seed stock, modern agricultural technologies in the conditions of small-scale production. It should be specially noted about the dependence of the development of agricultural production (especially irrigated agriculture) of the southern, western and central regions of the country on water resources of neighboring states.

Grain farming is the main branch of agriculture in Kazakhstan. It provides the population with grain products, and livestock farming-with fodder. Kazakhstan produces a lot of high-quality commodity grain. In recent years, the overall cereal crops occupied more than 80% of the sown area of agricultural crops. The northern regions of the country are specialized in growing cereal crops and meat and milk livestock breeding. The southern regions of Kazakhstan are specialized in irrigated agriculture, have a greater diversification of crops - cereal and legumes, forage, oilseeds and fruit, melons, etc. 14,5-20,1 million tons of grain are produced in Kazakhstan, which gives the right for the country to occupy the third place in the CIS after Russia and Ukraine. Average grain yield is 10-13 q/ha. More than 3/4 of grain crops accounts for crops of spring wheat, the main strategic grain, ensuring food security of the country. The total sown area for wheat is 11,8-13,5 mln. ha. Yields of 9-13 q/ha allows to obtain 11,2-16,6 mln. tons of wheat. In 2007 and 2009, Kazakhstan has received the maximum yield of grain crops (20,1 and 20,8 mln. tons in weight after processing), which allowed to increase the level of the country's self-sufficiency in grain to 130,0 and 130,8%. Dynamics of average yield of grain and leguminous crops in Kazakhstan for the 14 year period is presented in Figure 4 [7].

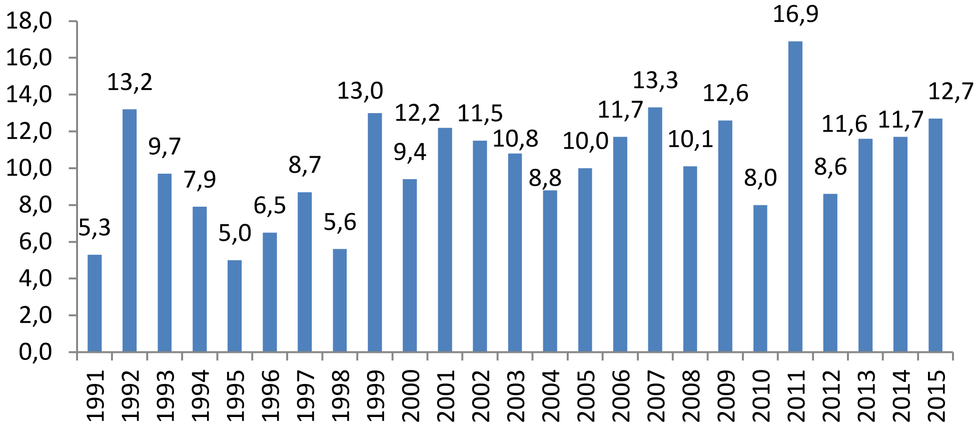

Figure 4 - The dynamics of the average yield of wheat in Kazakhstan, q/ha

Kazakhstan is among the countries where irrigated farming in agricultural production plays a leading role in providing the population with food. The distribution of irrigated lands in the country is uneven. Main irrigated tracts are concentrated in the south and southeast of the country within Almaty (27,5% of the irrigated lands of the country), Kyzylorda (10,5%), Zhambyl (10,9%) and South Kazakhstan (25,0%) regions (Figure 5) [8].

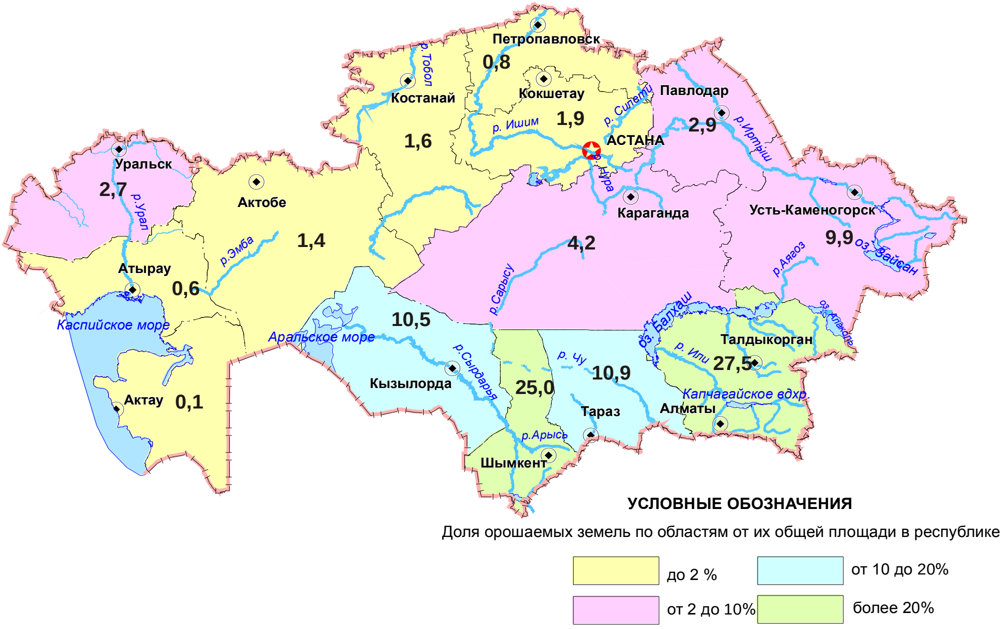

Figure 5 - Distribution of irrigated lands by the regions of the Republic of Kazakhstan, %

Development of irrigated agriculture in Kazakhstan depends largely on the availability of water resources and soil-reclamation conditions. Currently, the volumes of water use for irrigation have surpassed the limits of the permissible level of their withdrawal from irrigation sources. This has led to the degradation of river basins, especially in the lower reaches of the following rivers: Syrdariya, Shu, Talas, Ile, etc. It should be noted that the country received more than 30% of all agricultural products [2] from the irrigated areas, which amounted to 2,5 mln. ha or 9,6% of arable land in 1990, and this created a stable condition for food security in arid regions of the country, where there is no alternative to irrigated agriculture. In 2015, only 1,5 mln. ha were used out of 1,8 mln. ha of irrigated land, and about 1,2 mln. ha were actually watered (Figure 6) [8].

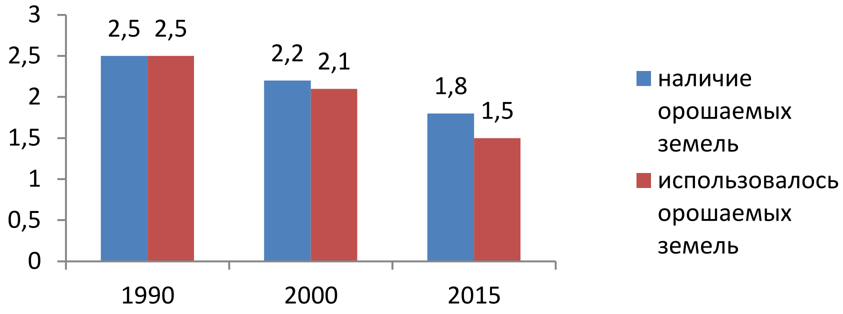

Figure 6 – Dynamics of irrigated lands in Kazakhstan, mln. ha

It was determined that water consumption for irrigation of lands has decreased from 16,8 km^3 in 1992 to 7,0 km^3 in 2014. The condition of irrigated agriculture and land reclamation systems in Kazakhstan has worsened. The economic activity in the irrigated area of Kazakhstan is currently carried out by tens of thousands of peasant farms, several thousands of production cooperatives and other agricultural formations of non-state and state forms of ownership. The extensive way of development of agriculture, the lack of economic incentives for water saving have contributed to unjustified increase in water consumption, deterioration of water quality, its depletion in a number of river basins, leading to unstable yield of agricultural crops, especially wheat, which is one of the strategic cereal crops, ensuring the country's population with food. Despite the scarcity of water resources and the decrease in the areas of irrigated land from 2,5 to 1,8 mln. ha, water discharge in some agricultural regions still remain unjustifiably high. The above-standard loss of water leads to the depletion of water sources, the increase in the share of expenses in the production costs, reducing its competitiveness, as well as contributes to the growth of tariffs for water. For example, about 5 thous. m^3 of water on average is spent for the production of one ton of rice in the world, and in the southern regions of Kazakhstan - 10,4 thousand; water costs in cultivation of one ton of cotton are, respectively, from 3 to 4,3 thous. m^3 of water [4].

According to the results of the research of the Kazakh Research Institute of Water Industry of the MoA of the RK [4], the desert regions of the country have 17,1 km^3 of surface water in the average long-term year (50% probability), 13,34 km^3 in the low-water year (95% probability). Of them, 14,01 bln. m^3 and 10,25 bln. m^3, respectively, may be used for regular irrigation in connection with decreasing volumes of runoffs of transboundary rivers and growth of water consumption by the sectors of the economy; the projected volumes of available runoff for irrigation in regular and low-water years will be reduced to 12,44 bln m^3 and 8,93 bln m^3 by 2020, and by 2030 - to 11,47 bln m^3 and 8,12 bln m^3, respectively [1-4], which may affect the provision of the population of the southern regions of Kazakhstan with agricultural food products.

A series of low-water years is expected in accordance with the long-term forecast data in the Syrdariya river basin, the main river artery of the Southern Kazakhstan. This means that in the next few years, the irrigated lands will be constantly experiencing an acute shortage of irrigation water during the growing season. Consequently, all the measures on the use, restoration and expansion of irrigated lands should be carried out systematically, without increasing the intake limit, taking into account the intergovernmental agreements on the use of water and energy resources of transboundary Syrdariya river, mostly on the basis of the release of water resources by transferring the existing irrigated lands to water saving.

Up to 200 thous. ha of irrigated lands were previously used, currently - only 50-55 thous. ha in the steppe zone (lowland, foothill and mountain areas of East Kazakhstan). As a result, this region receives ¾ of agricultural products less than it was grown on irrigated lands previously.

330 thous. ha of irrigated lands were used and 88,5 thous. ha are used currently in the steppe, dry steppe and semi-desert zones of Kazakhstan, covering the northern, central and western regions of the country. Due to the solving of the problem of water supply, vegetable and potato-growing agriculture and the production of meat and milk can be effectively developed on the irrigated lands in these regions of Kazakhstan on the basis of the recovery of the previously functioning irrigation systems.

It should be particularly noted that the sustainable development of irrigated agriculture of Kazakhstan can be achieved through a comprehensive reconstruction of irrigation systems (with an increase in coefficient of efficiency from 0,5 to 0,75) and the introduction of modern irrigation technology with decreasing irrigation rate from 9250 to 7100 m^3/ha (Figure 7) [4].

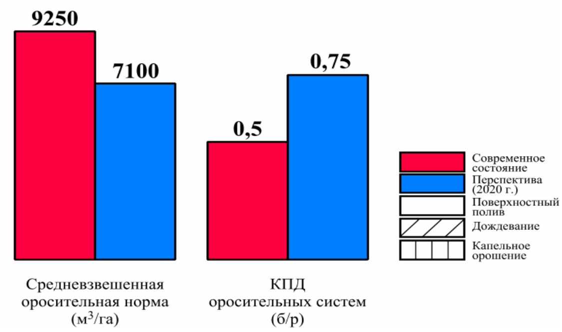

Figure 7 – Coefficient of efficiency of irrigation systems in Kazakhstan

Another branch of agriculture, which plays an important role in providing the population with food, is livestock breeding. Livestock breeding in Kazakhstan holds about 43% of the gross agricultural output. Development of livestock breeding is one of the major strategic economic problems of Kazakhstan. This sector of agriculture is the main source of employment, food and income for the rural population.

Currently, the number of livestock requiring pasture grazing is the following: sheep and goats – 18015,5 thousand head, cattle – 6183,9 thousand head, horses – 2070,3 thousand head. Dynamics of the number of sheep and goats, giving about 60% of meat produced in Kazakhstan, is presented in Figure 8 [7].

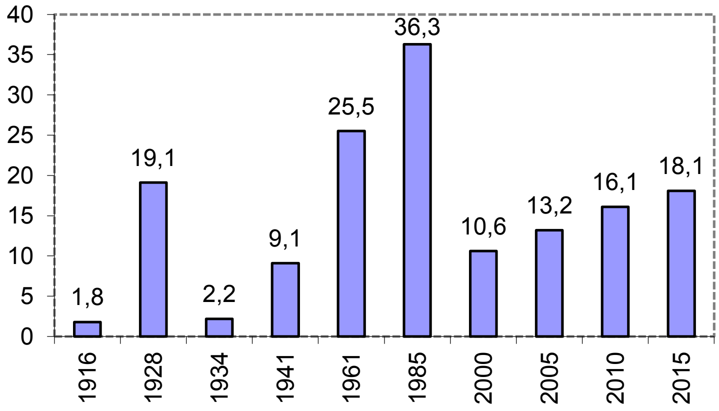

Figure 8 - Dynamics of the number of sheep and goats in Kazakhstan, mln cond. head (in terms of sheep)

It was recorded that the largest number of livestock in the country was in 1985 – 36,3 thous. cond. head. The sharp decline in the number of livestock was observed from 1987 to 2000. Currently, there is a tendency of increase in livestock number. However, since 1992, the country has turned from self-sufficient into importing country for meat and eggs [5,6]. Dynamics of meat produced in the country is shown in Figure 9 [7].

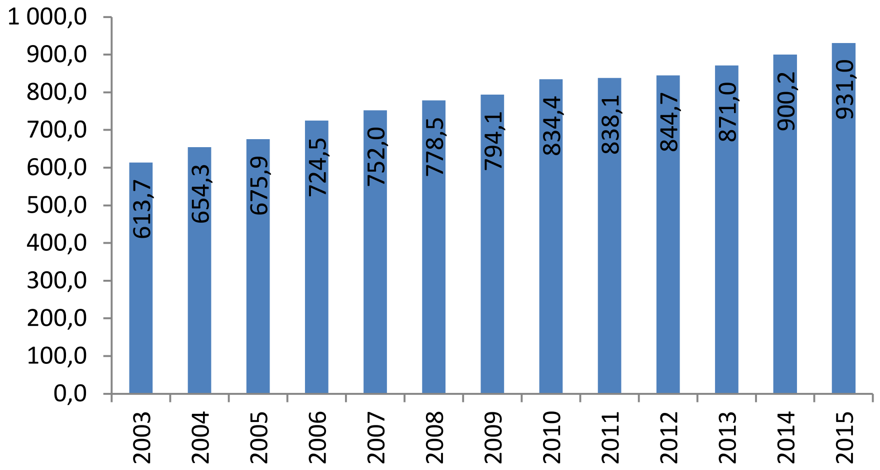

Figure 9 - Dynamics of meat production (slaughter weight) in Kazakhstan, thous. tons

Availability of watered pastures in Kazakhstan plays a crucial role in the development of distant-pastoral livestock breeding, providing the country with important food products - meat and milk. There are 105,5 mln ha (56.5% of all pasture area) of watered pastures (from surface and underground water) in the country. Dynamics of the areas of watered pastures is shown in Figure 10 [8]. In Kazakhstan, as in the country with an arid climate, watering of pastures is carried out in two ways - from open sources (streams, springs, rivers, etc.) and from groundwater delivered to the surface by engineering structures.

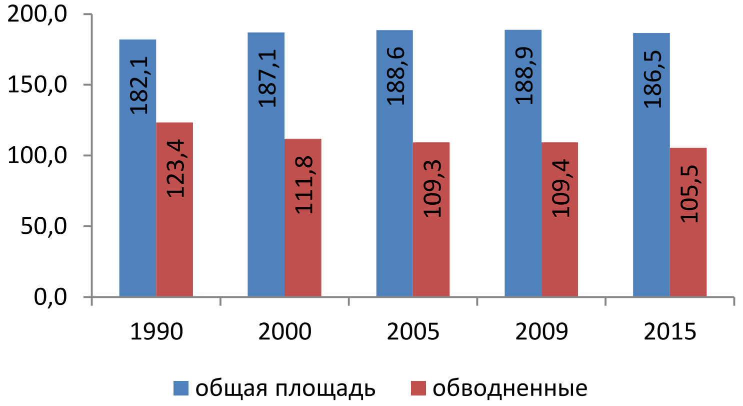

Figure 10 – Areas of watered pastures in the territory of Kazakhstan, thous. ha

According to the data of the Kazakh Research Institute of Water Resources, the natural water sources of the country can enable the use of only 30-32 mln. ha of pastures (1/5 of the entire pasture area) [4]. Usually, water sources are close to the villages and auls, which exacerbate the condition of the near-aul pastures. Almost the total number of farm animals in the country is on pastures with the area of 30-32 mln. ha. Consequently, there is global overgrazing and degradation of pasture areas, which affects the livestock productivity (meat and milk). Currently, there are open watering places for livestock in pasture areas, but due to their remoteness, grazing of livestock there is stopped. These water sources can be used in mobile livestock breeding, during the development of seasonal pastures, in the spring-summer-autumn period. It should be particularly noted that the engineering structures used in the 1970-1990-ies (more than 60 thousand of mine and tube wells), are out of order. Tube wells, for the most part, cannot be recovered.

Our studies in the framework of grant funding on the project: "Landscape-ecological foundations of food security" in 2012-2014 has shown that the science-based territorial organization of agricultural production (crop production and livestock breeding) in Kazakhstan should be carried out based on the analysis and taking into account both component-wise landscape conditions, and water supply to the territory. The study found that in the total area of irrigated lands in the country, the southern area (consisting of four administrative regions) account for about 86-93% of irrigated lands used, where 30-35% of cultivated agricultural crops is concentrated. Every year, large areas of irrigated land, from 20 to 30%, remain unused for various reasons in the zone of irrigated agriculture, which affect the gross volumes of crop production - rice, potatoes, fodder crops. Coefficient of efficiency of irrigation systems in the country is 0,5-0,6 on average, which means that about 40-50% of the water in the irrigation systems is lost, resulting in deterioration of land-reclamation state of land, which affects the decrease of gross harvest of agricultural crops.

Conclusions. Water supply in agriculture of Kazakhstan is an important issue, on the solution of which depends the food security of the country. Ensuring sustainable use of water in agricultural production should be the main trend determining water management policy of Kazakhstan. The main objectives of ensuring food security and water supply to agriculture of the country in the nearest years should be the following: technical re-equipment and complex reconstruction of irrigation systems; reconstruction of watering plants in pastures; systematic reproduction of fertility of soils in irrigated areas and the introduction of biologizing farming systems.

The ensuring of water and food security in Kazakhstan requires an integrated approach combining sustainable water use and agricultural production based on the principles of integrated water resources management (IWRM). IWRM is a holistic approach that promotes sustainability by taking into account the quality and quantity of surface and underground waters, interactions between water resources, environment and land resources, as well as the relationship with the social and economic development.

Food security is a subsystem of the national security, it directly depends on agricultural production (crop and livestock production), which ensures the needs of the population in basic foodstuffs. In turn, the development of agricultural industries in Kazakhstan depends on the availability of water resources, which determine the agricultural orientation of farms. The development of rice, melon, potato growing and other agricultural sectors, requiring irrigated land, depends on the availability of irrigated areas, especially in the southern regions of Kazakhstan. The development of distant-pastoral livestock breeding, providing the population with the main products - milk and meat, is out of question without availability and reconstruction of watered pastures.

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PROBLEMS OF FORMATION AND USE OF WATER RESOURCES OF TAJIKISTAN

The issues of the formation of water resources and their use in Tajikistan are considered in the article. Particular importance is given to the issues of apportioning of water in Central Asian countries and the problem of equitable redistribution of water as the most valuable economic resource.

Tajikistan located in the most elevated part of the Amu Darya basin is a country, in which the highest mountain ranges, starting from Turkestan in the north and including the Wakhan in the south, stretching in the latitudinal direction, and ridges of the Academy of Sciences and Sarykol, extended in the meridional direction, have an average height of 5-5,5 thous. m with some peaks elevating to the levels of 6-7 thous. m.

Therefore, the catchment area of the Amu Darya basin, in spite of its southern position and highly positioned snow line, is characterized by an exceptionally large spread of glaciers and eternal snows. The territory of Tajikistan accounts for about 50% of the area of the glaciers of entire Central Asia.

The area occupied by glaciers in Central Asia is 8,5 times larger than the glaciers of the Great Caucasus and 28 times – than the glaciers in the Altai Mountains [1].

B In total, there are nearly 10,0 thousand glaciers with a total area of about 8500 sq. km in the territory of Tajikistan. The glaciers with an area of up to 1 sq. km account for 80% and with an area of more than 1 sq. km - about 20% of their total number, but the main area of glaciation is made up by the glaciers larger than 1 sq. km – up to 85%; and the small glaciers, despite the large number of them - only 15%. The glaciers which have dimensions of 2-6 km are the mostly spread along the length - about 60% of their total number.

As for the river basins, the largest number of glaciers and the largest area of glaciation are in the Amu Darya basin –82 % and 84 %, respectively; the glaciation of the Zeravshan river basin, the basins of Karakul lake and Markansu river is considerably less.

Table 1 below shows the distribution of glaciation in the basins of individual rivers.

Table 1 – Distribution of glaciation by river basins of Tajikistan

River basin	Number of glaciers:		Area of glaciation:	
	number	%	sq.km.	%
Kafirnigan	380	4,0	85	0,3
Zeravshan	1225	14,0	575	7
Vakhsh	2595	26,0	3150	57
Pyanj	4700	50,0	2960	29
Karakul lake and Markansu river	575	6,0	555	7
TOTAL:	9475	100	7325	100

The largest area of current glaciation in the region is Pamir, the area of glaciation of which is almost 7900 sq km, which is 3,5 times larger than the glaciation of the entire Caucasus. With the same height of the snow line – 4,4-4,5 km above sea level, the area of glaciation of the Western Pamir (6400 sq km) is four times larger than of the glaciation of the Eastern Pamir, which confirms the very low moistening of the latter.

There are 16 glaciers in the Pamir stretching over 15 km and 7 glaciers with a length of over 20 km. The largest glacier - one of the largest valley glaciers on the globe - Fedchenko glacier has a length of about 77 km and its area is 907 sq km.

High mountainous, sharply broken relief, as a factor of climatic-hydrological processes and, first of all, powerful capacitor of moisture causes the development of a dense hydrographic network on the territory of Tajikistan. There are 947 rivers here with a length of over 10 km, of which 4 have a length of more than 500 km, 16 - length of 100-500 km, and more than 10 thousand small rivers have a length of less than 10 km.

All rivers in Tajikistan belong to the two major river systems: Syr Darya and Amu Darya. The basin of not reaching it Zeravshan river relates also to the system of Amu Darya.

The largest rivers of Tajikistan for their absolute water content are the rivers Vakhsh, Zeravshan, Kafirnigan and, of course, Pyanj, the waters of which within the flow in the border area of Afghanistan-Tajikistan belong to the territory of both states. Specific water content of the rivers of Tajikistan, as it was already emphasized, is determined by the orographic and altitudinal position of catchment areas and varies widely. The most specific water content is characteristic for the streams, the area of feeding of which is located on the southern slopes of Hissar, Zeravshan and eastern part of the Turkestan ridges.

Table 2 shows the average annual runoff of the largest rivers in the territory of Tajikistan.

Table 2 – Water resources of the largest rivers (km^3)

River basin	Average long-term volume of annual runoff	incl. formed within Tajikistan	Catchment area	Volume used	Losses
Pyanj	33,4	17,1	1,97	1,5	0,47
Vakhsh	20,2	18,3	4,6	3,5	1,1
Kafirnigan	5,1	5,1	2,5	1,95	0,55
Karatag	1,0	1,0	0,64	0,38	0,26
Zeravshan	5,3	5,1	0,43	0,4	0,03
Syr Darya	15	0,8	2,96	2,6	0,36

According to the data of the Tadjikistan's State Institute for Water Management Design, the total runoff flowing through the territory of the country is 65,1 cubic km, 64,0 cubic km of this volume is formed within Tajikistan, including that in the basins of the rivers of Amu Darya – 50,5 cubic km, Syr Darya – 0,8 cubic km. The main runoff is formed by the rivers of Pyanj, Vakhsh, Kafirnigan and Zeravshan.

In total, there are 1449 lakes in Tajikistan with a total surface area of 716 sq km. (0,5% of the country's territory) and the total water volume of 46,5 cubic meters. Most of them have an area of not more than 1 km^2. 78% of the lakes are located in mountainous areas at an altitude of 3500-5000 m.

In recent years, a broad international fame was gained by Sarez lake formed in a narrow mountain depression after the great landslide caused by the earthquake with a magnitude of nine in the Murgab valley in February 1911. In October 1997, Dushanbe hosted an international conference on the problems of Sarez with the participation of scientists from countries of the near and far abroad, where it was recognized that the possible impact of the catastrophic draining of the lake can be attributed to environmental problems of the World Community. The proposals on the use of Sarez lake as a recreational zone, i.e. the area for recreation, tourism, hunting, are the most promising. But, above all, the problem of safety of the lake should be solved, and this task is extremely difficult both economically and technically and almost insoluble without the help of other Central Asian states.

Hydro-power engineering and, above all, the use of huge hydro resources was the main trend in the use of the water resources of Tajikistan till 90-ies.

Total potential hydropower resources of the country are estimated at 527 billion KWh, and in the specific context it is 2100 thousand kWh per 1sq km of the territory.

Nurek hydropower plant on Vakhsh river with an installed capacity of 2,7 mln. kWh is the largest hydropower project in Tajikistan. Earlier in the 60-80-ies, the perspective plans suggested building a cascade of eight hydro power plants on Vakhsh river with a total installed capacity of 8 mln. kW, and a cascade of eight hydro power plants with a total installed capacity of 16,6 mln. kW on Pyanj river from Khorog to the mouth. It was supposed to bring the total capacity of the cascades of major hydro power plants of the complex power-irrigation purpose to 550-600 mln. kW in total.

The rational use of water reservoirs in the conditions of Tajikistan will allow the improving of cost recovery and meeting socio-economic demands of today. The total volume of the 11 operating reservoirs of the country is currently 15,68 cubic km, the useful - 7,605 cubic km, and the total surface area of reservoirs is 706,7 sq km.

The operating reservoirs work on the irrigation mode in the period of intensive irrigation, regulating the natural hydrological regime of rivers.

The main drawback in the process of the operation of the reservoirs of our country is an intensive silting of rims of the reservoirs, 2-3 times exceeding and advancing the project scopes and timelines due to increased turbidity of rivers, large amount of suspended matters in the stream of flowing water, etc.

Now I would like to draw attention to the problem of the use of water resources in Central Asia.

The problems of apportioning of water moved from the category of intra-state and inter-economic ones to the interstate economic and political problems with the collapse of the Soviet Union and the formation of independent states on the territory of Central Asia. It should be added that the demographic growth, the increasing anthropogenic pressure on the natural environment, the activation of the processes of desertification, global warming and the general aridization of the region give special urgency to the problem of equitable redistribution of water as the most valuable economic resource.

According to experts' opinion, as a result of climate change, water resources of the northern plain part of the Central Asia in the first half of the XXI century will be reduced from 6% to 10% until 2030, and until 2050 – by 4-8%. In the mountain regions, the runoff will vary within the natural variability up to 2030, and the decrease of runoff by 7-17% is possible by 2050 [2]. In the future, as the water reserves in glaciers will be reduced and the losses in the freed from ice surfaces of river basins will be increased, water inflow in rivers will shrink due to the degradation of mountain glaciers. As a result of almost complete degradation of mountain glaciers expected in the last decades of the XXI century, water resources of mountain areas will be reduced by 10-12 % [2].

Although in the second half of the XX century already some scientists have raised the alarm about the degradation of glaciers in mountainous regions of Central Asia, the main attention at that time was focused on the development of new lands. The specialization of each region in the conditions of the planned economic system was mainly taken into account in the distribution of water resources among the countries.

Despite the fact that Tajikistan is rich in water, its consumption here is relatively low: only 18% of the total runoff formed in the country and only 11,3% of the volume of the runoff of the Aral Sea basin are consumed here.

General and specific indicators of water security of the states in the region are based on the volume of their own water resources formed directly on the territory of these states and the average annual runoff of the rivers of the Aral sea basin, constituting 115,6 km^3/year, including in Amu Darya river- 78,5 km^3/year, Syr Darya river - 37,1 km^3/year.

Table 3 – The own runoff of the rivers of the Aral Sea basin, formed on the territory of the states of the region (km^3 /year) [3]

State	Total for the Aral Sea basin		Amu Darya river basin	Syr Darya river basin
	km^3/year	%	km^3/year	km^3/year
Afghanistan	13,0	11,2	13,0	0
Kazakhstan	4,5	3,9	0	4,5
Kyrgyzstan	29,3	25,3	2,3	27,0
Tajikistan	56,2	48,7	55,7	0,5
Turkmenistan	2,8	2,4	2,8	0
Uzbekistan	9,8	8,5	4,7	5,1
Total	115,6	100	78,5	37,1

The data in Table 3 show that most supplied in water states in the region are Tajikistan and Kyrgyzstan, in the territory of which the main volume of annually renewable water resources of the Aral Sea basin is formed: 48,7% and 25,3%, respectively, while 71,0% of the runoff of Amu Darya river is formed in Tajikistan, and 75,4% of the runoff of Syr Darya river - in Kyrgyzstan.

It is necessary to note that, despite the very high rates (the 1st place in the region and the 2nd place in the CIS after Russia), Tajikistan is experiencing a rather serious problems with water security associated with the extremely uneven distribution of river runoff, both over the territory and by seasons of the year. The most acute water scarcity falls on the northern and southern regions of the country, where the main irrigated areas and the bulk of agricultural production are concentrated. The situation is aggravated by the fact that sometimes rich enough groundwater reserves are very little used here due to pollution, increased salinity and unfit for irrigation and domestic water use. Water scarcity in the countries of the lower course of Amu Darya and Syr Darya rivers is associated with the lack of the own water resources, while the problems of accumulation and transport of runoff in areas with scarce water resources in Tajikistan (and Kyrgyzstan) are limited by only technical and economic difficulties. During the period of the unified state planning and economic system, the issue of water resources distribution between the countries of the region was solved by the Protocols of the Ministry for Water Management of the USSR on the principle of "allocation of limits of water intake" from the rivers in certain amounts of the total river runoff, with preference given to major cotton producers. As a result, Tajikistan and Kyrgyzstan "received" only 25% of the volume of their own runoff, and Kazakhstan, Uzbekistan and Turkmenistan 3,5; 5 and 12 times, respectively, more than the volume of their own water resources.

Such water distribution hampered the introduction of new irrigated areas and the development of agriculture in Tajikistan and Kyrgyzstan, but this was compensated by a variety of supplies and joint construction of large cascades of hydro complexes at Vakhsh and Naryn rivers.

But after the collapse of the Soviet Union, when all the states of the region gained independence and secured the right to monopoly on their own natural resources in their constitutional acts, and water resources have acquired the status of the most valuable economic commodity in the arid conditions of Central Asia, the politically and economically outdated scheme of limiting of apportioning of water continues to operate , but, of course, without the participation in the costs associated with the formation of water resources. All costs connected with the protection of the landscape of catchment areas, prevention of gully formation, reinforcing the river banks, water-related natural disasters, operating costs on seasonal, monthly and expeditious runoff regulation by the Kairakkum and Nurek reservoirs and many others are covered independently by the countries of the runoff formation zone.

Frankly speaking, Kazakhstan, Kyrgyzstan, Tajikistan and Uzbekistan have concluded a framework agreement on the joint use of water-energy resources of the Syr Darya river basin (1998), which was to regulate the exchange of energy sources in the autumn -winter and spring-summer seasons and compensatory measures. Однако, это соглашение почти не работает. However, this agreement hardly works. The supply of electric power from Uzbekistan to northern areas of Tajikistan also cannot be called compensation, as Tajikistan returns 1,5-2 times more electricity per one kWh of electricity back to Uzbekistan in summer.

Levers, through which an unfair water distribution system is managed to maintain, are known enough. The states experiencing an acute shortage of water resources, but with the rich oil and gas reserves, taking advantage of a deficit of hydrocarbon energy resources in Tajikistan and Kyrgyzstan and applying various methods of political and economic influence, force them to engage in the exploitation of their own water resources in the regimes favorable for irrigation needs of their downstream neighbors to the detriment of the own private economic interests.

Population growth and the environmental situation in the neighboring regions of Central Asia in the coming decades will lead to a hard shortage of drinking water.

One of the important tasks of solving environmental and food security in the region is the construction of large hydroelectric power plants.

After all, the construction of large hydroelectric power stations with reservoirs, on the one hand, means multiplying the real energy potential of the region, which is characterized by its high economic, social and environmental effectiveness, and, on the other, increases the level of controllability, especially in terms of safety and to avoid natural disasters, hence the management of water resources in the river basins.

The development of unused energy resources of Vakhsh river and start of construction of the cascade of the Pyanj HPPs could become a qualitatively new stage of mutually beneficial cooperation between the Russian Federation, Kazakhstan and other Central Asian countries on energy.

Unfortunately, currently the concept of regulating the water runoff in the region is approached unilaterally. After all, the runoff regulation means also the implementation of measures for the efficient use of water in the land tracts along the entire river basins. In the downstream countries, there is a huge over-discharge of water. In Uzbekistan only, there is an over-discharge of irrigation water in the volume of 7-8 km^3 every year. This explains the emergence of large toxic, environmentally unhealthy lakes such as Arsanai (40 km^3) and Sari-Kamysh (over 30 km^3). If the waters of these lakes are transferred to the Aral Sea, over 70% of the surface of the sea would be completely recovered.

The construction of large hydroelectric power plants and reservoirs in the region, on the contrary, would eliminate water scarcity in the lower reaches, provided there is careful use of irrigation water there. And during the construction of the Rogun HPP and reservoir, only 5% of the water of the Vakhsh River runoff is taken annually during the entire period of the filling of the reservoir.

There is no doubt that all of the Central Asian and South Asian countries are deeply interested in more full use of the energy potential to meet the demands of millions of people in these regions.

But the obstacles of some countries lie in the fact that they consider Tajikistan as a serious competitor in the electricity market in South Asia. This is exactly the one of the causes of violent struggle against the construction of the Rogun HPP.

In the future, to our opinion, Kazakhstan and other Central Asian countries, together with Russia, could solve the region's water and energy problems on the basis of integration, and the use of hydroelectric power will result in a marked reduction in the use of coal, oil and wood, reducing huge carbon dioxide emissions into the atmosphere.

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NUMERICAL SIMULATION OF WATER AND THERMAL REGIMES IN LAKE-RIVER SYSTEMS UNDER THE INFLUENCE OF WATER MANAJEMENT

Mathematical models (1D, 2D – longitudinal-vertical and its combined 2D+1D) and numerical methods for the research unsteady processes in the water bodies under the influence of water management actions are used.

The analysis and comparison of the calculation results is showed

- *economical and effective using of the developed mathematical model for the study of wave processes in water objects.*
- *by studies of physical processes at complex structures' water systems, contained the waterways with very different morphology and geometrical sizes, the use of only one model is inexpediently, often not economy. For such water systems the use of complex of mathematical models with different dimension is more preferably*

Используются (1D, 2D- продольно-вертикальная и их комбинация 2D+1D) математические модели для исследования неустановившихся процессов в водных объектах, находящихся под влиянием водохозяйственных мероприятий.

Анализ и сравнение результатов расчетов показал:

- *экономичность и эффективность использование разработанных математических моделей для исследования гидрологических процессов в водных объектах.*
- *изучение физических процессов, происходящих в сложных водных объектах, имеющих в своем составе сильно разные по масштабам составляющие, с помощью какой-либо одной (по размерности) избранной математической модели не экономично и не эффективно с точки зрения затрат машинного времени.*

During the latest decades the intensification of the impact of the man's factor on nature water objects, increasing scale of this factor is supervised (superintended). It concerned the hydroelectric development, the water-supply of settlements, especially the plough-land's irrigation and water abstraction for industrial, national- economic requirements. This feature brings (leads) to sharp deterioration of ecological situation into river basin, to increasing of the beginning's risk of the several hydrological, geomorphologic phenomena. Sometimes they are irreversible (as Aral destiny, for example) and produce the serious security threat for mankind.

This work gives up to the investigation of activity's dynamic of some river and lake-river system, connected with national economy complex (NEC) and dependent upon the extensive effects of hydro economic measures. In this case it is expediently to consider, to use and to state the value of possibility of this system to function as a single whole nature object (hydrological system). The changes due to anthropogenic loads of different intensity are under consideration too.

The research used the mathematical models and numerical methods developed in HI SB RAS and based on one- and two-dimensional (lateral-vertical) shallow water equations (Sent-Venan equations) and their combinations.

The numerical modeling was completed by using of computer programs, including the same ones of the program complex meant for solving of broad circle of research and practical problems on hydrologic substantiation of water supply projects, the assessment of their possible negative environmental impact, development of effective defense against disastrous phenomena on water objects [1].

The model description. For mathematical modeling of hydrodynamic and ecological regimes two different dimensionally types of mathematical models are used [2-6].

1. One-dimensional model (1D) of unsteady water motions into open channels (passages, streams, watercourses, waterways) and their systems taking (and not taking) into account the heat-mass transfer.

The theoretical base of mathematical models 1D is the one-dimensional Saint-Venan equations (the shallow water equations), average on channel's (bed's) cross-section, written down by generalized form and taking into account the different physical factors, such as climatologic (wind, atmosphere pressure), the water density's changes due to probable modification of water temperature and its salt concentration. The account of water density's changes is provided by the constitutive equation; the changes of water temperature and salinity – by corresponding equations of heat transfer and salt [2, 3].

So, generally the unknown functions of mathematical models 1D are time and space variations of the next: rate of discharges, water-levels, water velocities, averaged by section, density, temperature and salt concentration.

2. Two-dimensional (lateral-vertical) model (2D) of temperature- stratified flows at deep gaunt water bodies.

The base of this model is the two-dimensional equations, produced by 1) the averaging of three-dimensional hydrodynamic equations throughout the width of channel and 2) the assumption about hydrostatic pressure low. The detailed description or the model presented at [4-6]. According to it, unknown functions are: the time and space distribution of rate of discharge and water-level (equations of continuity and motion are written at rate of discharge – water level variables), vertical and horizontal velocity fields, likewise the fields of time-space distribution of temperature and salinity and depending on them density fields. At the same sequence the numerical calculation of unknown functions is carried out by corresponding equations (2D).

The mathematical model is developed for calculations hydrothermal processes at weakly running density stratified, narrow deep cisterns (water bodies).

Numerical method is based on implicit absolutely stable (steady) differential schemes and methods of splitting on physical processes.

The developed algorithms of solution of differential equations' systems take proper account of system's matrix structure to give the method's economy in case of large dimension problems, that's very important [2, 3].

3. Complex two-one-dimensional mathematical model for calculation of hydrological regimes in systems of open channels.

This model is provided on the base of these ones, being produced above, and represents the combination of one-dimensional and two-dimensional (lateral-vertical) models [2, 3, 5-7].

This mathematical model may be used for study of the wave processes' dynamic, taken place from water objects with complex structure and components, different strongly on its geometric, hydraulic and morphometric characteristics.

During the construction of one- and two-dimensional models, the real hydraulic and morphometry characteristic of channel and adjacent flood-land tracts, their interaction, so as meteorological factors' (wind, atmosphere pressure) influence on wave processes, are taken into account.

The numerical modeling was carried out step-by-step accordingly with methods mentioned above and described in details in [8, 9]. So, during the modeling the starting physical matter is schematized by corresponding physical model-topologic scheme (single or several), i.e. the real matter analogue. Then selected the physical model is associated with appropriate mathematical model (problem). The correspondence between the both problems may be achieved by set of different types of boundary and coupling conditions, specified at computer programs.

Let's consider the examples of some applied hydrodynamic's problems, during the solving of which the computer's program complex produced on the base of above-mentioned mathematical models, numerical methods and algorithms, produced in IH SB RAS [1].

Example 1. The estimate of anthropogenic factors' influence on the Tom river water regime [10].

During a lot of years the development of local (native) materials (sand- gravel mixture) is keeping at the Tom river channel for Tomsk build industry requirements. As a result, the two-five times much (and more) increasing of wetted cross-section happened inside the quarry as comparison with the life regime. The consequences of it consisted in the significant reduction of Tom river water surface slope over 54 km length from Tomsk to Kozulino: from $38\cdot10^{-6}$ in 1963 year., $9\cdot10^{-6}$ in 1982 year to $3\cdot10^{-6}$ in 1999 year. The further uncontrolled groove of local (native) materials from the Tom river channel can produce the good conditions for backflow formation at Tom river channel. This feature is extremely objectionable because of possible dangerous up-stream diffusion of toxic agents (substances), which can come in river channel with sewage of plants (works, factories, enterprises, concerns, developments) at the distance of 25 km below Tomsk.

The main purpose of study was the clarification of possibility for the backflow to be generated at the Tom river length between Tomsk and the Tom river mouth during low-flow period (summer and winter) depending on Novosibirsk hydro-electric power-station water release and taking into account the redistribution the Tom river flowing off (drainage) due to Krapivino hydroelectric station knot waterworks facility.

One of the factors preventing from free wave flow during the channel is the backwater. Particularly, the most common case is the variable backwater, which occurs where the Tom flows into the Ob river as a result of lack of phase convergence between the oscillations of water-levels at main river and the tributary. Under the fixed hydrologic conditions, it can produce the backflow at the Tom river. For to recognize these conditions, the long-time oscillations of both rivers' flowing were carried out, the data analysis was done, the possibilities of interaction between flows (under different routine, procedure) was studied taking into account the Tom river channel modifications due to quarry activity. As a result, the regimes (procedures) showed the best correlation with the most extreme combination of the Tom and Ob rivers regimes (procedures), under which the counter flows are possible, were selected. The selection such criterion was:

1) for the Ob river – year with the most water fault from Novosibirsk reservoir;
2) for the Tom river – year with the summer and winter lower low water.

As a result, the combination of 1984-th for the Ob with 1986-th for the Tom was selected to study the interaction between the waves during all the year.

This regime called the "fictitious year" was considered as the most dangerous in respect to possibility of backflow's beginnings on the Tom river at there part from Tomsk to the Tom river mouth.

As object of inquiry at this problem, two different topologic schemes, called by convention "Tom" (the channel model 1) and "Junction" (the channel model 2) were constructed. The first of them, "Tom", represents the Tom river part from Tomsk city control to gauging station Kozulino. Its both are the upper and lower boundaries for this channel model. The "Junction" system represents the T-joint, including the Ob river section from gauging station "Pobeda" and the Tom river from Tomsk city control to exit of this flows into the Ob river (figure 1).

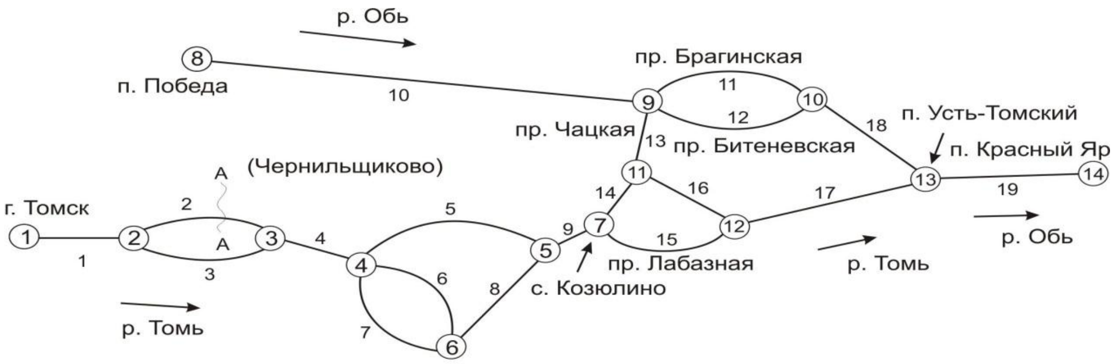

Figure 1 – The calculate scheme of the junction region Ob and Tom rivers

The calculations of unsteady water motion by both channel models are fulfilled in frame of one-dimensional mathematical model. In doing so, the program complex carried out in IH SB RAN for an arbitrary system (with loops) of open channels and schematized by some plain graph (so that the graph segments or edges correspond to the sections of waterways, and it's vertexes – to the units of branching and end alignments. On each graph edge the system of Sen-Venan equations is considered, on each it's vertex the boundary or coupling conditions are defined [2, 3].

For "Tom" model the boundary conditions were: at Tomsk city (vertex 1) – the rate of discharge motion in time Q = Q (t), at Kozulino (vertex 7) – the motion of water levels in time Z = Z (t). For "Junction" model the boundary conditions were: at Tomsk city (vertex 1) and p. "Pobeda" (vertex 8) - the rate of discharge in time Q = Q (t), at the end range p. Krasny Yar (vertex 14) – so called "the curve of connection" Q = Q (h), calculated at ZabSibNIGMI.

On each section (the graph edge) the functions with corresponding initial hydraulic and morphometry data, including the bottom marks, the channel and flood-lands width depend upon the depth for all ranges of possible changes of depth and coefficients of roughness, flood-lands and travel inflow [9], were given.

The distribution (on all computation system given points and given time moments) of water consumptions and levels, as well as flow velocities averaged by cross-section, is the result of calculations.

Before to begin the calculations, the calibration of model parameters for periods of ice closed and open channel was carried out. During the calibration of parameters corresponding to icy closed channel's period the imitation of different ages of icy covering (blanket) was fulfilled by defining of roughness coefficients, which are variable in time and calculated sections' length and decrease when "age" increases.

By accurate "Tom" model the calculating, based on data of mostly typical periods of floods' row in nature, as the problem called "fictitious year" and accepted with extremal flow conditions, were carried out. The result analysis of calculating of free surface's curves according to "Tom" model showed that the most negative situation is superintended under the calculating by so called "fictitious year" routine (variant A). As this routine takes places, at the distance about 20 km above Kozulino range the water surface declivity close to zero are forming: from 0,0000007 at twentieth days of count up to 0,0000005 at 72-th and 0,0000002 at 100-th and 128-th days.

Furthermore, for "fictitious year" conditions the calculations by "Tom" model of two other variants of hypothetical quarries activity for using of local materials lower Tomsk city on the section of 20 km length were realized. One of them (variant B) simulated a quarry increasing the width of Tom river channel twice as much (without changes of the river bottom marks), – so called beach quarry. Another one (variant C), in spite of increasing of width of

Tom river channel twice as much, provided for its embedding from 2 m to 0,5 m, changing with length. The analysis of the free surface curves, which were obtained for all calculating variants (A, B, C), showed, that

1) the return flow phenomenon was not fixed at all computation sections from Tomsk city up to Kozulino;

2) at 20 km section above Kozulino the inclines close to zero are settled: from $0{,}15 \cdot 10^{-6}$ до $0{,}088 \cdot 10^{-6}$ и $0{,}083 \cdot 10^{-6}$ (the variants A,B,C correspondingly).

The calculations results by channel model 2 (“Junction”) confirmed qualitatively the calculations results by model 1 (“Tom”) for the same seasons (open channel).

Example 2. The calculation of thermally-stratified flow at standing water body [6]

The standing water body of stretch form (length 500 km, water level z = 33,0 m) with mirror common area Ω = 22, 75 thousand square km, inflation value W = 141 cub. km is presented as a stream, composed of two communicant sections by length 250 km with parameters given in the table.

Table – Calculations parameters of a water body

Baseline	Sections 1 west small	Sections 2 east deep
Depth, m	3…9	4…45
Width, km	15…110	17…45
Mirror area, thous. Km.^{2}	16,375	6,376
Volume of filling, Km.^{3}	58	83
Temperature, °C	0	0
Salinity, %	78	78

As the initial data the information corresponding to Aral sea supposed morphology. During long time (t = 1,5 year) the river flow comes to it shallow-water part.

The hypothetic hydrograph (monthly flow quantity) coming to east part of water body (east section), changing of water temperature, atmosphere air temperature and salinity are given at figure 2.

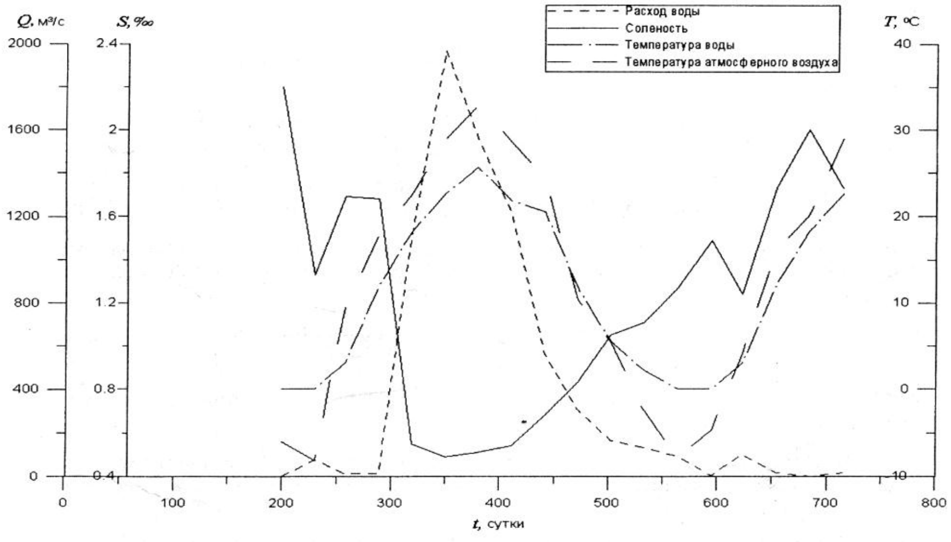

Figure 2 - Calculation parameters of a water body

The temperature distribution by the sections length at different time moments is presented at figure 3.

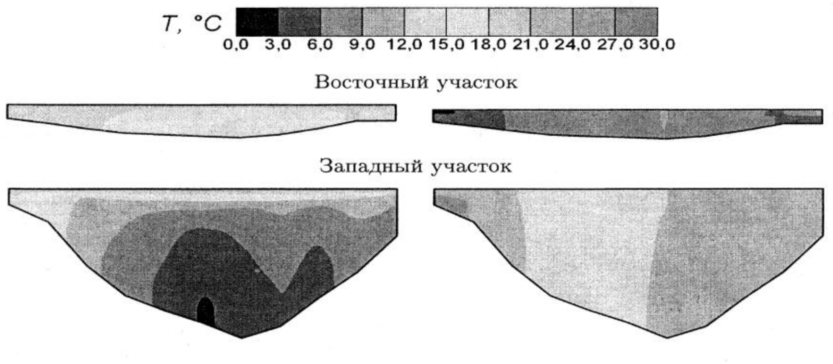

Figure 3 – Temperature distributions at section length at the different moments of time.

Example 3. The calculation of the unsteady flow at running system of Lama lake – Lama river [7].

The main task the conducting of calculations was the clarification of possibility to use the developed complex mathematical model $(2D+1D)$ for study of wave processes at system similar to "river – lake - river" one. With this purpose the fragment of the lake-river system of Putoran lake province, placed at north-west of Krasnoyarsk territory, Russia [11]. This system fragment includes running in the Lama lake, which reaches from east to west on 80 km, and flowing into and outward from it rivers. Lama lake presents the narrow deep reservoir having in its middle part 3.7 km of width and 254 m of depth, at the west edge - 10-13 km of width (with 2.5 - 9 m of depth).

The flowing into the lake river played a part of the centre tributary (inflow) with water level raising $Z = Z_{pritok}(t)$; the river flowing out was considered as a channel with arbitrary cross-section (length 20 km, maximum width up to 500 m, depth 4 – 7, figure 4).

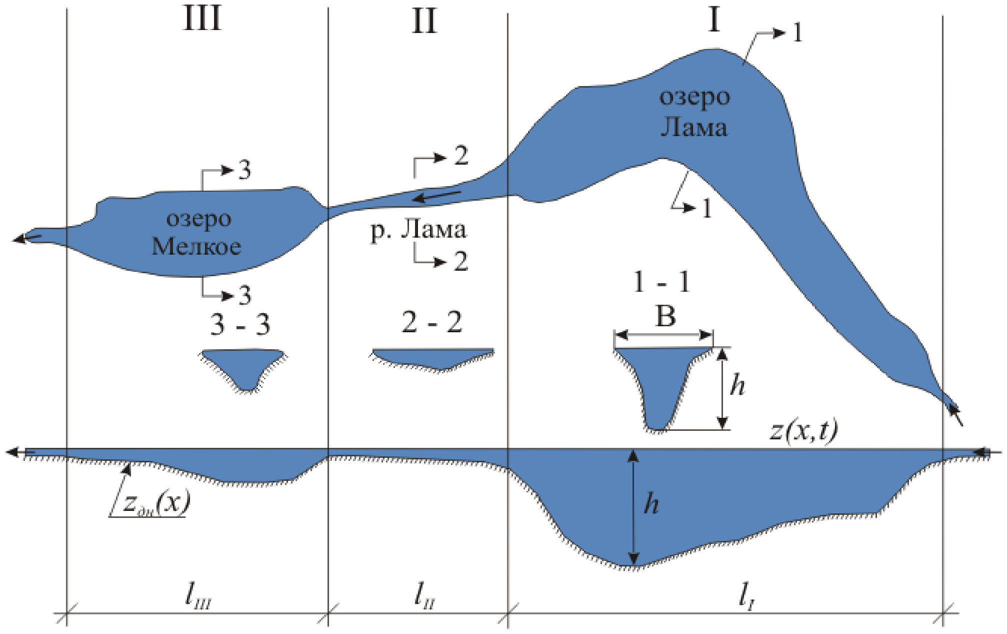

Figure 4 – The lake-river system (Putoran province)

For numerical modeling, two different topologic schemes of lake-river system fragment were constructed. Accordingly to the first of them the lake-river system (lake and river both) was considered as two interrelated two-dimensional domains by extension of $L_1 = 80\,км$ and $L_2 = 20\,км$ correspondently. The numerical calculations on scheme 1 were carried out on the base two-dimensional ($2D$) mathematical model. Accordingly to the second one the lake-river system was considered as associated one-to-one two-dimensional domain (length lake is $L_1 = 80\,км$) and one-dimensional river section ($L_2 = 20\,км$). The calculations by the scheme 2 were produced on the base of combined ($2D + 1D$) mathematical model. At the both cases the lake and the river were described by corresponding hydraulic and morphometric characteristics. In so doing, at the both calculating domains the same roughness coefficients was using.

As the base of numerical calculations the middle- longstanding flood, which reflects real flood's wave and can reflect probable flood's wave at the territory under consideration.

The boundary conditions at the process of calculations by the schemes 1 and 2 were:

- on the left (input $x^{(1)} = 0$) boundary - the condition $Z = Z(t)$, appropriate with raising of water in river flowing into the lake, which meanings are selected on the base of repeated water raisings-abatements at spring-summer seasons (from the end of may to the beginning of august) during the 70 days. Accordingly to observations, the magnitude of raising level above the mean water in the lake was equal maximum to 4, 5 m (in the middle of June) and after that gradually (to the beginning- middle of august) decreased up initial level.

Beside at this boundary (in both schemes) vertical distribution of longitudinal component of velocity (elliptic low) was set [12].

– on right boundary (the Lama river closed cross section $x^{(2)} = L_2 = 20\,км$) – the water stage discharge curve $Q = Q(z)$.

- on the joint of calculation domains (the flowing out cross section river $x^{(1)} = L_1 = x_0^{(2)}$) the balance of discharges and equality of water levels are assigned.

The initial conditions were set as results of establishment regime numerical calculation, i.e. the rate of discharges and levels water, corresponding to hydraulic steady ($Z^0 = 53\,м = const$, $Q_{L_2} = Q(z)$).

As mentioned above, the purpose of numerical modeling was to compare the both mathematical model's results of producing of flood wave expansion's process at real river-lake system (observation data are absent). By the way the question about method to set the vertical distribution of horizontal velocity $u(x_0^{(1)}, z, t)$ on the two-dimensional domain left boundary. The study showed the setting by elliptical low does not break the common picture of lake flow for steady (and unsteady) conditions. The velocity given on the boundary was arranged to the lake's field of velocities as early as the first calculation step ($x = \Delta x$) from boundary was done, in the both flow routines (figure 5).

The possibility to set the value of longitudinal constituent velocity as the vertical constant one in the process of problem solving was marked at [13].

The calculations of unsteady motion's expansion at the water system were done on the base of both models, with constant time step equal to 30 sec.; the general duration of calculations of flood passing's physical process in river-lake system was equal to 70 days.

The calculation results analysis.

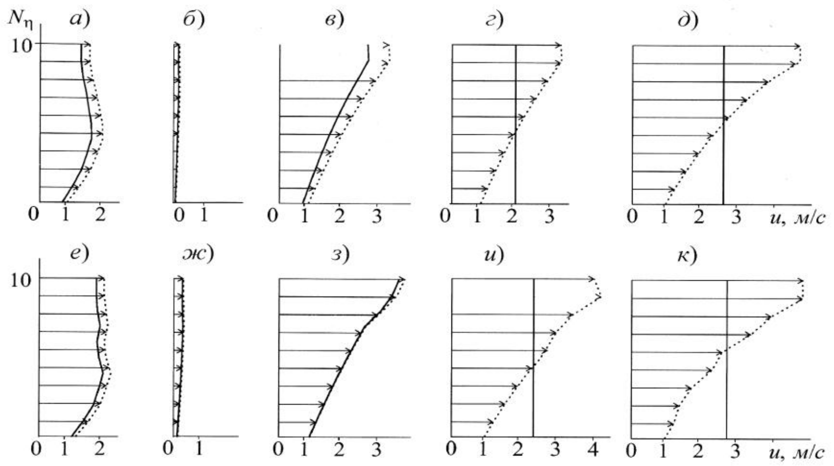

Figure 5 – The longitudinal constituent of vertical velocity profile at time moment $t = 12days$ (steady regime – $(a-d)$) and $t = 42days$ (unsteady regime – $(e-k)$) by the models 2D and 2D+1D (consequently dotted and solid lines)

Because of observation data's absence the analysis was done by the way of comparison between the results of calculations, being carried out on the both mathematical models. The conclusions were:

1) the water levels for both cases – the steady and unsteady motion – practically coincides at the lake (max divergence was equal to 0.14%); at the river the divergence reaches the 2.03-2.5% max;

2) the calculated flow quantities varied in max 9.0-9.5% at file closer range of river-lake system;

3) the machine time consumption for calculations of 70-days flood by the two-dimensional model (2D) practically four times as much as machine time consumption for the same calculations by the complex model (2D + 1D) other all things being equal.

Conclusion. In this work the mathematical modeling of hydrologic regimes in real object was done. The calculations were fulfilled with help different mathematical models: 1D, 2D and its combined (2D+1D). The analysis and comparison of the calculation results is showed

– the possibility for using of the developed mathematical model, its economy and efficacy for the study of wave processes at reservoirs (cisterns, ponds, water bodies, wells) and water passages of complex structure.

– by studies of physical processes at complex structures' water systems, contained the waterways with very different morphology and geometrical sizes, the use of only one model is inexpediently, often not economy. For such water systems the use of complex of mathematical models with different dimension is more preferably [2].

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INTERSTATE WATER RESOURCE RISK MANAGEMENT: TOWARDS A SUSTAINABLE FUTURE FOR TRANSBOUNDARY RIVER BASINS OF CENTRAL ASIA

The background for this study was the importance of the allocation and use of water resources of Transboundary Rivers in Central Asia. Firstly, for the equitable use of water resources by the countries of the region requires first the determination of the actual volume of water flow of Transboundary Rivers. This requires systematic monitoring of dynamics of change of water flow. The paper presents the results of study of dynamics of change of water flow of the Transboundary Zeravshan River for the period 1931-2011 and main tributaries of Amudarya the Vakhsh River. The significant change of the river flow and the impact of climate change on the state of glaciers of the Zeravshan river catchment observed. Present result of research of relationship of the components of geoecological systems of the Zeravshan river basin on the example of changing the chemical composition of water from the formation zone to the downstream of the river Zeravshan. The content of chemical components in the upstream waters of the Zeravshan River due to the processes of interaction of components of geoecological system consisting in the erosion of rocks water runoff is established. It is established that. The anthropogenic influence on the territory of the Republic of Uzbekistan is caused by pollution of the river Zeravshan collector and drainage and household waters

Introduction. About 60% of the water that potentially flows to the lower Aral Basin originates in the high mountains of Tajikistan. The demand for winter hydropower generation in the upstream countries, where the dams are located, conflicts with the summer demand for irrigation in the downstream parts of the basin. The poor and inadequate information on the available water resources is leading to erroneous planning decisions and a biased distribution of water resources. Hence, these issues contribute to interstate Transboundary water sharing conflicts between the riparian states.

To provide sustainable water management, it is important to obtain reliable information on the present and future water resources and their evolution in relation to human activities, to global changes and to climate evolution affecting the hydrological and melting regime of the main tributaries to the Amu Darya and Sir Darya.

The Zeravshan River one of the tributaries of the Transboundary Amudarya Rivers formed on the territory of the Republic of Tajikistan and flows to the territory of the Republic of Uzbekistan Main hydrological characteristics of the river described in [1]. The average annual flow of water of the Zeravshan river is 158 m^3/sec and the average annual volume of runoff is about 5.0 km^3 [2]. Monitoring meteorological conditions of the basin of the Zeravshan River and hydrological parameters of the river on the territory of the Republic of Tajikistan carried out in four meteorological and five hydrological stations. There is currently only hydrological station Dupuly. The total glaciation area of the Zeravshan river basin is 437.9 $км^2$. Among 632 glacier of the Zeravshan river basin, the largest is Zeravshan glacier by a length of 27.8 km and an area of 132.6 km^2.

According to the Hydrometeorology Agency of the Republic of Tajikistan, there was a substantial change of the geometric dimensions and mass loss of glacier Zeravshan for the period 1927 - 1991. Only for the period 1991-2009 years, the glacier retreated at an average annual 88-94 m and its area decreased by 700 Th. m2 and by 2050 to decreases by 30-35% is expected [3].

The Vakhsh River is the main river of the Republic of Tajikistan and one of the tributaries of the Transboundary Amudarya River in Central Asia. It has a length of 691 km and the area of the basin is 39160 km^2, almost a quarter of the area of the Republic of Tajikistan. Glaciers occupy a tenth part of the Vakhsh River Basin and the water supply source of the Vakhsh River is glaciation area the altitude of 4685 m a. s. l. The Vakhsh River has 6276 inflows, and the lakes in its basin are twenty covering a total area of 4.0 km^2. The average discharge of the Vakhsh River in the Vakhsh valley (at the head of the construction of the Vakhsh main channel) is 2273 m3/sec; the height is 4500 m^3/sec, the least is 1420 m^3/sec. The high water amounts to an abundance of water on Vakhsh River proceeds from March - October, and the average duration of a high water is 221 days. At this time on the river passes 87 % of an annual flow. The average water discharge in the middle reaches 660 m^3/sec, the highest (in July) is 3120 m^3/sec, and the smallest (in February) is 130 m^3/sec. The total hydropower resources of the Vakhsh River is 28.6 Mln. kWt, which can give 250Bln. kWt·h of the electricity per year [4-10].

The Vakhsh River is born at the merge of the Surkhob to the right and Obikhingoy to the left that in turn are formed by the merging of two or more tributaries. Surkhob and Obikhingoy merge at a height of 1151 m a. s. l., the mouth of the Vakhsh is at a height of only 316 m a. s. l. The right inflow of the Vakhsh Rivers-the Surkhob by the length of 81 km, area of basin 1760 km^2, average height of 3140 m above sea level there are 246 glaciers in Sorbog River basin with a total area of 105.6 km2.

The left component of the Vakhsh - the River Obikhingoy has a length of 196 km and an area basin of 6660 km2. There are 756 glaciers in its basin with a total area of 712 km^2. In the Obikhingoy River Basin, there is a large glacier of Pamir-Garmo, giving rise to the same river coming down. Its length is 34 km with an area of 114 km^2. Now this glacier has the western layout, is intensively receding, its surface is going down, and the big ice blocks are separating from a glacier. The River Garmo comes out from the icy grotto (cave) and after twenty kilometers; the Kirgizob joins it from the right side and the Bohud from the left side. After merging this river formed the Obikhingoy River.

The feature of the hydrological regime of water objects significantly affects economic activity, safety, and living conditions of the population. For safe and effective use of the resources of the rivers, it is necessary to assess water resources areas or specific water objects, determine the maximum, minimum and other characteristics of water consumption, assess the impact of economic activities on the regime of rivers, and dangerous hydrological processes. Reassessing the modern resources of surface and underground waters in connection with climate change is one of the urgent tasks of hydrology and hydrogeology [11-14]. Low-flow assessment and minimum flow is particularly important to preventing environmental problems. A study of spatial-temporal regularities of runoff formations and the features of the hydrological regime of rivers allows for identifying the main relations between the elements of the water balance, particularly of underground and surface waters and the formation of their natural resources under existing and future climate conditions.

Research Methods. In the present paper were used the data of meteorological stations of Dehavz close to the Zeravshan glacier and Iskanderkul in the basin of the Yagnob river for the period 1931-2011. Measurement of hydrological characteristics of the Zarafshan River is at the station Dupuly that is the only hydrological post on the Zeravshan River. The influence of meteorological condition of the Vakhsh River tributaries basins on change of water flow carried out by used of meteorological data from stations Lyakhsh (Kyzilsu river basin), Tavildara (Obikhingou river basin) and Garm (the basin of the river Surkhob river basin) for the period 1960-2012.

The deviation of annual average temperature in the area of the Zeravshan glacier for the periods 1931-1961 and 1981-2011presents on the Figure 1(a, b).

The considered period is characterized by abundant precipitation in the form of a solid phase (at a height of over 2500 m, precipitation falls only as snow). This suggests that the period 1931-1961 characterized by a favorable condition for the increase of glacier mass.

The trend of change of temperature for the period 1981-2011 shows opposite character to comparison with the period of 1931-1961 while precipitation maintains its almost constant value (Figure 1b).

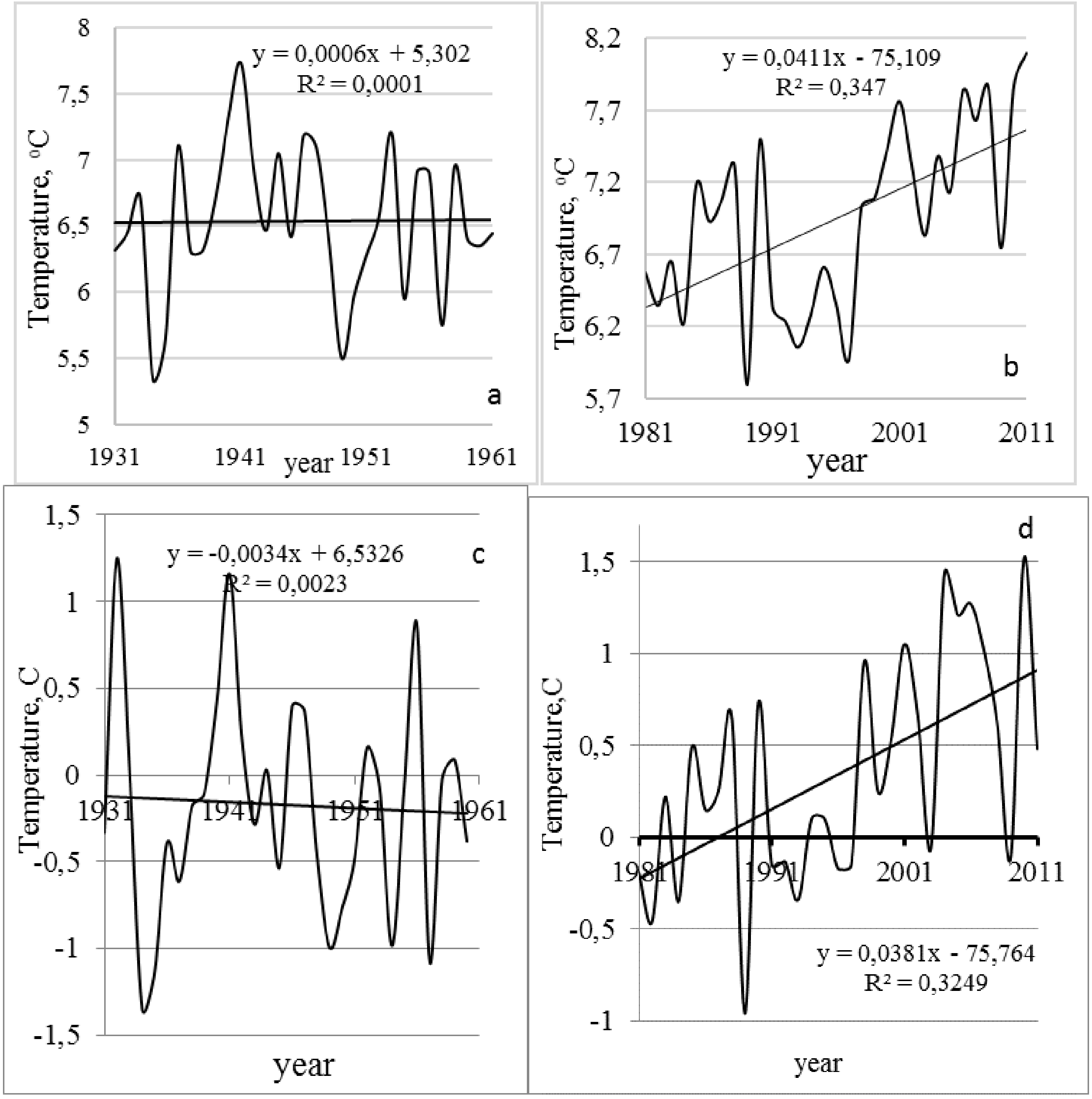

Figure 1 – Change of annual average temperature for the periods 1931-1961 and 1981-2011 in the area of the Zeravshan glacier (a, b) and in the Yagnob river basin (c, d), respectively

The results of meteorological observations in the basin of the Yagnob river presented on the Figure 1(c, d) shows that the change in temperature for the period 1931-1961years remains almost unchanged value and as in the case of Zeravshan glacier region during the period 1981- 2011 a significant growth is observed.

Meteorological Condition of the Tributaries and Vakhsh River Basins. For monitoring meteorological conditions of the respective basins of the rivers, data from meteorological stations in Garm, Lyakhsh (basin of the river Kyzilsu), and Tavildara (Obikhingou river basin) for the period 1960-2012 was used.

Systematization of the data of meteorological stations shows that in the Vakhsh River basin (including the basins of the tributaries of the river) the change in temperature has an increasing trend (Figure 2, 3). On the other hand, as shown in Figure 3 (b, d) atmospheric precipitation on the Kyzilsu River basin has a decreasing character with almost constant value on the Obikhingou River basin.

The Hydrograph of the water flow of the Zeravshan River and its tributaries. The measurement of hydrological characteristics of the Zeravshan River was made on the Dupuly Hydropost that is now the only operating station on the Zeravshan River. The annual average of water consumption of the Zeravshan River for the periods 1931-1961 and 1981-2011 is present in Figure 4 (a, b).

The decreasing trend of the Zeravshan River water discharge for the period 1931-1961 can be explained by the fact that due to the low and near-constant value of the temperature, the precipitated solid precipitations are not the subject of an aggregate transformation but rather accumulate in the form of another layer of seasonal snow. This interpretation can be attributed to changes in the Yagnob River water flow as the period 1931-1961 is characterized by almost a constant value (Figure 4c).

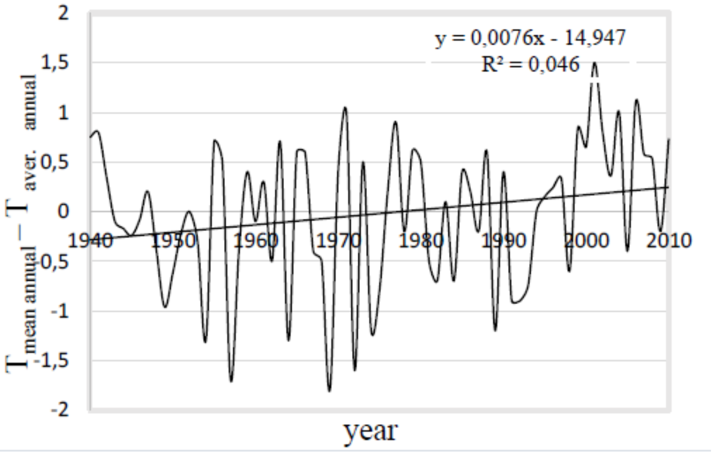

Figure 2 – Dynamics of change of temperature in the Vakhsh River basin (Meteostation Garm)

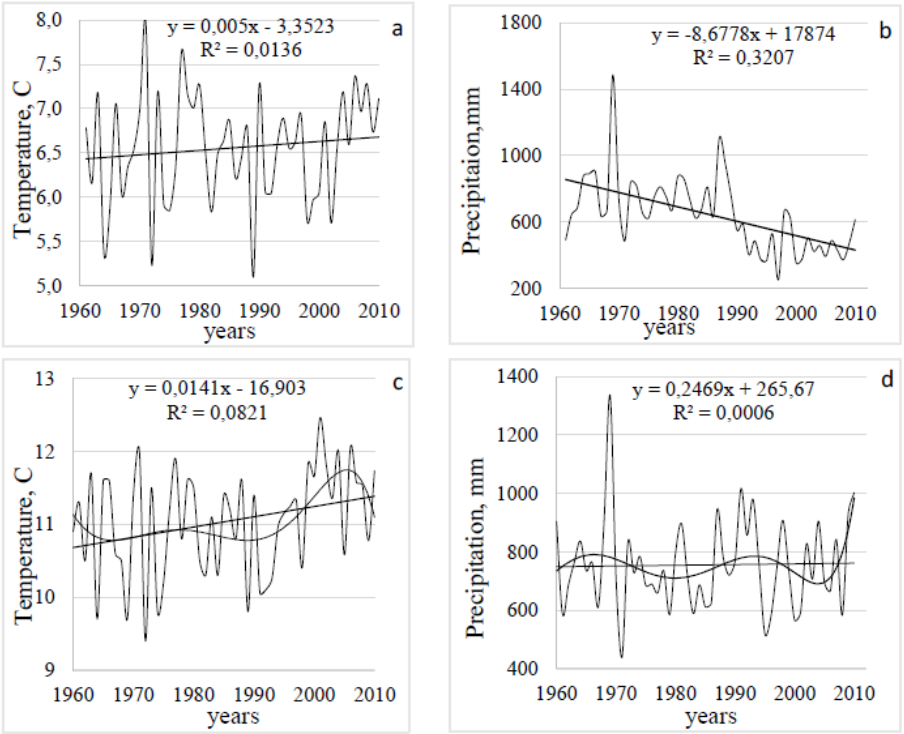

Figure 3 – Annual average precipitation and temperature according to meteorological stations Lyakhsh (a, b) and Tavildara (c, d) for the period 1960-2012

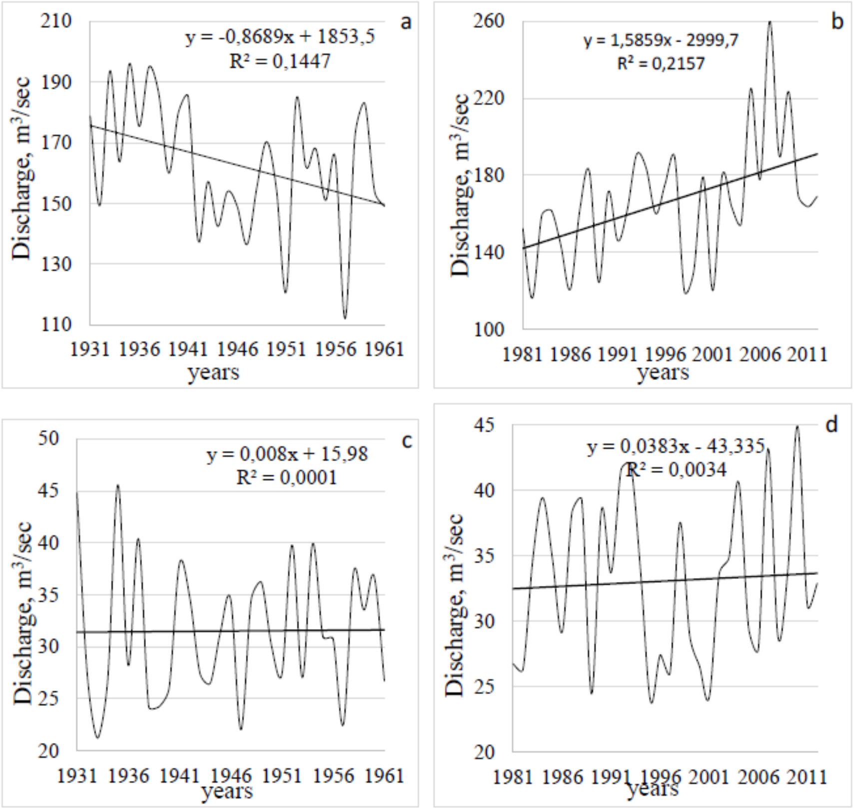

Figure 4 – The water discharge value of the Zeravshan (a, b) and Yagnob (c, d) rivers for the periods 1931-1961 and 1981-2011, respectively

A completely different pattern of runoff changes of the Zeravshan River is observed for the period 1981-2011; that is a significant increase of water discharge (Figure 4b). The actual hydrographs of the Zeravshan (a) and Yagnob (b) Rivers for the periods 1931-1961 and 1981-2011 demonstrated that for the Zeravshan and Yagnob rivers water discharge is the maximum in July and June, respectively (Figure 5). It can be assumed that different observations in different months of the maximum flood of rivers are caused by the location of their catchment on different heights a.s.l.

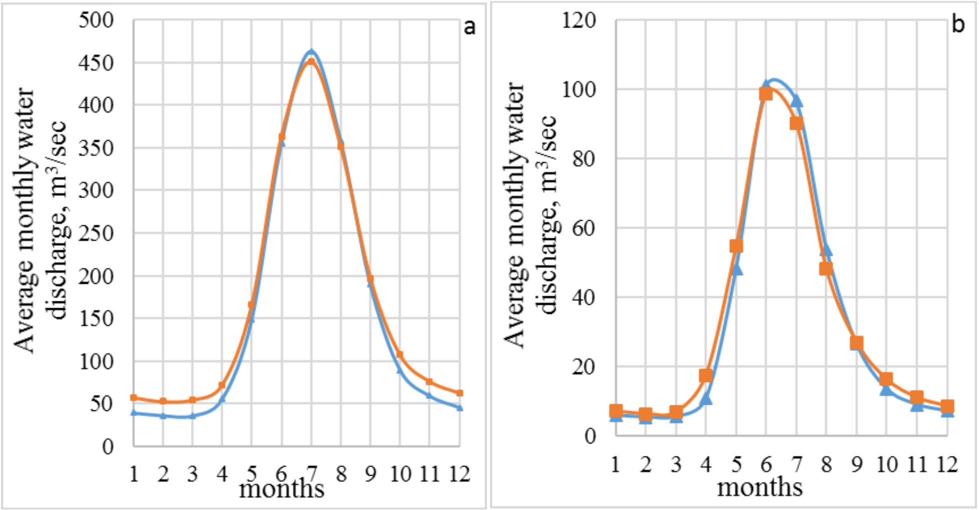

Figure 5 – The hydrograph of the Zeravshan (a) and Yagnob (b) rivers for the periods 1931-1961 (▲) and 1981- 2011 (■)

The period 1981-2011 for the Zeravshan River as can be seen from Figure 10 (a) is characterized by a reduction of the flow in comparison with the period 1931-1961. According to the estimated data, the mean annual runoff for the period 1981-2011 is 5.36 km^3, contrary to 6.08 km3 of the period 1931-1961 that is a decrease of the mean annual runoff by 12 %.

According to the results of the calculations, the mean annual flow of the Yagnob River for the periods 1931-1961 and 1981-2011 are 1.02 and 1.04 km3, respectively, and their difference is not more than 2%, which is within the measurement accuracy of water consumption.

The impact of climate change on the volume of water was calculated for Zeravshan River based on the deviation of annual runoff from mean annual (Figure 6):

$$\Delta Q = Qi - Qo$$

where Qi is total water flows for i^{th} year and Qo is the mean annual water flow for the period 1931-2011.

The volume flow trends of the Zeravshan River for the periods 1931-2011(a), 1931-1961 and 1981-2011 are shown in Figure 6(b) and Figure 6(c), respectively.

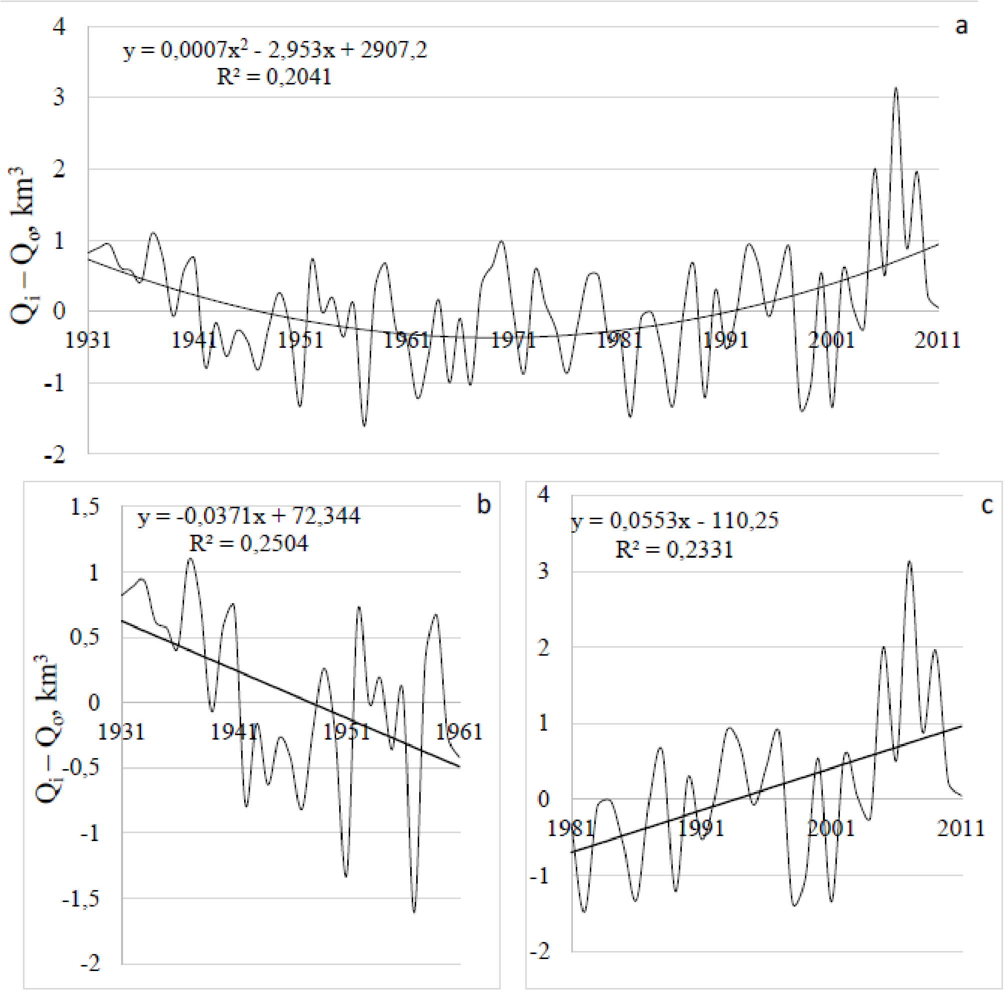

Figure 6 – The actual water content of the Zeravshan River (a) for the period 1931-2011(a) and for the periods 1931-1961 (b) and 1981-2011 (c)

The Hydrological Characteristics of Tributaries and Transboundary Vakhsh River. The increase of the water volume of the Vakhsh River and its tributaries-Surkhob and

Obikhingou rivers as shown in Figure 7 is in tune with the statements that currently there is a reduction of the glaciation areas of Tajikistan, probably due to an increase in the overall temperature of the background in the region and changing precipitation patterns.

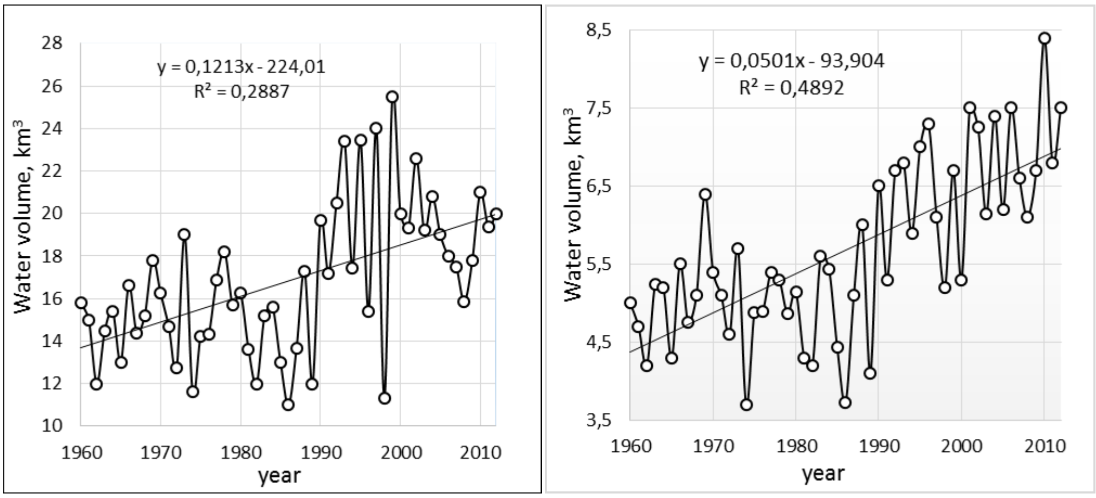

Figure 7 – The water volume change of the Surkhob (a) Obikhingou (b) Rivers for the period 1960-2012

In the Surkhob River basin, there are intensively melting small glaciers of the Northern slopes in the Western part of a ridge of Peter the Great. On the southern slopes of the Alay Ridge, glaciation decreases slower as there are larger glaciers. In the Obikhingou River basin, the largest glacier Garmo is intensively melting. During the XX century, it became shorter by almost 7 km, having lost more than 6.0 km^2 in area. It is currently retreating at an average speed of 9 m/year, and the surface settles due to the melting of up to 4 m/year. Another glacier in the same basin, Skogach, retreats annually at 11 m [15].

The existence of another but important aspect of the hydrology of the rivers-the cyclical nature of the water flow should be borne in mind.

In hydrology, from the point of view of the forecast of water flow, an important issue is the assessment of long-term fluctuations of annual runoff and their periodicity. On the other hand, there are attempts to link fluctuations in water availability with various geophysical processes. The lack of a clear periodicity in long-term fluctuations of flow does not rule out the tendency to the formation of more or less continuously alternating groups of high water years, called cyclical fluctuations of water flow. The length of the cycle, their sequence and the degree of deviation from the mean value inside the loops over a period years vary. It is not always possible to make clear boundaries between wet and dry groups.

A characteristic feature of changes in the volume of runoff in the Vakhsh River for the period 1932-2012 as seen in Figure 8 his cycle.

For allocation of periods with high and low water content are used differential integral curves of average annual discharge. A differential integral curve takes into account the fluctuations of the flow over some relatively short periods. It is defined by summing the deviations of modular coefficients from the middle, i.e. the ordinates are calculated as $\Sigma(K-1)$. Thus, the ordinates of the curve give at the end of each i-th year the cumulative sum of deviations of the annual modular coefficients from the long-term average (K=1). Foe comparison long-term fluctuations of runoff of different rivers eliminated the influence of temporal flow variability by reflecting the coefficient of variation (variability) of a set of observations (C_v), i.e. Σ (K-1)/C_v. The use of differential integral curves gives a vision of cyclical fluctuations without the effect of the displacement of the boundaries between the phases of the cycles of low and high duration [16].

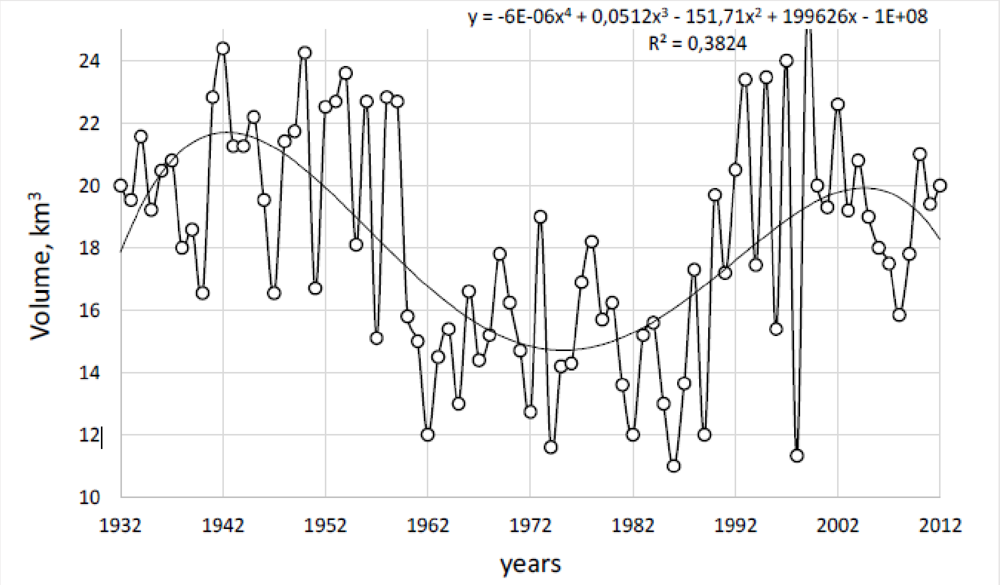

Figure 8 – The water volume change of the Vakhsh River for the period 1932-2012

The presence of average annual water flow on Figure 9 differential integral curve allows for defining periods of high and low water availability of the Vakhsh River. It should be noted that the appearance of cyclicality in the water flow of rivers allows for predicting future scenarios of changes in the water flow of the river. From Figure 10 it can be seen that the harmonic law changes the Vakhsh River volume of water for the period 1932-2012. Hence, the continuation of the right part of the harmonics may indicate the volume of water by 2030.

Figure 9 – differential integral curve of average annual water discharge of the Vakhsh River

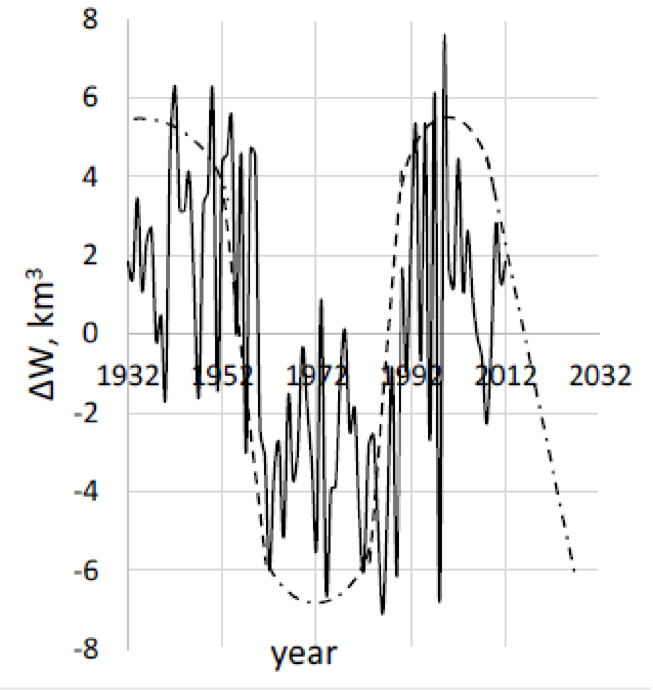

Figure 10 – Cycle of the Vakhsh River water flow for the period 1932-2012

As noted above for the period 1960-2012, water runoff in most of the rivers of the basin of the Vakhsh River has a tendency to increase. Thus, the increase of water volume in rivers and the reduction of amount of atmospheric precipitation in river basins give reason to believe that in the Vakhsh River basin there is a continued reduction in the area of glaciation. A detailed study of the process and the establishment of the relationship of water resources in glacial lakes with the formation of water flow of rivers is important from the point of view of planning the efficiency of hydropower facilities and irrigation activity in agriculture.

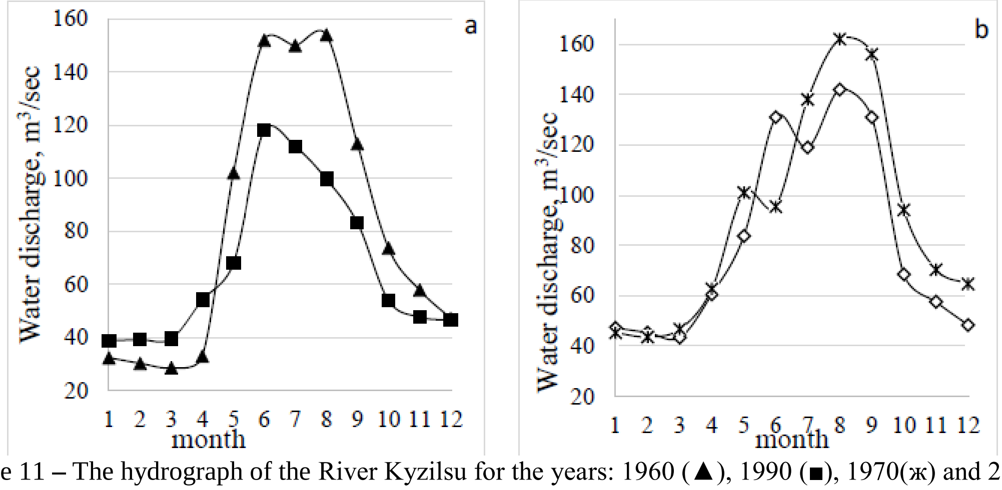

Figure 11 – The hydrograph of the River Kyzilsu for the years: 1960 (▲), 1990 (■), 1970(ж) and 2000 (◊)

The hydrograph of the Kyzilsu River for the years 1960 and 1990 present on the Figure 11(a) and it is characterized by the presence of two maxima in the months of June and August. The hydrograph of the river in 1990 has an extensive character with a maximum in June. On the curve of the hydrograph is observed a weak high ccorresponding to August and indicating a mixing of the flows formed at the melting of seasonal snow and seasonal precipitation with glacial feed. This is more evident on the hydrograph of the Kyzilsu River for the years 1970 and 2000 (Figure 11 b).

Risk Assessment and Risk Management of accumulation of chemical pollution in seasonal snow and glaciers and their transportation by waterways

The main sources of formation of water flow of rivers and the climate forming factor glaciers as favorable natural media for accumulation of atmospheric aerosols, chemical compounds and metals are considered. A similar phenomenon observed at analyzing the content of heavy metals and distribution of heavy metals in the snow cover on the glaciers of the southern slope of Mount Elbrus due to their transport to long distances in the form of microparticles by an airflow [17].

It is likely that accumulated in snow cover and glaciers contaminants in the process of melting of snow and glaciers to come to rivers and to distribute to long distances.

The choice of snow cover as a natural indicator to air pollution it is actual because the snow effectively absorbs impurities from the atmosphere and depositing dry dust emissions from anthropogenic sources [18].

The concentration of pollutants in the snow by 2-3 orders higher than in atmosphere. This allows measurement of the content of substances of quite simple methods with a high degree of reliability [19]. In order to have information about the chemical composition formed from glaciers water flow in the formation zone was conducted a complex of physical and chemical analyses of seasonal snow on the glaciers of the Zeravshan, Rossinj, and Tro of the Zeravshan river basin and tributaries of the Zeravshan River emerging from these glaciers. The river Zeravshan one of the major rivers of Central Asia originates at a height of 2775 m. On the territory of Tajikistan, it flows about 300 km and takes more than 100 small streams and 3 large rivers [20]. The annual flow of the Zeravshan River is on average about 5.2 Bln. m^3.

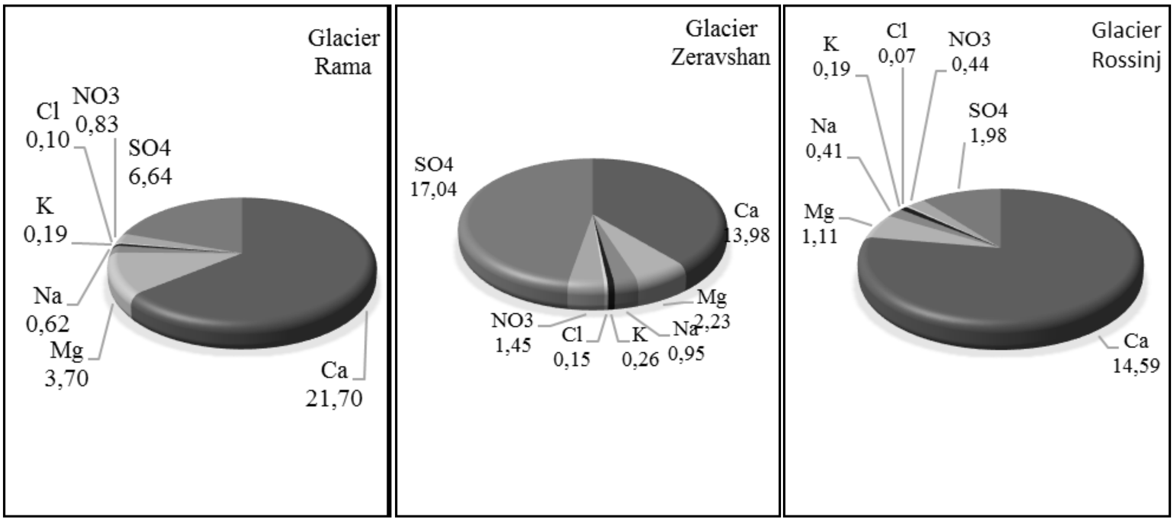

Figure 12 – Chemical composition of seasonal snow on glaciers of the Zarafshan river basin.

According to the fig.12 in seasonal snow on the Zeravshan, Rossinj and Tro glaciers observed dominate of anions SO_4^{2-}, NO_3^-, Cl^- and cations of Ca^{2+} and Mg^{2+}.

The isotopic composition of oxygen and deuterium, deuterium excess is an informative indicator of hydrological and glaciological researches for establishment of regularities of processes of ice formation, the snow accumulation and mutual transformations.

The water of the Zeravshan River and their tributary: Sabag, Yarm, Samjon, Tro, Dehavz, Dihadang, Gusn, Dashtioburdon, and seasonal snow from glaciers of the Zeravshan, Rossinj and Tro were objects of isotopic analysis. Sampling of snow and water were carrying out according to the manual developed by the University of Colorado at Boulder on Wavelength-

Scanned Cavity Ringdown Spectroscopy (WS-CRDS). The isotopic composition of hydrogen and oxygen are expressed in relative terms $\delta 1^{8}O$ and $\delta^{2}H$:

$$\delta = [(Rsample / Rstandard) - 1] - 1000\%_{o}$$

where Rsample and Rstandard are ratio of 2H/ 1H и 18O/16O in samples and standards (mid-ocean water; SMOW, Vienna, IAEA). The accuracy of the measurement ±0.05‰.

The Zeravshan River water and upstream inflows according to results of isotope analyses are characterized by the following values: $\delta^{18}O \leq 13.0$ %o, $\delta^{2}H \leq -100$%o and $\delta^{18}O$ (-13.23:-13.43), $\delta^{2}H$ (-88.92:-88.32) accordingly. The Deuterium excess for inflows of Zeravshan River is (16.92:19.21).

Therefore, it can argued that the fractionations is a result of freezing and snow accumulation occurs in winter.

In turn, the isotopic composition of the downstream tributaries of the Zeravshan river the following: $\delta^{18}O$ (-11.98:11.61) and $\delta^{2}H$ (-78.45:-75.80). This indicates about seasonal changes in the isotopic composition of precipitation and their influence on the isotopic composition of the river waters.

It is know that chemical elements and compounds can transported by water to long distances. For example, compounds of uranium in bicarbonate waters could be transported on 30-80 km.

The physical - chemical analysis of water the main tributaries and the Zeravshan River, for define of the transportation mechanisms of seasonal snows contaminants to the tributaries and then to the river Zeravshan, were studied. The agriculture in the upstream of the Zeravshan Rivers poorly developed due to the limiting of irrigated territories. Consequently, the runoff flow of collector-drainage waters with a high degree of salinity from upstream territory to the river is insignificant. On the Figure 13 presents the results of chemical analyses of water objects of the middle flow of the Zeravshan River.

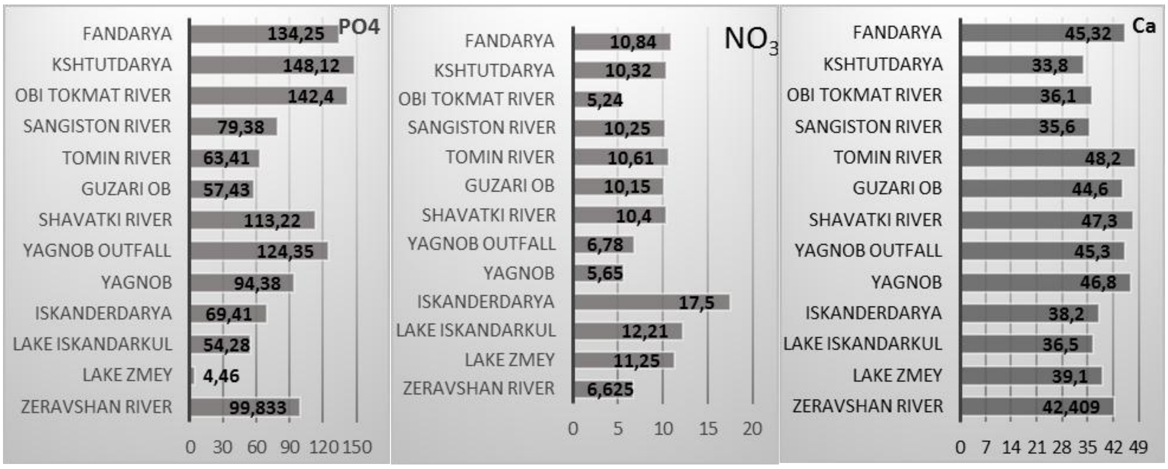

Figure 13 – Results of chemical analyses of water objects of the middle reaches of the Zeravshan River.

The analysis of the composition data of the water presented on histogram is demonstrated that the upstream tributaries of the Zeravshan River do not experience any anthropogenic influence and their mineralization mainly caused by the washout of coastal mineral deposits. The upstream tributaries of the Zeravshan River shown on the Figure 14.

In the formation of hydrochemistry and water balance of the Zeravshan River considerable contributions belongs to its tributaries. The results of physical-chemical analyses of the main upstream tributaries of the Zeravshan River are summarized in Table1.

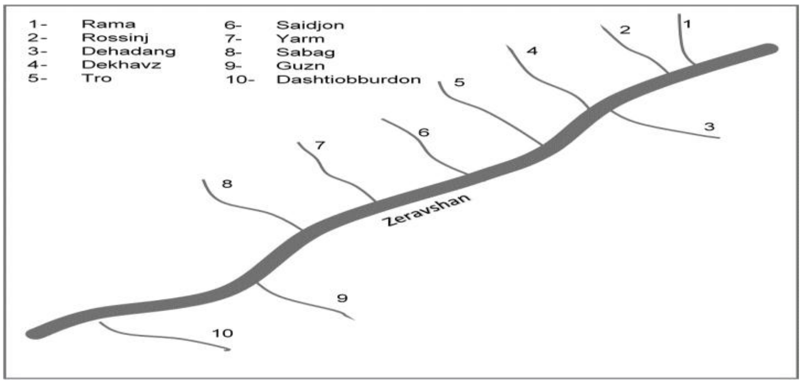

Figure 14 – Scheme of location of the tributaries of the Zeravshan River from the Zeravshan glacier to downstream

Table 1 – Content of chemical anions and cations of the tributaries of the Zeravshan River

№	River	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Cl^{-}	NO_3^{-}	$S0_4^{2-}$
mg/l								
1	Rama	21,704	3,696	0,618	0,190	0,10	0,825	6,643
2	Rossinj	14,587	1,111	0,406	0,187	0,066	0,441	1,975
3	Dihadang	20,166	2,5845	1,4434	0,8279	0,225	1,703	35,036
4	Dehavz	12,308	3,6026	1,1576	1,1433	0,220	1,836	29,941
5	Tro	17,031	4,2614	1,1769	1,3927	0,217	1,919	42,485
6	Samjon	11,052	2,4956	1,0554	1,4106	0,181	1,552	31,449
7	Yarm	13,347	3,1950	0,9808	0,2241	0,152	1,357	26,650
8	Sabag	27,013	7,0868	1,6627	0,4018	0,232	1,788	42,296
9	Dashtioburdon	45,725	19,4042	4,9101	0,9292	0,851	2,422	70,125

The dynamics of changes in the concentration of chemical compounds along the entire length of the Zeravshan River shown on the Figure 15. The numbers of the points on the abscissa of the Figure 15 is the names of the rivers from the Table 1

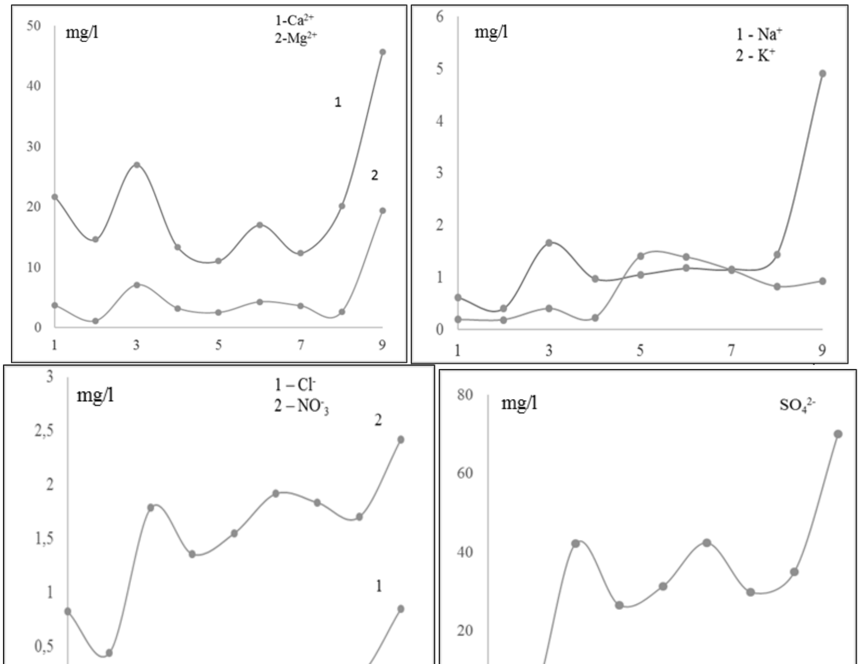

Figure 15 – The change dynamics of cations and anions along the Zeravshan River

Except for some (Sabag and Dashtioburdon) in most tributaries of the Zeravshan River the content of cations of Ca2+and Mg2+ is quite small. This pattern is typical also for (K^+, Na^+) and anions (Cl-, SO_4^{2-}, NO_3^-) (Figure 15).

A sharp increase of Na^+, SO_4^{2-} and moderate alteration of K^+ in the waters of the lower tributaries of the Zeravshan River is due to the weathering of mineral rocks and salinity of coastal surfaces.

The formation of hydrochemistry of the Zeravshan downstream by influences of drainage and municipal wastewaters

Currently the Zeravshan River irrigates about 551 Th. ha agricultural lands (13% of the total area of irrigated lands of Uzbekistan). One of the most important indicators of the Zarafshan River in the downstream is the salinity that often reaches maximum values of up to 2.6 MPC. This trend continued during the entire annual cycle [21]. The main sources of pollution of the river Zeravshan on the territory of Uzbekistan are agricultural drainage water from irrigated land [22, 23].

A degree of mineralization was determined by measuring the conductivity of the water. The values of the electroconductivity of water in different parts of the flow of the Zeravshan river and drainage channels on the territory of the Republic of Uzbekistan shows the extreme values in the collectors and canals that indicate about high degree of soil salinity (Figure 16).

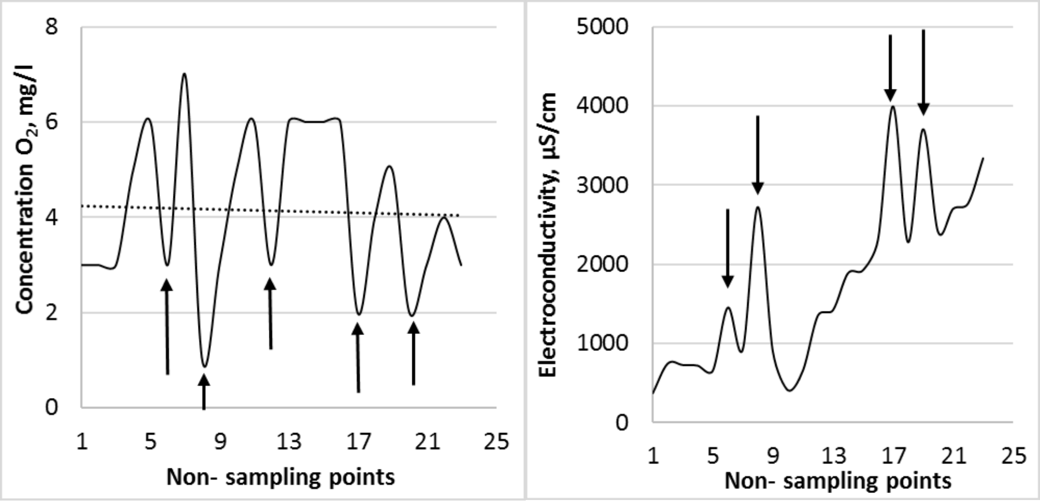

Figure 16 – The concentration of the chemical oxygen consumption (a) and the change of the electroconductivity of the water in upstream and downstream of the Zeravshan River (b).

The behavior of chemical oxygen demand opposite to the change in the electrical conductivity describes a natural process (Figure 16). The change of the water electroconductivity along the entire length of the Zeravshan River with the exception of collectors and canals in the downstream of the river shown on the Figure 16. Point 13 on the Fig. 6 corresponds to the section of the river on the border of Tajikistan with Uzbekistan. As can see on the Figure 17 electrical conductivity of water on the territory of Tajikistan is characterized by a minimum value 240 µS/cm and after crossing the border there is a sharp increase in electroconductivity of water.

The results indicate that mineralization of the Zeravshan river water mainly occurs in a downstream of the river on the territory of Uzbekistan.

The increase of the phosphate concentration on the border territory of the Republic of Tajikistan (points 9, 12) is observed due to the influence of phosphate deposits of Rivat that is located on the right bank of the Zeravshan River with the balance of 22Mln.t (Figure 18).

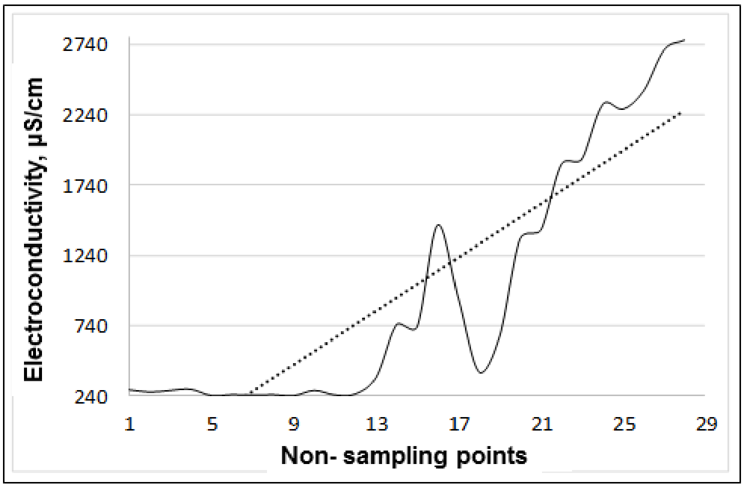

Figure 17 – The electroconductivity change of the water in the upstream and downstream of the Zeravshan River.

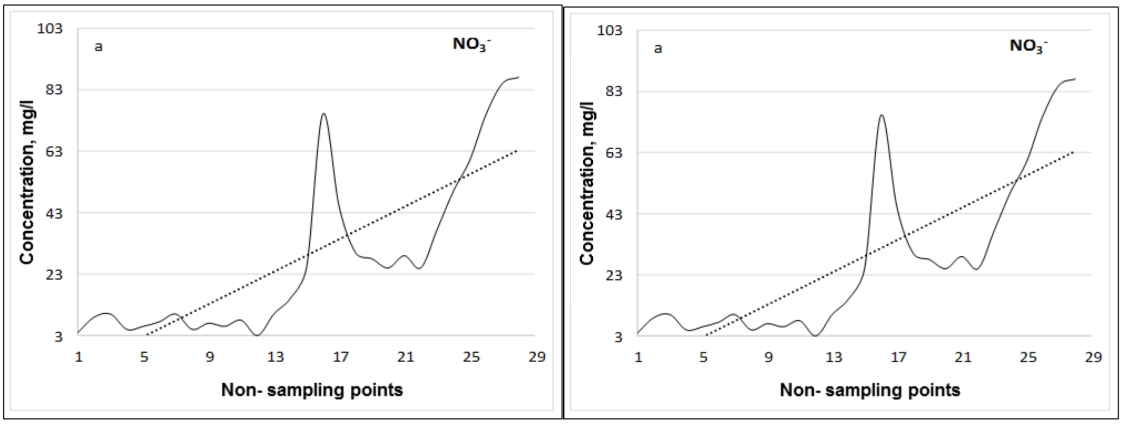

Figure 18 – Dynamics of change of concentration of ions of nitrate (a) and phosphates (b) on river length of Zeravshan

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WATER RESOURCES OF CENTRAL ASIA: CALLS AND THREATS, THE PROBLEM OF USE

Актуальность проблемы водных ресурсов давно признана и активно исследуется, особенно в свете проблемы - глобального изменения климата. В статье рассматриваются основные угрозы и вызовы в области водообеспечения и возможные пути снижения нагрузки на водные ресурсы и устранения дефицита пресной воды в Центральной Азии. Следствиями реализации водных опасностей могут стать обострение межгосударственных водных противоречий, развитие новых очагов экологической нестабильности, срыв программ социально-экономического развития.

Су ресурстары мәселелелерінің өзектілігі бұрыннан белгілі және климаттың ғаламдық өзгерістерінің кезінде қарқынды зерттелуде. Мақалада Орталық Азиядағы тұщы су тапшылығын жою, су ресурстарына түсетін ауыртпалықтардың мүмкін жолдары және сумен қамтамасыз ету облысындағы негізгі қауіп-қатерлер қарастырылды. Су қауіптерінің жүзеге асуының салдары мемлекетаралық су қарама-қайшылықтарының асқынуы, жаңа ошақтарының дамуы, экологиялық тұрақсыздық, әлеуметтік-экономикалық даму бағдарламаларының үзілуі.

Relevance of a problem of water resources is recognized long ago and is actively investigated, especially in the light of a problem - global climate change. In article the main threats and calls in the field of water supply and possible paths of decrease in load of water resources and elimination of deficiency of fresh water in Central Asia are considered. The aggravation of interstate water contradictions, development of the new centers of ecological instability, failure of programs of social and economic development can become corollaries of realization of water dangers.

Introduction. The main threats and calls in the field of water supply are global and regional climate changes, incoordination of the interstate water relations, use of waterexpensive technologies and imperfection of technical means of water regulation and water distribution [1]. Deficiency of water resources can cause an aggravation of interstate water contradictions, development of the new centers of ecological instability, failure of programs of social and economic development.

According to the Fourth report of the Intergovernmental Group of Experts on Climate Change, as a result of warming of climate change of atmospheric circulation and reduction of an amount of precipitation is expected. According to some scenarios by 2100 decrease in rainfall can reach nearly 20%. In addition, researches showed that in a zone of formation of drains of Syrdariya and Amudariya an intensive melting of glaciers continues. According to different data, in 50 years volumes of glaciers decreased from 20 to 40%, and in recent years rates of reduction make about 1% a year. Glaciers will disappear – also the river's bearing life will disappear.

Statement of a problem. Central Asia occupies the huge space - more than 4 million sq.km, but at the same time on deserts, semi-deserts and dry steppes more than 70% of all territory are necessary; that speaks about poor humidification of the region (figure 1).

The main sources of water resources of Central Asia depend on mountain systems and adjacent regions. Glaciers of Tien Shan, Altai, Pamir play the main role in providing and maintenance of balance of water resources in Central Asia. They occupy the space equal of 17950 sq.km. By 8,5 times it exceeds a freezing of Greater Caucasus and by 28 times a freezing of Altai [2]. They are distributed unevenly cross territories of the countries of the region. Within Kyrgyzstan there are 8200 glaciers occupying 4,2% of the territory of the country. The water stock of glaciers of Kyrgyzstan is estimated in 650 km$^{\mathbf{3}}$. The quantity of glaciers in Tajikistan makes 8492, about 6% of the territory of the republic. Other part of glaciers is concentrated in Kazakhstan [3].

Figure 1 - Location of Central Asia

In Central Asia more than 4000 reservoirs – lakes and reservoirs are located. The largest of them are the drying-up lake sea Aral Sea, one of the deepest lakes of the world – Issyk Kul, the lake Balkash with fresh-water western and salty east parts. Along with them there are more than 3000 very shallow mountain glacial lakes, tens of reservoirs of seasonal regulation, thousands of pools and ponds of decade and daily regulation.

For the last 100 years (1900 - 2002) temperature in the countries of the Central Asian region increased, and the amount of precipitation decreased [4]. In general the observed global fluctuations of climate which are characterized in the main thing by two periods of warming (till 1940th years and since 1976), have a similar response in regional climate of the countries of Central Asia. At the same time climatic conditions, especially in mountainous areas, fluctuated in wider limits on temperature when its body height in terms of 100 years on certain areas reached 2,5 °C that it is much bigger, than for Earth in general. The amount of precipitation on average across the territory could almost not change, but in certain areas was observed as their body height from 1 - 2 to 20 - 30%, and a larger decrease to 40 - 45%. All this speaks about inhomogeneity of local responses to global and even regional climate changes that needs to be considered at assessment of local climate changes.

In Kazakhstan the common average annual temperature grew by 1,4 °C, and the annual sum of rainfall decreased by 17 mm. Approximately similar climatic changes are observed in other Central Asian states though for the same period temperature in Kyrgyzstan increased by 1,6 °C, the amount of precipitation - by 23 mm. Warming in Turkmenistan happens more in high gear. Average annual air temperature in the territory of the country increases by 0,18 - 0,2 °C in a decade. Rates of change of temperature will become more intensive after 2040. Calculations show that temperature will grow from 2 °C to 7 °C by 2100, at the same time till 2020 slight increase in an amount of precipitation, and then their sharp decrease is expected. Rates of decrease will be more noticeable after 2040, and by 2100 the amount of precipitation will decrease from 8 - 17% [5]. This tendency demonstrates alarming changes if the existing trend remains, it will mean deterioration in climatic conditions Is central - the Asian region towards a larger siccation of climate.

Everything told about the happening climatic changes concerns also Kazakhstan, calculations demonstrate that by 2050 the volume of a river drain in a river basin of Syrdariya will be reduced by 6-10%, and Amudariya will be reduced by 10-15%" [4].

Figure 2 - An average atmospheric precipitation across Central Asia

Besides the volume for assessment of a condition of water resources, in the countries and regions of the world are usually used two more criteria: the specific water security counted as security with water resources per capita, and the extent of use of water resources found as the relation of the complete water consumption to renewable water resources. According to calculations for materials [6], and also on messages of colleagues of the countries of Central Asia on quantity of water resources, security with renewable water resources per capita in Turkmenistan and Uzbekistan – respectively 4681 and 1646 **м**^{3}/people in a year (figure 3) is lowest now. In other countries of Central Asia it is 2 - 3 times higher. At the same time on the Asian continent security with water resources per capita averages 5600 **м**^{3}/persons, on average on the world – 5996 m3/persons (figure 3).

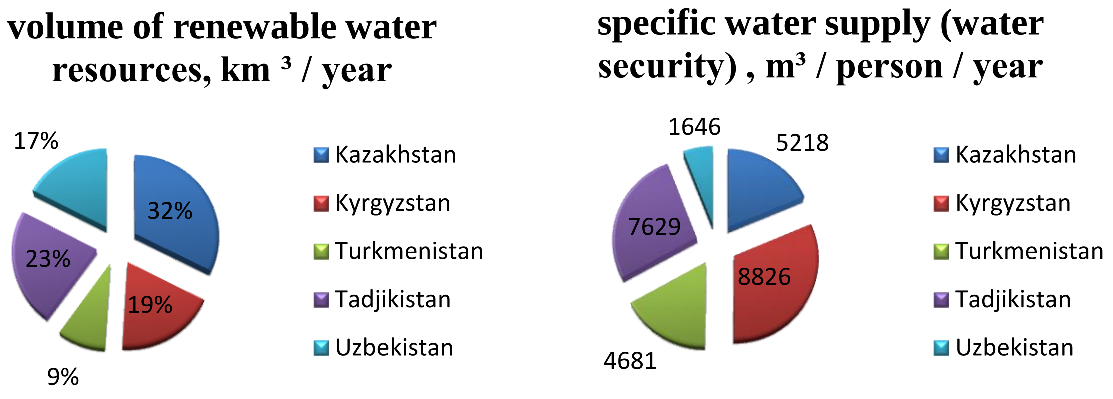

Figure 3 – the located water resources over the countries Central Asia (a), specific water security of the countries of Central Asia for 2015, м^3/persons/year.

In Kazakhstan, the provision of renewable water resources is a little higher than the average world size, in other states it is significantly lower. As a result of rapid population growth in Central Asia specific water supply is rapidly declining. In just half a century in

Kyrgyzstan it has decreased by 2.6 times, Turkmenistan - 3.3 times, Uzbekistan - 3.5 times, Tajikistan - 4 times.

More than 50% of the total flow of water in Kazakhstan is formed outside the country. The largest rivers of Kazakhstan Irtysh, the Syr Darya and the Ili originate in other countries.

The Institute of Geography of Kazakhstan initiated the development of a specialized scientific and technical program " Assessment of resources and forecast of natural waters of Kazakhstan in the conditions of anthropogenic and climate-driven changes" (2010 - 2013 yy.). Researches have shown that in our country, based on identified climate trends, the total surface water resources formed in Kazakhstan and coming from the territories of neighboring countries from 1974 to 2008 amount to 91.3 km^3 (50% probability); of which 44.3 km3 comes from neighboring countries, 47.0 - is a local drain reservoirs of the republic. The natural climatic runoff (restored) is respectively 115.1; 60.2 and 54.9 km^3 per year. Due to the economic activity of the resources of river runoff of Kazakhstan decreased by 23.8 km^3 per year (21%), including cross-border flow - 15.9 (26%), local runoff - 7.9 km3 per year (14%). In view of the implementation of the possible climatic and hydrological cross-border threats in the future, scientists predict a decrease in real resources of river flow as a whole in Kazakhstan in 2020 to 81.6 km^3 per year, including cross-border - up to 33.2; local - to 48.3 km^3 per year; 2030 - 72.4, respectively; 22.2 and 50.2 km^3 per year.

It also notes that "in view of the projected decline in available resources of river runoff in Kazakhstan may occur appreciable changes in the values and consumption patterns, possibly increasing conflicts and contradictions between individual water users, including the aggravation of interstate water relations in transboundary basins [7-9].

Water resources of Central Asia are distributed unevenly; Kazakhstan, Turkmenistan and Uzbekistan fall into to the countries with poor water resources, Kyrgyzstan and Tajikistan to the countries with sufficient water resources. Important feature is that two of its countries, Tajikistan and Kyrgyzstan, are located in a zone of formation of a water drain, and other republics are in its area of dispersion.

From a drain of the river Syrdariya Uzbekistan receives 50,5%, Kazakhstan - 42%, Tadjikistan - 7% and Kyrgyzstan - 0,5%. The drain of the river Amudariya is distributed as follows: to Uzbekistan - 42,2%, to Turkmenistan - 42,3%, to Tajikistan - 15,2%, to Kyrgyzstan - 0,3% [10]. The problem is that the long-term intergovernmental agreements between the Central Asian states on the use of transboundary water resources still do not exist.

Agriculture is the largest consumer of water, the majority of farmlands in the region demands an irrigation. Consuming more than half of all water used in the region, agriculture remains the most "wasteful" consumer - the loss of irrigation water through seepage and evaporation are huge. Channels of irrigational systems are not concreted and are destroyed by the most part; losses of water in them reach 50 - 70% of the entering water volume. Meanwhile, the fast-growing population of the region which increases by 2 - 3% a year, imposes all new requirements to the level of providing with food, potable (drinking) water.

The hydroelectric power share in the common share of a power engineering of the region reaches 27,3%. At the same time in Tadjikistan and Kyrgyzstan it makes 75 - 90%, but in Kazakhstan, Uzbekistan and Turkmenistan no more than 10-15% of the total amount of power generation. The hydropower role in economy of three states is not so important as an agriculture role, but for Kyrgyzstan and Tadjikistan the hydropower represents the most important resource of economic and social development of the country. The common potential water resources of two republics are estimated at 527 billion kW. h, and in the specific relation - 2100 thousand kW. h, on 1 sq.km of the territory.

Water resources play an important role and in development of the industry which consumes up to 29% of all water resources Limited water resources in the region, in particular because basins of the rivers of Central Asia are located in the territory of several states, are a source of the competition, potential probability of the conflicts in Central Asia concerning the quantitative distribution of a drain between the countries, and also because of quality of the water received by the countries, the river basins located in the lower currents.

Solutions of problems. The main contradictions are, in principle, the use of water resources in Central Asia, which is more important: irrigation or hydropower. For some countries, the most important is development of energy, for others - irrigated agriculture. Searches of measures which would allow to combine somehow two mutually excluding approaches to use of water resources in economy of the different countries are necessary.

The Kazakhstan scientists defined two ways of decrease in load of water resources and elimination of deficiency of fresh water. The first path provides realization of actions for decrease of water consumption and use of more modern technologies for reduction of consumption of fresh water in the industry, rural and municipal services.

The second path assumes increase in water resources due to long-term and seasonal regulation of a river drain, use of reserves of underground fresh waters, desaltings of salty and saltish waters, territorial redistribution of water resources [1].

The use of water resources of Central Asia represents a complex of the interdependent problems today: social, political, economic. Lack of efficient management in the sphere of water resources plays a role of the constraining mechanism in their use and protection against pollution. National legislations of the countries of the region on water resources are too “one-sided", they consider only interests of the national states. The unwillingness of the political elites to find a compromise becomes a major obstacle that hinders the effective cooperation in the field of water resources. Though the matter is actively investigated by many experts and the organizations and numerous recommendations on how and what better to do are accepted, there are no actual changes to the best in the sphere of the water relations in common regional scale yet. There are separate examples of successful cooperation of the countries (for example, Kazakhstan - Kyrgyzstan), efficient management in this sphere (a measure for rescue of the Small Aral Sea). But this isn't enough. This question immediately affects all countries of Central Asia, interaction on it is extremely important for socially - economic development of all states of Central Asia. Only combined effects of all countries of the region, taking into account interests of all participants, represent a path for the solution of a problema of water resources. [11].

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MECHANISMS FOR WATER ALLOCATION FOR IRRIGATION IN ARID COUNTRIES: DECISION SUPPORT SYSTEMS, DATA SHARING AND INTERACTIVE SCHEME. EXAMPLES FROM THE MEDITERRANEAN REGION AND CENTRAL ASIA

Repeated droughts in the early 21st century showed the growing risks of conflicting uses of water, especially in the context of climate change. While technological progress is still targeted, especially as regards irrigated agriculture production, new attention is being paid by decision makers at national and transboundary levels to water allocation and to the feedback of relevant practitioners.

This presentation is examining the conditions for building a solid water allocation system between water uses when water resources are getting scarce, such as the institutional and legal framework for quantitative water management, the policy definition and coordination at different territorial scales, the mechanisms for planning and allocating water to farmers based on monitoring devices, and the search for a balance between flexibility and supply guarantee at local level.

The examples feature different sharing of responsibilities between the central and the regional administrations, levels of involvement of users representatives in the water allocation process, and sharing of information including at transboundary level.

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IMPACTS OF CLIMATE CHANGE ON RIVER DISCHARGE IN THE NORTHERN TIEN SHAN: RESULTS FROM LONG-TERM OBSERVATIONS AND MODELLING

В статье представлены предварительные результаты исследований наблюдаемых и прогнозируемых изменений в стоке рек снежно-ледового питания Балхаш-Алакольского бассейна, Казахстан, с использованием продолжительных однородных рядов наблюдений и климатических прогнозов из ансамбля моделирования климатических сценариев. Положительные тенденции расходов были отмечены на большинстве постов в период с 1950х до 2010х гг.. Увеличение расходов наблюдалось на всех постах с мая по октябрь в период с 2000 по 2013 гг. в сравнении с предыдущими десятилетиями, увеличение было особенно значительно в июле-августе на реках с высокой долей оледенения. Эта положительная тенденция в расходах происходит, вероятно, в основном из за повышения температуры. Представлены результаты четырех климатических сценариев с пространственным разрешением 25 км. Эти сценарии были созданы с использованием региональной климатической модели PRECIS, на основе HadGEM GCM для RCP 2.6 и RCP 8.5 сценариев, HadCM 3Q0 и ECHAM5 GCM для сценария A1B. В то время как все сценарии изменения климата показывают увеличение температуры, прогноз осадков варьируется между моделями, по сезонам и пространственно. Была использована модель HBV-ETH для моделирования наблюдаемого и будущего стока рек Улкен и Киши Алматы с использованием климатических прогнозов полученных на основе модели PRECIS-HadCM3Q0 для сценария A1B. Результаты показали, что пик стока на обеих реках был уже достигнут, и вероятно сток будет увеличиваться ближайшие 10-15 лет. Прогнозируется небольшое уменьшение (7-10 %) годового стока рек Улкен и Киши Алматы в период с 2025 по 2044 гг., возрастающее в дальнейшем, и прогнозируемое уменьшение стока наиболее значительно летом.

This paper presents preliminary results of investigation of the observed and projected changes in discharge of the snow- and glacier-nourished rivers of the Balkhash-Alakol basin, Kazakhstan using the long-term homogeneous records and climate projections from an ensemble of climate simulations. Positive trends in discharge were registered at most sites between the 1950s and 2010s. An increase in discharge was observed at all sites between May and October in 2000 – 2013 in comparison with the previous decades which was particularly strong in July-August at the rivers with a high proportion of glacierized area. This positive trend in discharge appears to be driven primarily by an increase in temperature. Results for four climate scenarios with spatial resolution of 25 km are presented. These scenarios were generated using regional climate model PRECIS driven by HadGEM GCM for RCP 2.6 and RCP 8.5 scenarios, HadCM3Q0 and ECHAM5 GCM for A1B scenario. While all climate experiments project increase in temperature, precipitation projections vary between models, seasons and spatially. HBV-ETH model was used to simulate the observed and future discharge for the Ulken and Kishi Almatinka rivers using climate projections from PRECIS-HadCM3Q0 simulation for A1B scenario. The results show that peak flow has already been reached at both rivers and is likely to continue for the next 10-15 years. A small decrease of 7-10% in annual discharge is projected for the Ulken and Kishi Almatinka for the 2025-2044 period increasing thereafter and the projected decline in discharge is more significant in summer.

Introduction. Snow and glacier ice melt play an important role in the formation of river discharge in the mountains and this makes water resources in mountainous regions particularly vulnerable to climate change. Variability and change in discharge are of practical importance in the areas where mountains supply water for domestic, industrial and agricultural use on the water-deficient plains and for electricity generation. One of such regions is the Tien Shan mountains and its foothills. Here, water derived from snow and glacier melt is used for irrigating agricultural land, from the industrial-scale cotton production in the Aral Sea basin to the smaller-scale commercial and subsistence farms in the Balkhash-

Alakol basin. Many rivers cross national boundaries and changes in discharge, either natural or due to the growing water abstraction, have become an issue of high political importance which is envisaged to grow with time.

While the need for reliable information on the observed and projected future changes in discharge is well recognised, there are still few reliable quantitative assessments of both because of a lack of the long-term, homogeneous and continuing discharge observations and future climate projections generated using regional climate models capable of resolving individual mountain ranges and valleys. A detailed review of changes in river discharge in the Tien Shan has been provided in [1] where contrasting trends were reported for its different sectors including increasing summer runoff in the northern and inner Tien Shan, decreasing summer runoff in the central and western Tien Shan and at the lower elevations in the inner Tien Shan. More recently, positive trends in the discharge in the headwater catchments of the Tarim River were reported [2, 3, 4] attributing these changes primarily to the increasing glacier melt but highlighted as a limitation of the studies their inability to quantify water abstraction and its contribution to the long-term trends. A sensitivity study [5] investigated changes in discharge in the upper Pajn catchments in response to selected shifts in temperature and concluded that under the annual temperature rise of 2-3^{o}C, while annual discharge will change little, a significant shift in discharge maximum from summer to spring will occur by the 2050s unfavourably affecting water resources.

One region where the long-term records of discharge exist is the Balkhash-Alakol basin of Kazakhstan. Its rivers originate in the ranges of the northern Tien Shan (i.e. Zailiiskiy Alatau) and in Djungarskiy Alatau where glacier area and volume loss at a rate of 0.8% a^{-1} and 1% a^{-1} respectively between 1950-s and 2010a have been reported [6]. In this paper, we investigate climatic and hydrological trends in the northern Tien Shan and Djungarskiy Alatau using the long-term, homogenous data sets, present multiple climate change projections from an ensemble of RCM simulations and preliminary results of projections of hydrological change.

Data and Methods

Meteorological and Discharge Data. Monthly and daily meteorological data have been obtained from multiple sources including archives of the Institute of Geography, Almaty, and the Kazakhstani National Hydrometeorological Service for the 1960-2013 period (1978-2013 for the Tuyuksu station). For the analysis of trends in temperature and precipitation, we selected thirteen stations located above 1500 m a.s.l. in northern, central and western Tien Shan which supply continuous and uninterrupted data, are not affected by urban influence and whose locations have not changed significantly over time. For hydrological modelling and attribution of hydrological trends, we used daily data from three stations located in the Zailiiskiy Alatau in the valleys of the rivers Ulken (Bolshaya) Almatinka and Kishi (Malaya) Almatinka – Bolshoe Almatinskoe Lake (2500 m a.s.l.), Mynzhilki (3010 m a.s.l.) and Tyuksu (3440 m a.s.l.).

Daily hydrological data have been collected for the rivers of the Balkhash-Alakol basin, Kazakhstan. The hydrological data have been collected from the Annual Data on Water Regime and Resources reports published annually by the Kazakhstani National Hydrometeorological Service since the 1940s. Prior to the analysis, the data have been digitised and data quality control has been implemented checking for errors which may have been introduced during either archiving or digitization. The number of gauging stations in the Balkhash-Alakol basin varied in time reaching its maximum (well over 100) in the 1980s, declining to just 22 in the 1990s and being partially re-installed in the 2000s. For the analysis of long-term trends, we applied the following criteria to the selection of hydrological gauging sites: (i) at least 40 years of ongoing measurements; (ii) less than 10 years of missing data; (iii) permanent location or insignificant changes in location or surroundings; (iv) no water abstraction; (v) no significant disturbances to sites (e.g. mudflows or landslides) affecting homogeneity of the records. Using these criteria, six gauging sites were selected for further analysis (Table 1).

Table 1. Selected discharge gauging sites and catchment characteristics. The catchment areas are calculated up to the gauging site. The names of the gauging sites are given as in the Annual Data on Water Regime and Resources reports.

River	Site	Start year	Missing years	Catchment area (km^2)	% glacierized (year)
Ulken (Bolshaya) Almatinka	Upstream from Bolshoe Almatinksoe Lake	1952	1994, 1999	71.8	16.6 (2006)
Kishi (Malaya) Almatinka	Below Sarysai mouth	1974	1994	45.2	12.3 (2006)
Prohodnaya	At its mouth	1965	1994	82	4.1 (2008)
Turgen	At Tauturgen	1950	1994, 1998-99	598	3.3 (2008)
Osek (Usek)	1.7 km upstream of Kishi Osek	1961	1994, 1999-2006	724	4.9 (2006)
Kishi (Malyi) Osek (Usek)	0.2 km upstream from confluence with Osek	1961	1994, 1999-2006	407	6.4 (2006)

Climate scenarios. The baseline and future climate change scenarios were generated using RCM PRECIS (PREdicting Climate for Impact Studies) developed by the UK Met Office [7]. PRECIS is a hydrostatic, primitive-equation model with a horizontal resolution of 0.22^o (~25 km). Factional grid box land cover is used to improve detail of surface characterisation. PRECIS derives lateral boundary conditions from Global Circulation Models (GCM) and Era Interim reanalysis. In this study, five integrations have been performed forced by ERA Interim reanalysis for 1980-2004 and three GCM including HadGEM for RCP 2.6 and 8.5 scenarios and HadCM3Q0 and ECHAM5 for A1B scenario whereby the baseline climate was simulated for the 1960-2004 period and future climate for the 2005-2099 period. The model domain extended between 32.3^{o}N and 51.5^{o}N (Fig. 4 and 5 later in the text) and included the plains of Kazakhstan and Central Asia in the north and the mountainous areas of the Tien Shan, Pamir and Djungarskiy Alatau in the south. The present day land cover was assumed with two land cover types representing over 50% and over 25% of each grid box. The boundaries of the Aral Sea were adjusted manually on the seasonal basis.

Model validation was performed using the simulation driven by ERA Interim reanalysis and observational data sets including the Climate Research Unit temperature and precipitation data sets (CRU TS 3.23), Global Historical Climatology Network temperature data set (GHCN_CAMS) and Global Precipitation Climatology Centre data set (GPCC V6) for the 1980-2004 period. We used the set of metrics from [8] to evaluate the GCM-driven simulations of air temperature and precipitation.

Hydrological modelling. The HBV-ETH model, whose full description is given in [9] and a description of the latest version in [10] was used to simulate discharge. The input data consist of topographical and daily meteorological and discharge data, the former required to drive the model and the latter for calibration. Glacier mass balance can be used as an objective function to constrain the model. The topographical input data include total and glacierized area and aspect presented by three classes (north, south, east-west-horizontal) required for the calculation of solar energy input, all calculated for 200 m elevation bands. Solid and liquid precipitation are distinguished using vertical temperature gradients and a threshold temperature while basin precipitation is calculated using a seasonally stable precipitation gradient. The snow and glacier melt are calculated using temperature index method and meltwater refreezing in snowpack is accounted for by the use of a refreezing coefficient which is applied when temperature falls below the threshold temperature for melt. Rainwater and meltwater provide input for the soil moisture routine while actual evapotranspiration is calculated from potential evaporation dependent on the soil moisture content. The model output consists of discharge, basin precipitation, evapotranspiration and storage change for glaciers, snow and groundwater.

In this study, we modelled discharge for the Ulken and Kishi Almatinka rivers using daily discharge for the 1984-2004 period (used in part for calibration and validation), daily temperature and precipitation data from the Tuyuksu station, annual mass balance for the Tuyksu glacier (from which the Kishi Almatinka originates) and glacier masks for 1990 and 2000 derived the Landsat imagery. The Nash–Sutcliffe efficiency (NSE) criterion was used to characterise the agreement between the measured and simulated daily discharge.

The future discharge scenarios were developed using the outputs from the range of numerical climate simulations using PRECIS, described in the previous section, for the 2005-2099 period. The modelled data were bias corrected using observations from the Tuyuksu station. Daily air temperature data were corrected using scaling factors and precipitation data were corrected using the delta change method. While various glacier change scenarios will be considered in the future, here we used an assumption that glacier area will continue shrinking at a rate of 1% per year. In this paper, results for the PRECIS-HadCM3Q0 A1B scenario are shown for the 20-year time slices. The calibration mode HBV-ETH parameters were used for modelling future discharge.

Results

Observed meteorological and hydrological trends. Analysis of the monthly temperature time series has shown that the strongest warming in the Tien Shan takes place in the autumn (September-October-November; SON) months. Positive linear trends, statistically significant at 0.05 confidence level, were registered at all stations with the rates of warming varying between 0.19^{o}C per 10 years to 0.46^{o}C per 10 years. The variability in the rates of warming did not exhibit any spatial or altitude-related pattern. In winter (December-January-February; DJF), eight of thirteen stations exhibited statistically significant positive trends. In spring (March-April-May; MAM) and summer (June-July-August, JJA), the warming signal was less pronounced. Thus in MAM, only three stations in the Zailiiskiy Alatau exhibited a statistically significant warming trend. In JJA, statistically significant trends were registered in the northern and central Tien Shan above 2500 m a.s.l. in line with the hypothesis of elevation-dependent warming [11]. The precipitation time series exhibited strong interannual and decadal variability but no significant long-term change.

Analysis of the long-term trends of seasonal discharge from the selected gauging sites shows that in most seasons and at most gauges positive trends in discharge were observed (Figure 1). Thus at four rivers, discharge increased in every season with a strong growth in SON, when discharge was increasing at a rate of about 1% a^{-1}. In JJA, an increase in discharge of 0.7 – 1 % a^{-1} was observed at the rivers in whose catchments the proportion of glacierized area was relatively high such as the Ulken Almatinka and Kishi Almatinka (Table 1). On the monthly basis, the strongest increase was observed in September indicating that the duration of melting period extends into the early autumn. It is also in SON that the number of days with the extreme discharge, defined as daily values in excess of 95th percentile (calculated for each season), increased throughout the region. Figure 2 illustrates the observed increase in the frequency of days with extreme discharge values for the Kishi Almatinka river.

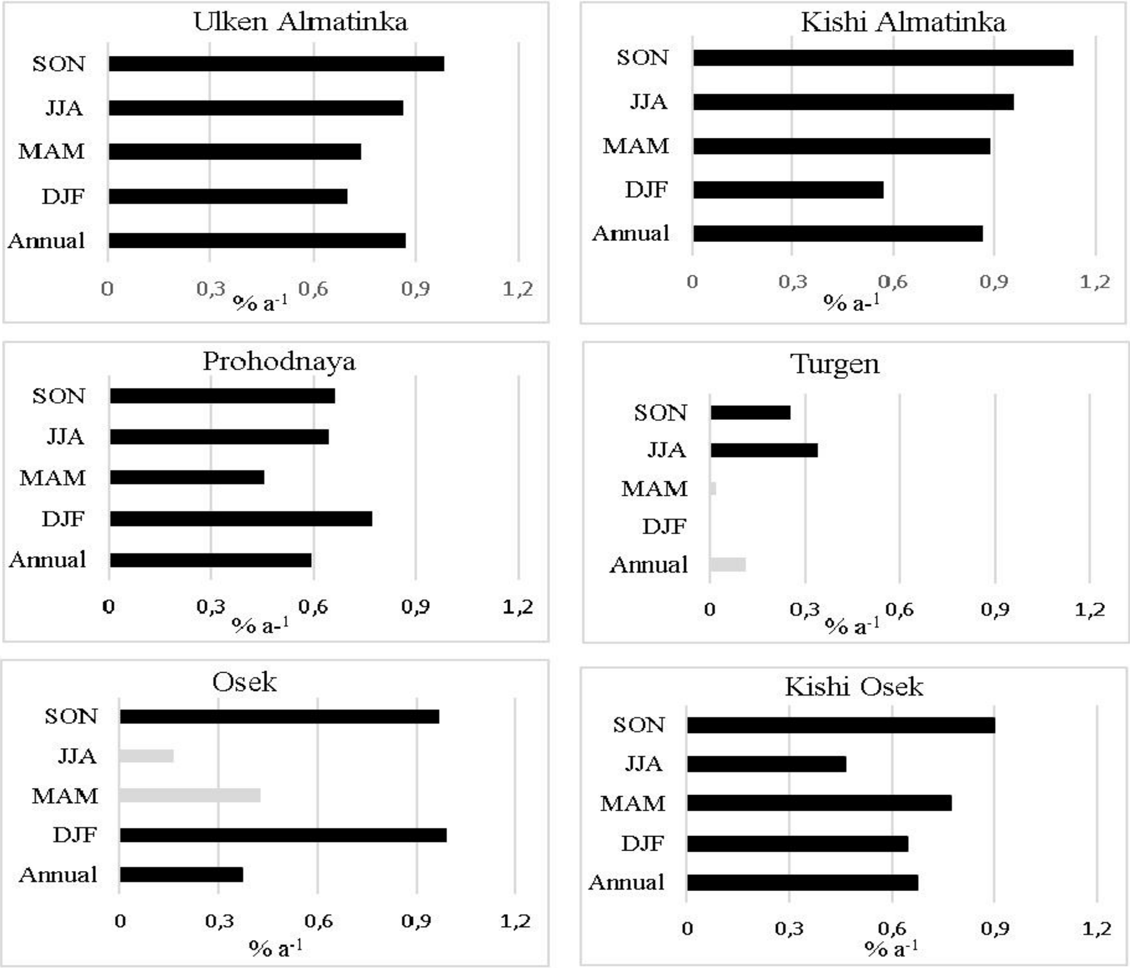

Figure 1 – Trends in seasonal discharge (% a^{-1}) over the periods of observation (Table 1) calculated using Mann-Kendall test. Black bars represent trends significant at 0.05 confidence level.

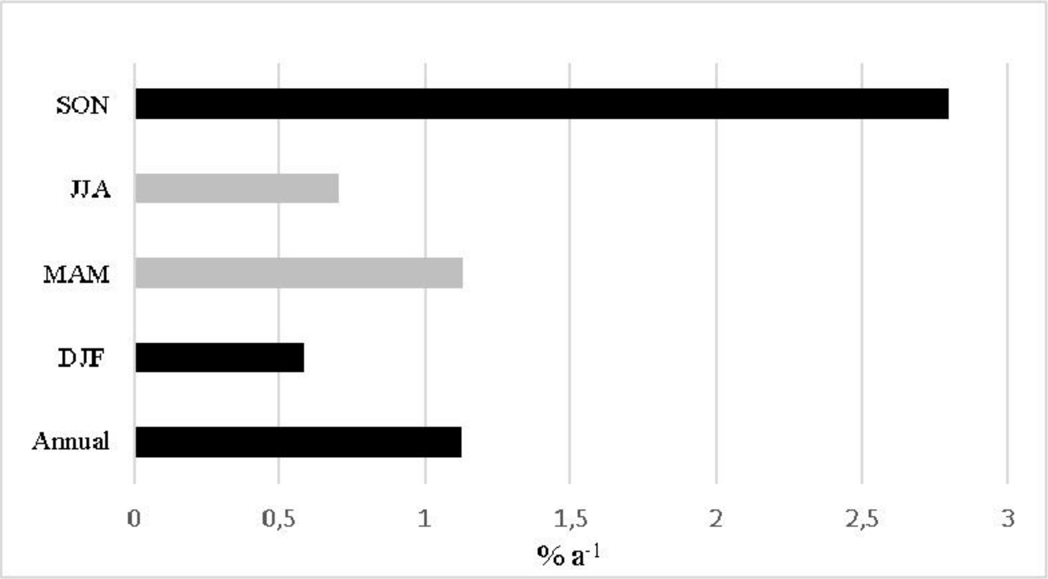

Figure 2 – Trends in occurrence of the number of days with extreme discharge values (% a^{-1}) at the Kishi Almatinka river between 1974 and 2013 calculated using Mann-Kendall test. Black bars represent trends significant at 0.05 confidence level. The extreme values are defined as those exceeding 95th percentile.

In order to assess changes in hydrographs, decadal averages of daily discharge were calculated for the selected gauging sites (Figure 3).

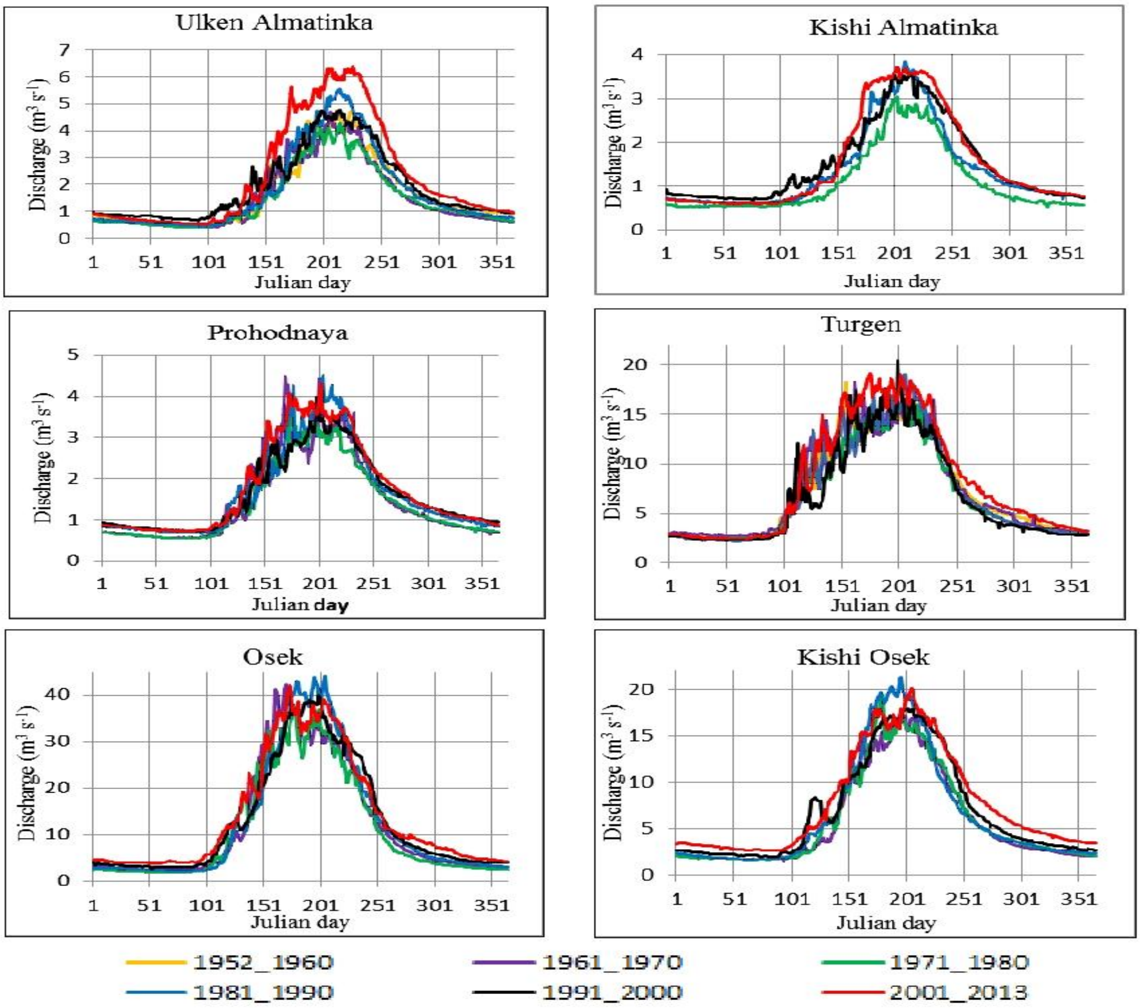

Figure 3. Decadal averages of daily discharge. Note that for the Osek and Kishi Osek rivers, data for the 1991-1998 and 2006-2013 time periods were used.

An important change, observed at all rivers of the Zailiiskiy Alatau, was an increase in discharge between the end of May and the end of September (extending into October-November), after the 1980 and particularly in the 2000-2013 period in comparison with the earlier decades when discharge, although varying from year to year, on average remained stable. This trend was particularly notable in the Ulken Almatinka which has the highest percentage of glacierized area as well as the extent of buried ice and permafrost. At the Ulken Almatinka, a clear peak in discharge as well as the strongest increase were registered in the last decade of July and two first decades of August which is the period of strongest glacier melt. At the Kishi Almatinka, the highest discharge values were observed throughout JJA pointing at importance the snow melt contribution into discharge. Changes in discharge at the Djungarian rivers of the Osek and Kishi Osek follow the similar pattern although in the 1980-1990, the JJA discharge values were comparable with those registered in the 2006-2013 period or higher which can be partly attributed to the missing data and partly to the lower proportion of glacierized area (see Table 1).

Linear regression analysis was used to quantify the relationships between mean seasonal discharge of the Ulken and Kishi Almatinka rivers and seasonal temperature, precipitation and glacier mass balance for the concurrent seasons and with a time lag, i.e. discharge lagging temperature and precipitation by 3, 6, 9 and 12 months. It was assumed that MAM and JJA temperatures served as predictors of impact of snow (MAM, JJA) and glacier (JJA) melt on discharge; precipitation for any concurrent season served as predictor of direct impact of [mostly liquid] precipitation; and precipitation for the earlier months signified the relationship with water release from catchment storage of which accumulated snow was the main component. For the Ulken Almatinka, coefficients of determination significant at 0.05 confidence level were obtained for JJA and SON discharge and temperature of the concurrent seasons (with R^2 values of 0.19 and 0.15 respectively) pointing at the importance of snow and glacier melt in the catchment with a higher proportion of glacierization as well as extension of glacier melt into the early autumn. For the Kishi Almatinka, there was a statistically significant relationship between SON discharge and temperature (R^2 of 0.15). In both catchments liquid precipitation persisted later into the season contributing to higher discharge. In both catchments, precipitation accumulated over previous twelve months was a significant predictor of JJA discharge. For the Kishi Almatinka, precipitation accumulated over previous 9 and 12 months was also a significant predictor of MAM discharge. In neither catchment precipitation of the concurrent season was an important predictor of discharge with an exception of JJA precipitation and discharge of the Kishi Almatinka, and neither were components of mass balance.

Climate scenarios. The validation of the numerical climate experiments has shown that all model combinations simulated air temperature well reproducing both annual cycles and spatial temperature distribution over the modelling domain correctly in all seasons. In the northern Tien Shan, bias in monthly temperature values simulated using PRECIS-GCM in comparison to the simulation driven by ERA Interim and the observational data sets varied between -1 K and +2 K. The values of pattern correlation, quantifying models' ability to reproduce spatial distribution of meteorological variables, varied between 0.93 and 0.99 showing that all model combinations reproduced spatial temperature patterns reliably in all seasons. Modelling precipitation was a more challenging task, especially in the mountainous areas. In our experiments, all models reproduced annual cycle of precipitation in the northern Tien Shan although modelled precipitation peaked in April while the observational data sets exhibited annual maximum in May. Modelled precipitation exceeded the observed values during the cold part of the year between October and April. This overestimation was particularly strong in the simulations driven by the ECHAM5 GCM which inflated monthly precipitation by the factor of two. The overestimation of precipitation resulted primarily from the overestimation of the westerly flow by the models. In summer, the Hadley Centre models tended to underestimate rainfall possibly due to the overestimation of evaporation from the falling hydrometeors during convective precipitation. Despite the high bias values, all models reproduced spatial distribution of precipitation well with pattern correlation values of 0.55 – 0.71 in DJF and higher values in other seasons.

Figure 4 illustrates changes in DJF and JJA temperature for four climate experiments. Until the middle of the 21st Century, changes in air temperature simulated in the experiments driven by HadGEM for 2.6 RCP scenario and by ECHAM5 for A1B scenario were within 1-2K in comparison with the baseline period of 1980-2004 for DJF, MAM and SON but were stronger at 2-3K for JJA. The simulation driven by HadCM3Q0 projected a stronger warming for A1B scenario as well as the simulation driven by HadGEM for RCP 8.5 scenario. As expected, the differences between scenarios increased in 2050-2075 with the weakest warming projected by the HadGEM-driven simulation for RCP 2.6 scenario and the strongest warming projected for the RCP 8.5 scenario. In the study region, in JJA temperatures were projected to increase by 2-3 K and 5-6 K respectively in the second half of the 21st Century.

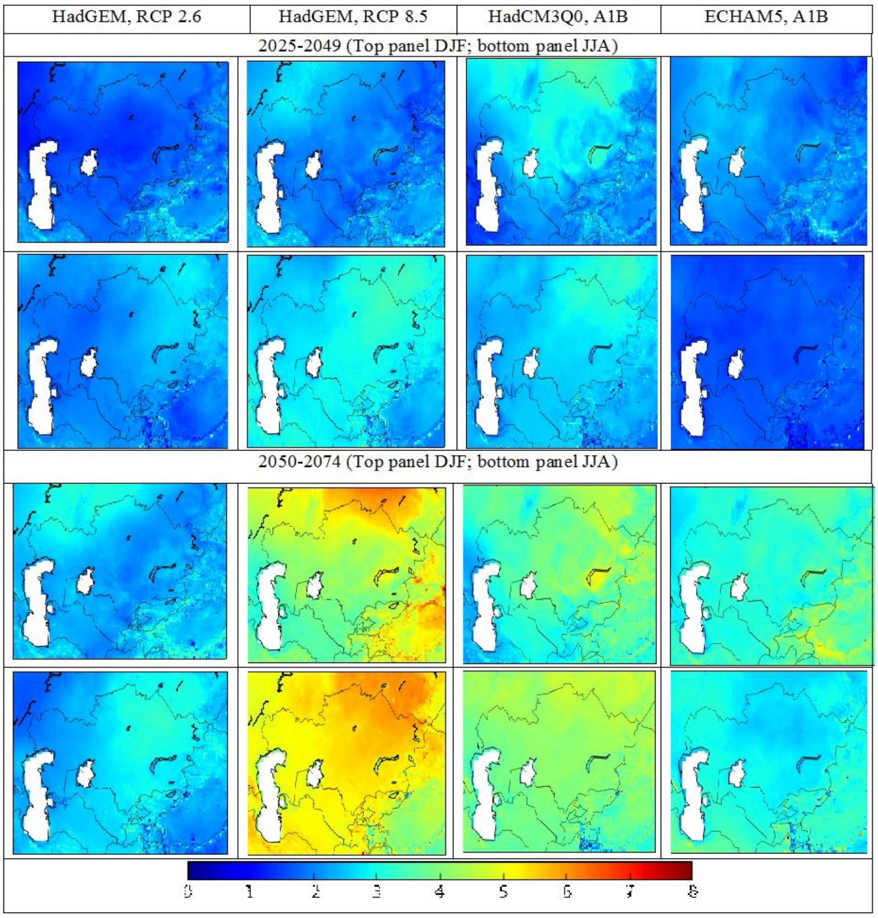

Figure 4 – Change in seasonal air temperature (K) in the 2025-2049 and 2050-2074 periods in comparison with the baseline period of 1980-2004.

The relative changes in precipitation are shown for all four seasons as precipitation maxima in most regions are observed in late spring and in autumn (Figure 5). The projected changes exhibited a complex, altitude-dependent pattern. In 2025-2049, all simulations except the one driven by ECHAM5 (which projected the weakest warming) projected an increase in DJF precipitation in the foothills and on the plains adjacent to the northern Tien Shan and no significant change or a small reduction in precipitation at higher elevations. The projected changes in MAM precipitation exhibited stronger spatial variability in the HadGEM-driven simulation for RCP 2.6 scenario and a decrease up to about 20% in all other simulations. A decline in JJA precipitation was projected in the study area. For the 2050-2074 period (not shown), all models simulate a 20-40% increase in DJF, 0-20% decrease in SON and 10-40% decrease in MAM precipitation. Projections of JJA precipitation were characterised by the largest differences between the different model combinations. The HadGEM-driven simulation for RCP 2.6 scenario and the HadCM3Q0-driven simulation for A1B scenario projected drying across the northern Tien Shan and the adjacent plains except for the high-elevation (approximately above 3000 m a.s.l.) region where an increase of 10-20% was expected. The HadGEM-driven simulation for RCP 8.5 scenario and ECHAM5-driven simulation for A1B scenario exhibited strong spatial variability in precipitation changes across the Balkash-Alakol basin with little change in the foothills and 20-30% increase in precipitation at higher elevations.

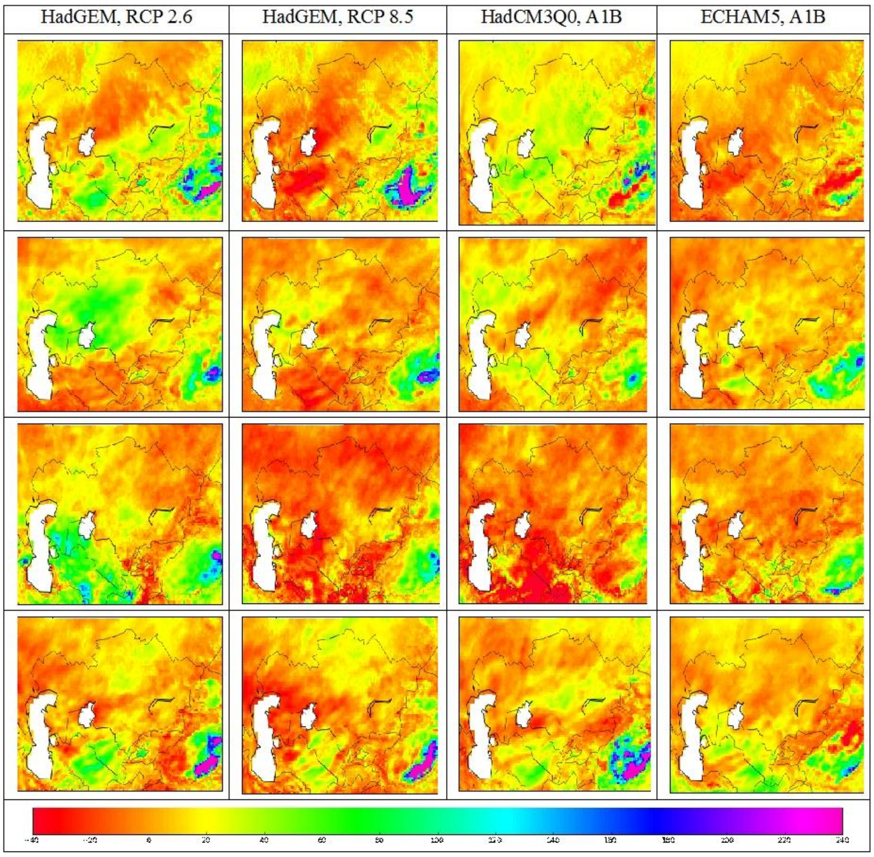

Figure 5 – Change in seasonal precipitation (%) in the 2025-2049 period in comparison with the baseline period of 1980-2004. From top to bottom, the panels are for the following seasons: DJF, MAM, JJA, SON. Note that a very strong relative increase in precipitation in the Taklamakan desert (as well as other desert areas) is an artefact of the very low baseline precipitation values.

Modelling discharge using observational and simulated climate data. The HBV-ETH model was run is the calibration mode for 6 years for the Ulken Almatinka and for 10 years for the Kishi Almatinka using the observed discharge and climate data. The NSE values for daily variations of discharge ranged between 0.83-0.94 for both rivers. The model was run in the calibration mode for 12 and 9 years for the Ulken Almatinka and the Kishi Almatinka respectively. The lowest and the highest values of NSE for daily discharge were 0.73 and 0.94 although most NSE values were within the 0.83-0.94 range showing that the model performed well on a daily time step. For the assessment of water resources, however, the model's ability to reproduce monthly discharge is more important. Coefficients of determination between the monthly values of the observed and modelled discharge for the validation years were 0.99 and 0.98 for the Ulken and Kishi Almatinka respectively. The monthly hydrographs for the Ulken Almatinka and Kishi Almatinka for the baseline period and future scenarios are shown in Figure 6. In all simulations, no change in monthly and annual discharge is projected for the 2005-2024 period in comparison with the 1980-2004 period.

For the PRECIS-HadCM3Q0 A1B scenario, in 2025-2044, annual discharge declines by 10% and 7% for the Ulken and Kishi Almatinka rivers respectively and in 2045-2064, by 23% and 17%. Seasonal differences, however, are more pronounced. No significant change in discharge was projected for the October – March and October – April periods for the Ulken and Kishi Almatinka respectively until the end of the century. The JJA discharge is expected to decline for the Ulken Almatinka, 13% and 29% decline is expected for the 2025-2044 and 2045-2065 periods. For the Kishi Almatinka, 13% and 27% decline is expected.

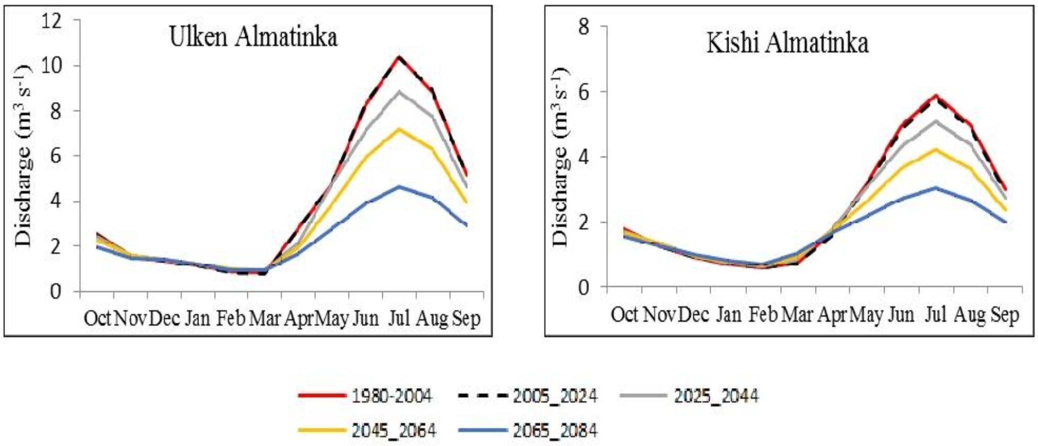

Figure 6 – The baseline (1980-2004) and future discharge scenarios for PRECIS-HadCM3Q0 A1B simulation.

Discussion and conclusions

This paper presented preliminary results of investigation of the observed and projected changes in discharge of the snow- and glacier-nourished rivers of the Balkhash-Alakol basin using the long-term homogeneous records and climate projections from an ensemble of climate simulations. The main findings are as follows:

(i) Positive trends in discharge were registered at most sites;

(ii) An increase in discharge was observed at all sites between May and October in 2000 – 2013 in comparison with the previous decades;

(iii) The strongest increase in discharge was observed between the end of July and the middle of August at the Ulken Almatinka which has the highest proportion of glacierized area;

(iv) An increase in the number of days with extreme discharge values was registered at most sites especially in SON;

(v) The observed changes appear to be driven primarily by an increase in JJA and SON temperature;

(vi) A small decrease of 7-10% in annual discharge is projected for the Ulken and Kishi Almatinka for the 2025-2044 period increasing thereafter and the projected decline in discharge is more significant in JJA.

Although glaciers lost about 40% of their area between the 1950s and the 2010s [11], summer and early autumn discharge increased across the study area and particularly strongly in the catchments with the higher proportion of glacierized area. This implies that glacier area reduction is compensated by the enhanced melt rates, a phenomenon observed in other regions of Central Asia [5]. Results of discharge modelling showed that while there was a close correspondence between the observed an modelled discharge values during the period of most intensive melt in late July – early September in the 1990s, an underestimation of discharge by HBV-ETH in the same season was observed in the recent years. We tentatively suggest that this underestimation indicates that melting permafrost and buried ice, which is not accounted for by HBV-ETH, may contribute to runoff compensating for the loss of glaciated area and sustaining high values of the currently observed discharge.

Analysis of the observational and modelled data suggest that peak discharge at the rivers of the Balkhash-Alakol basin might have already been reached and might be expected to continue for the next 10-15 years for the A1B scenario that is indicative of medium increase in greenhouse gas emissions and 1% a^{-1} decrease in glacierized area scenario. The HadCM3Q0 model is characterised by stronger sensitivity that ECHAM5 and PRECIS-

HadCM3Q0 experiment generates stronger summer and autumn warming for the same scenario (Fig. 4) representing medium to strong climatic warming. For this combination of scenarios, JJA discharge is expected to decline by 27-29% after 2045. The interviews with farmers and members of the Water Users Associations conducted in February 2016 in the Almaty region have revealed that already now, when discharge is at its peak, many farmers face a shortage of water. Most of the interviewed farmers and other water users erroneously believe that that the lack of water is caused by the climatic warming and associated reduction in discharge while in fact, it results from the poor state of the irrigation systems, ill-defined water rights and management in need of improvement. Combined with increase in evapotranspiration and summer drying, the projected decrease in JJA discharge is likely to raise further problems for water use in agriculture and considerable effort and investments will be required to adapt to this change.

Uncertainties in projections of discharge and timing of peak flow arise at every stage of the modelling process. The application of the full range of climate scenarios will enable us to assess uncertainty arising from the use of climate projections generated by different PRECIS-GCM combinations. This is particularly important with regard to the projected precipitation as strong between model variability exists especially with regard to the accumulation season precipitation (Fig. 5). This problem is further exacerbated by uncertainty in prediction of fractions of solid and liquid precipitation at different elevations. The use of modelled climate data with high spatial resolution will enable us to address this issue and will provide an improvement on the previously used GCM scenarios. The use of multiple scenarios of elevation-distributed glacier change is another planned improvement to this study as well as the extension of hydrological projections to other catchments of the Balkhash-Alakol basin.

Acknowledgements

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CENTRAL ASIAN BILATERAL AND MULTILATERAL AGREEMENTS ON WATER MANAGEMENT

This research in the scope of water law mainly developed on the basis of the principles of legal analysis, used in national and foreign legal science: formal-legal, comparative-legal, formal-logical and others. Main importance for the research were general theoretical and special scientific works of scientists-Jurists, reports on the work of the International Law Commission, the international legal instruments of universal, regional and bilateral nature.

The greatest importance for the research were general-theoretical and special scientific works of Jurists-scientists, reports on the work of the international legal instruments of universal, regional and bilateral nature.

Since analysis the important tools of qualitative research, the study has managed to use this method for data collection. Most of the documents which have been used were collected from the internet and the project documents taken from the projects. These were the reports of the programs. Some information was even taken from the journals, newspaper; nevertheless, it was useful to read them for later analyses.

The main objectives are theoretical and content analysis of regulations, international, regional, national water laws and other instruments developed in the field of the use of international watercourses, as well as to disclose the content of the principles and mechanisms of international water law for the establishment of joint bodies and identify gaps to establish joint bodies in the legal regulation of international, regional and national levels in Central Asia.

Это исследование в рамках водного права в основном разработано на основе принципов правового анализа, используемого в отечественной и зарубежной юридической науке: формально-юридического, сравнительно-правового, формально-логического и других. Основное значение для исследования имели общие теоретические и специальные научные труды ученых-юристов, отчеты о работе Международной Юридической Комиссии, международные правовые инструменты универсального, регионального и двустороннего характера.

Наибольшее значение для исследования приобрели общетеоретические и специальные научные труды ученых-Юристов, отчеты о работе Международной Юридической Комиссии, международные правовые инструменты универсального, регионального и двустороннего характера.

Проанализировав важность инструмента качественного анализа, для исследованиябыл использован этот метод сбора данных. Большинство использованныхдокументовбыли найдены в Интернете, а также была использована проектная документация взятая из проектов. Это были отчеты программ. Некоторая информация была даже взята из журналов, газет; тем не менее, было полезно прочитать их для последующего анализа.

Основными задачами являются теоретический и содержательныйанализ нормативных актов, международных, региональных, национальных законов о воде и других документов, разработанных в области использования международных водотоков, а также раскрытие содержания принципов и механизмов международного водного права для создания совместных органов, выявление пробелов в создании совместных органов в их правовом регулировании на международном, региональном и национальном уровнях в странах Центральной Азии.

Су заңдарының шеңберінде осы зерттеу жұмысы негізінен ұлттық және шетел заң ғылымы пайдаланатын құқықтық талдау принциптері негізінде әзірленген, олар - құқықтық-ресми, салыстырмалы-құқықтық, формалды-логикалық және басқалары. Зерттеу үшін негізіненғалым-заңгерлердің жалпы теориялық және арнайы ғылыми жұмыстары, Халықаралық Құқық Комиссияның жұмысы жөніндегі есептері, әмбебап, өңірлік және екіжақты сипаттағы халықаралық құқықтық құжаттар маңызды болды.

Зерттеу үшінең маңыздысығалым-заңгерлердің жалпы теориялық және арнайы ғылыми жұмыстары, Халықаралық Құқық Комиссияның жұмысы жөніндегі есептері, әмбебап, өңірлік және екіжақты сипаттағы халықаралық құқықтық құжаттарболды.

Сапалы талдаудың маңыздылығын біле тұразерттеуде деректерді жинау үшін осы әдіс пайдаланылды. Қолданылған құжаттардың көпшілігі интернеттен табылды және жобалардан жобалық құжаттар алынды. Бұл бағдарламалардың есептеріболды. Кейбір ақпараттіпті журналдар, газет алынды; Соған қарамастан, олар кейініректалдау үшін пайдаланыла алады.

Негізгіміндеттер-халықаралықағын суларын пайдалану саласындағы дамыған халықаралық, өңірлік, ұлттық су заңдары мен өзге де құралдарды теориялық және мазмұндықталдау, сондай-ақбірлеске нօргандардықұруүшін халықаралық су құқықтыңқа ғидаттары мен тетіктерінің мазмұнынашып көрсету, олардың Орталық Азиядағы халықаралық, өңірлік және ұлттық деңгейде құқықтық реттеу кемшіліктерін анықтау.

The legal regime of the vast number of international rivers is regulated by treaties concluded between coastal States. If the interests of international basins required, each of them has the right and the duty to make arrangements with other coastal States on the settlement of the joint use of the waters of the basin, and to do this, use the international instruments. In practice there are various precedents in international law for the settlement of disputes on the use of international rivers.

Water resources are a key link of the Central Asian countries -, major quantity of water sources are forming in upstream countries (Kyrgyzstan, Tajikistan) and major quantity are used by downstream countries (Kazakhstan, Turkmenistan and Uzbekistan).

Central Asian countries cooperate on transboundary waters more than 20 years. Effective management of water resources of Central Asia – retains its relevance for politic and economic cooperation as well as cooperation in the field of the environment on this region. Effects of climate change: increasing temperature, reducing the length of the rain season, drying up fertile land, lack of clean drinking water and water for irrigation, are becoming increasingly clear outlines and require increased cooperation among states. Water quality issues, which have been neglected in the past, are increasingly recognized as being of particular importance to regional cooperation in Central Asia region. Institutional and legal mechanisms for managing water resources in Central Asian states was founded in the late nineties, after the collapse of the Soviet Union, to provide leveling many negative tendencies manifest in the relationship of the states[1].

Table – Treaty law as applied to transboundary waters in the Aral Sea Basin

		Kz	Kg	Tj	Tm	Uz
Agreements						
1992	Agreement on cooperation in the joint management, use and protection of water resources of interstate sources	✓	✓	✓	✓	✓
1993	Agreement on joint action to address the problem of the Aral Sea and surrounding areas, environmental improvement and socio-economic development of the Aral Sea region.	✓	✓	✓	✓	✓
1996	Chardjev Agreement	✓	✓	✓	✓	✓
1996	Agreement on the use of fuel and water	✓	✓	✓	✓	✓
1998	Agreement on the use of water and energy resources in the Syr Darya River basin	✓	✓	✓		✓
998	Environmental Cooperation Agreement	✓	✓	✓	✓	✓
1999	Agreement on the Status of the International Fund for Saving the Aral Sea and its Organizations	✓	✓	✓	✓	✓
2006	Framework Convention for the protection of the environment for sustainable development in Central Asia		✓	✓		✓
Declarations						
1997	Almaty Declaration	✓	✓	✓	✓	✓
1999	Ashkhabad Declaration	✓	✓	✓	✓	✓
1995	Nukus Declaration	✓	✓	✓	✓	✓
2001	Tashkent Declaration	✓	✓	✓	✓	✓
2002	Dushanbe Declaration	✓	✓	✓	✓	✓

Note: Source – http://ec-ifas.waterunites-ca.org/aral_basin/legal-issues.

Statement, signed 12.09.1991 by the ministries of water resources of Central Asian countries laid the foundation for international cooperation recognizing the need to address issues of water resources in the basin of the Aral Sea as a common to all countries based on the principles of fair regulation in the interests of all countries in the region. Besides, there are other agreements related to cooperation on water in Central Asia. Since reaching the independence countries adopted a numbers of multilateral and bilateral agreements on shared water resources management on main basins (Syr Darya and Amu Darya), established institutions and joined the international conventions on water. Thus, from the legal point, countries have established binding instruments and documents.

Sustainable and equitable use of water in Central Asia is one of the important factors for the future sustainable development of the region. Joint problem solving, equitable use of transboundary rivers on the basis of international law is a vital need[2].

Conditions of bilateral and multilateral water cooperation in Central Asia. Water cooperation in Central Asia is reflected in regional and sub-regional agreements, mainly agreement signed by all 5 states of region, such as the Agreement on cooperation in joint management, use and protection of water resources of interstate sources of 1992 and on joint actions to address the problems of the Aral Sea environmental improvement and social economic development in the Aral Sea region of 1993, sub-regional Agreement on water and power resources use in the Syrdarya River basin of 1998 (between Kazakhstan, Kyrgyz Republic, Tajikistan and Uzbekistan).

The 1992 Agreement on cooperation in the joint management, use and protection of water resources of interstate sources. This is first fundamental instrument, which defines the principles of cooperation in the region, regarding to using of “water resources of interstate sources”. The adoption of the Agreement happened immediately after the collapse of the Soviet Union. The 1992 Agreement allowed, to an extent, to put in order the relationships between the independent states of Central Asia regarding transboundary water resources. At the same time, the understandable haste with which the 1992 Agreement was drafted and adopted could not but affect its content and form.

The main purpose of the Agreement was to create a firm legal framework for regional water cooperation through joint management of water use and allocation. The main principles of Agreement corresponded to international practice. These include: [3]

–the equality of rights to use and common responsibility for the states for transboundary water resources;

–obligation to respect the agreed procedure and rules for the use and protection of transboundary water resources;

–obligation to avoid actions that may affect the interests of other States.

The Agreement played crucial role in establishing institutional mechanisms for water cooperation in the region.

The 1993 Agreement on joint action to address the problem of the Aral Sea and surrounding areas, environmental improvement and socio-economic development of the Aral Sea region. The main goal of 1993 Agreement - define the objectives of regional water and environmental cooperation in Central Asia. Unlike the 1992 Agreement, it does not contain any regulations or requirements of a general. However, it calls for the rational use of water resources of the Aral Sea Basin, for adequate water using in rivers, reservoirs and underground sources, and all water inflow into the Aral Sea.

The objectives of 1993 Agreement is to streamline the system and improve the discipline of water use in the basin, as well as to develop relevant interstate legal and regulatory acts. However, the most significant aspect is the institutional dimension. The 1993 Agreement contributed to the development of a mechanism for regional cooperation by establishing the Inter-State Council for the Aral Sea Basin and the Commission on Socio-Economic

Development, Scientific, Technical, and Environmental Cooperation (the predecessor of ICSD), and the Commission on Socio-Economic Development, and by including the ICWC within the newly created organization.[3]

The 1998 Agreement on the use of water and energy resources in the Syr Darya River basin. Agreement addressed a rather specific and practically includes the most significant issue: water and energy exchange among the Syr Darya basin. Four states linked by the common water and energy relationship. The 1998 Agreement does not contain any general principles of law. Its main focus is on the creation of a scheme of water and energy exchange between upstream (Kyrgyz Republic and Tajikistan) and downstream (Kazakhstan and Uzbekistan) countries, which is based on the idea of harmonizing the regime of hydro-power facilities and reservoirs of the Naryn-Syr Darya cascade so as to provide a sufficient amount of water for irrigation.

The 1999 Agreement on the Status of the International Fund for Saving the Aral Sea (IFAS). Its Organizations provides a general legal platform for the existing regional institutions - the Fund, the ICWC (with its subsidiary bodies) and the ICSD (with its subsidiary). However, the Agreement, both in terms of its content and form, is not flawless. Currently, there is an on-going regional debate aimed at significantly improving the 1999 Agreement.

In terms of international legal practice, a rather unusual but nonetheless important role in the system of regional institutional acts is played by the decisions of the Heads of State on establishing or modifying the institutional mechanisms and cooperation bodies. They include for example the Decision on “Founding the International Fund for Saving the Aral Sea” of January 4, 1993 and the Decision on “Restructuring the International Fund for Saving the Aral Sea” of February 28, 1997. The latter, while not being an international agreement either in form or content, has in fact changed some provisions of the earlier agreements.

The 1998 Agreement on the use of water and energy resources in the Syr Darya river basin. With respect to water resources the Convention stipulates provides for the development of additional protocols on the following issues:[4]

- improving national frameworks for monitoring;
- establishing a regional system for monitoring water quality in transboundary watercourses;
- identifying and prioritizing water pollutants;
- agreeing upon the schedule to reduce their discharges;
- undertaking joint action to ensure adequate supply of good quality drinking water;
- prevent and reduce transboundary pollution harmful for the downstream Parties;
- cooperating jointly in the sustainable use and protection of water resources.

Agreement between the Republic of Kazakhstan, Kyrgyz Republic, Republic of Tajikistan, and the Republic of Uzbekistan. Additionally produced a cascade of Naryn-Syrdarya hydro electrical power associated with the water in the vegetation period and long-term management of water in the Toktogul reservoir, over and above the needs of the Kyrgyz Republic to the Republic of Kazakhstan and the Republic of Uzbekistan

The 2006 Framework Convention for the protection of the environment for sustainable development in Central Asia. Relevant to regulating the utilization of transboundary water resources. At present, the Convention is signed by only three countries: Kyrgyzstan, Tajikistan and Turkmenistan, and is not yet in force. As a framework instrument the Convention provides the legal basis for long-term cooperation between Central Asian states on a wide range of issues: the water conservation, sustainable use of water resources protection of air quality and biodiversity. The objectives of the Convention is to be achieved through a combination of national measures, relevant regional projects and other bilateral and multilateral schemes and mechanisms for cooperation.

The 2006 Framework Convention for the protection of the environment for sustainable development in Central Asia. The Parties are expected to adopt additional protocols that would establish rules and procedures for developing general obligations in specific areas of environmental activities.The Convention provides base for establishment of an independent institutional mechanism - Conference of the Parties and a permanent Secretariat, headed by the Executive Secretary, as well as other subsidiary bodies. It also provides the establishment of a separate financial body in charge of the financial mechanism of the Convention, including collection, management and disbursement of financial resources.

Almaty Declaration. Recognized that the management of water resources of transboundary river resources should adopt the ecosystem approach and precede in a fair and rational way, avoiding damage, reaffirmed previous commitments on full cooperation on the international and inter-state levels.

Ashgabat Declaration. Central Asian countries pay continuous attention to the improvement of the situation in the region, and to attract international organizations to address water problems of the region. Together with international organizations and foundations is the implementation of the regional project water resources and environmental management in support of the global environment facility.[5]

- development of cooperative measures for the implementation of the regional strategy and concrete actions on management of water resources in the region;
- use of water resources in the Aral Sea basin must be managed for the benefit of all;
- provide all possible assistance and support to the project under the auspices of the World Bank and GEF project water resources and environmental management in the Aral Sea basin.

Dushanbe Declaration. Integrated use and protection of water resources in the Aral Sea basin is carried out taking into account the interests of all the countries of the region; the role of the Executive Committee of IFAS on donor coordination and fundraising projects and programs in the Aral Sea basin and the Interstate Commission for water coordination in the management and regulation of the use of transboundary waters was strengthened; the system of monitoring and information between countries on the condition of water resources was improved.

Tashkent Declaration. The heads of State are convinced that concerted and coordinated action in the area of rational and mutually beneficial use of water bodies, water resources and water management facilities in Central Asia on the basis of the universally recognized principles and norms of international law, will serve as a basis for the effective use of available agricultural and energy potential of the States of the region for the benefit of the peoples of the region.

Nukus Declaration. Regional authorities and specific plans of action were approved. This has opened up new ways to attract international support, inter alia, on the program of the Aral Sea. It is based on the plan aimed at sustainable development of the region. The scale and complexity of the problems related to water resources, require an integrated and multisectoral approach and the development of cooperation between the States of the region and the international community. Organizations for coordination and cooperation are the World Bank, UNDP and UNEP. Donors provide substantial support for the Aral Sea program, aimed at the solution of problems and the causes of the Aral Sea crisis.[6]

- a reaffirmation of the commitment to full cooperation at the regional level
- an appeal to the international community, Governments of States and peoples all over the world to help us in our joint efforts.
- establishment of a regional monitoring system, water resources;

– agreed that the Central Asian States to recognize previously signed and valid agreements, contracts and other legal acts regulating the relationship between them on water resources in the basin of the Aral Sea and take them to a steady performance.

– statement of its full support for international agreements, in particular, the Declarations on sustainable development (Rio de Janeiro, 1992), the World Charter for nature, the international conventions to combat desertification, global climate change, conservation of biological diversity and the protection of transboundary waters.

– creation of the International Convention on the Aral Sea basin sustainable development. Joint water management and harmonization of environmental standards and related laws should be the priority.

– appeal to UN agencies, particularly UNDP, to assist in the drafting of such a Convention.

Joint statement by the heads of State of the Republic of Kazakhstan, Kyrgyz Republic, Republic of Tajikistan, Turkmenistan and Republic of Uzbekistan 8-9 April 1999 year Ashgabat:

– agreement, that the development of water resources should adopt the ecosystem approach and proceed in a reasonable manner without causing mutual harm, taking into account the interests of all parties and respect for the principles of good-neighborliness and mutual advantage, to raise the level of development of agricultural production, the tasks of the UN strategy on food 21-st century.

– mobilization of resources for joint activities on the protection of air, water, land, flora and fauna;

– funding for joint research projects and development for the management of transboundary inland waters.[7]

Joint statement by the heads of States-founders of IFAS. April 28, 2009, Almaty - parties reaffirm their interest in developing a mutually acceptable mechanism for integrated water resources management, taking into account the interests of all States in the region.

Protocol amending the agreement between Government of the Republic of Kazakhstan, Kyrgyz Republic, Republic of Tajikistan, and the Republic of Uzbekistan. Republic of Tajikistan every year provides the Kayrakkum reservoir and dams on the regime, and the Republic of Kazakhstan and the Republic of Uzbekistan provides in equal parts electricity supplies to the Republic of Tajikistan during accumulation of water in the reservoir with follow returning a consistent energy level equivalent in summer.

Analyzing existing bilateral and multilateral agreements and “soft law” documents, we could see that Central Asian states have taken all the measures to create strong legal framework for cooperation in water sphere. Some of them provided basis for creating joint bodies. But, with that, taking in mind current situation, we can conclude that not all of the agreements are working properly.

Institutional mechanisms and bodies of water cooperation in Central Asia. An important role in regional water resources regulation should play the "Framework Convention on the protection of the environment for sustainable development in Central Asia" 2006, which describes the principles and the situation regarding the management of water resources. To date, the Convention has been signed only by the Kyrgyz Republic, Tajikistan and Turkmenistan.

The special role of regional and sub-regional instruments played by institutional acts that create the legal framework and legal status and competence of the joint bodies of Central Asian countries in water management have resulted in the agreement described in previous chapter. The below-mentioned organizations were established in Central Asia with the character of joint bodies.

International Fund for saving the Aral Sea (IFAS). IFAS was established in accordance with the decision of the heads of Central Asian States dated January 4, 1993 year in Tashkent. The main objective of the Fund is financing and crediting of joint actions and projects for the Aral Sea saving, ecological rehabilitation of the Aral Sea basin in general and its surrounding areas, taking into account the interests of all States in the region.

At the moment, IFAS is considered to be the most powerful institutional mechanism in the water management system of Central Asia, which involves all five countries to decision-making process and provides platform for cooperation.[8]

The founders included (Republic of Kazakhstan, the Kyrgyz Republic, Tajikistan, Turkmenistan and Republic of Uzbekistan) and on an equal basis can be other countries, supporting and participating in the financing of projects and programs. Participants of the Fund may be international organizations and other legal entities and natural persons.

The Fund is financed by contributions from the States of the Republic of Kazakhstan, Turkmenistan, Republic of Uzbekistan at a rate of 0.3%, Kyrgyz Republic and Republic of Tajikistan in the amount of 0.1% of the budget revenues, by: contributions of enterprises, international and individual organizations, businesses and individuals.

Law of IFAS:

– establish branches and representatives;
– carry out credit and other operations to acquire the shares, bonds and other securities;
– investing in environmental programs and projects.
– enter into contracts in its own name, open the account.[9]

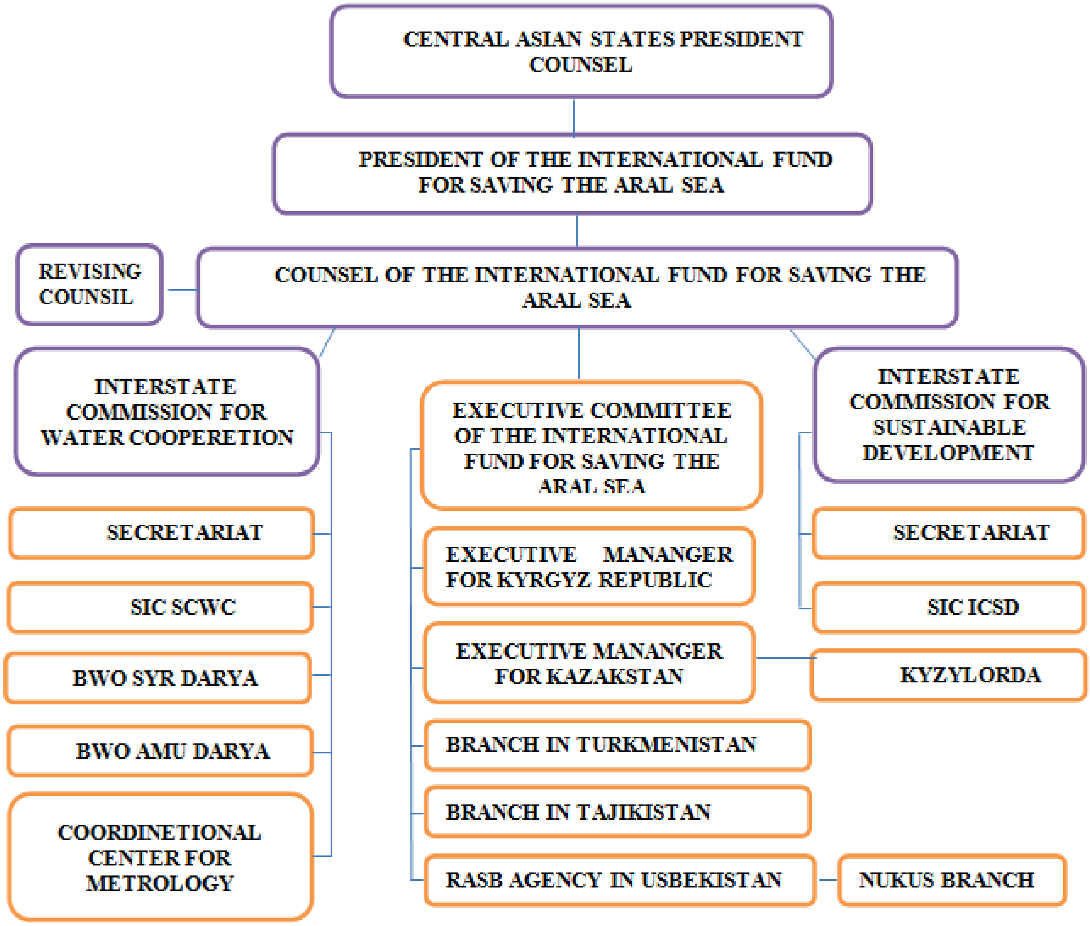

Figure 1 – Organizational structure of the International Fund for saving the Aral Sea
Source: http://www.waterunites-ca.org (last visit 11.12.15)

The main areas of activity of the Fund:[10]

- financing and crediting of joint international environmental, scientific and practical programs and projects aimed at saving the Aral Sea and the improvement of the ecological situation in the areas affected by the impact of the Aral disaster as well as general socio-environmental problems of the region;
- joint financing of fundamental and applied research, scientific and technical developments for the restoration of the ecological balance, sustainable use of natural resources and environmental protection;
- establish and operate the Interstate environmental monitoring system, database, and other systems on the State of the environment in the Aral Sea basin;
- mobilize resources for joint activities on the protection of air, water and land resources. flora and fauna;
- funding for joint research projects and development on transboundary inland waters;
- participate in international programmes and projects to save the Aral Sea and the environmental rehabilitation of the Aral Sea basin.

Interstate Coordination Water Commission (ICWC). ICWC in the structure of IFAS is a joint body, established for joint management of shared waters of Amu Darya and Syr Darya. Aware of the difficult transition period the leaders of water management bodies of the Central Asian countries adopted a declaration, which laid the basis for signing Agreement on cooperation in joint management of use and protection of water resources international sources to promote stability in water management. On the basis of this agreement was created by the Interstate Commission for water coordination (ICWC).

ICWC is going to 3-4 times a year, alternately in the countries of the Aral Sea basin, in urgent cases, gather for extraordinary meetings on specific basins.

In its practical activities of ICWC executive bodies with works in the following main directions:[11].

- river basin management;
- conflict-free water allocation;
- organization of water conservation in transboundary watercourses;
- interaction with hydro meteorological services, forecast and inventory of runoff;
- the introduction of automation of buildings;
- continued work on the improvement of the activities of ICWC and bodies;
- preparing interstate agreements; International relations;
- scientific research;
- training activities.

For the implementation of its activities, the ICWC cooperates with international agencies and donors, such as the World Bank (WB), European Union (EU), the Canadian International Development Agency (CIDA), the Swiss Agency for development and Cooperation (SDC), the Asian Development Bank (ADB), Government of Norway and Finland, UK Department for international development (DFI), the United States Agency for international development (USAID), Japan Water Forum, UNDP, FAO, the global water partnership (GWP), and others.

Scientific research center of Interstate Commission for water coordination (SIC ICWC). SIC ICWC was established by ICWC decisions of 5th December 1992, on the basis of Scientific Research Institute (SANIIRI), and was approved in 1996 as an independent body with functions of planning, development, research and information support for the activities of the ICWC. From April 1999 SIC ICWC is a part of IFAS and has status of international organization.

SIC ICWC carries out its activities with a network of scientific and design organizations of the five Central Asian countries and international organizations, has national branch in

Kazakhstan, Kyrgyz and Tajikistan, which provides research and information exchange at the national level.

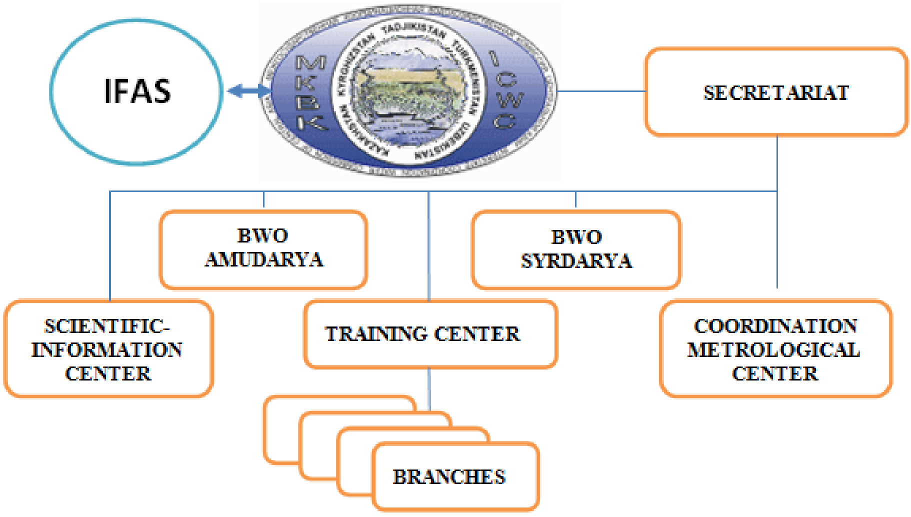

Figure 2 – Organizational structure of ICWC/ Source: «ICWC 20 years».

The information is obtained in SIC, translated, processed, and distributed for information support of water sector of Central Asia.

SIC ICWC consists of:[12]

- directorate of the Division of regional water resources;
- scientific organizational Department;
- department of foreign relations;
- editorial-Publishing Department;
- the regional computer center;
- division of continuing education;
- division of design work.

The Interstate Commission on sustainable development (ICSD). ICSD was established in accordance with article 2 of the agreement on joint action to address the problems of the Aral Sea and Priaral, environmental rehabilitation and socio-economic development in the Aral Sea region, signed by the heads of Central Asian States in Kzyl-Orda March 26, 1993.

The ICSD follows decisions by the Central Asian Heads of State, of the International Fund for saving the Aral Sea (IFAS), the decisions of the United Nations Conference on environment and development (Rio, 1992), as well as this Statute. The main purpose of the ICSD is to coordinate and manage regional cooperation in the field of environment and sustainable development in Central Asian countries.

The main objectives of the ICSD are: [13]

- development of proposals for development of the Aral Sea basin;
- introduction of non-traditional industries;
- develop and implement activities to improve the environment of the Aral Sea region;
- promotion of research on the improvement of the Aral Sea basin;
- adoption of coordinated decisions, promote sustainable development of the region.

All projects of region considered by ICSD and approved/endorsed. On the basis of the approved projects, SDC is a strategy and plan for their integration in the regional action program. To ensure regional coordination of projects to create and maintain database projects of CA countries and donors.

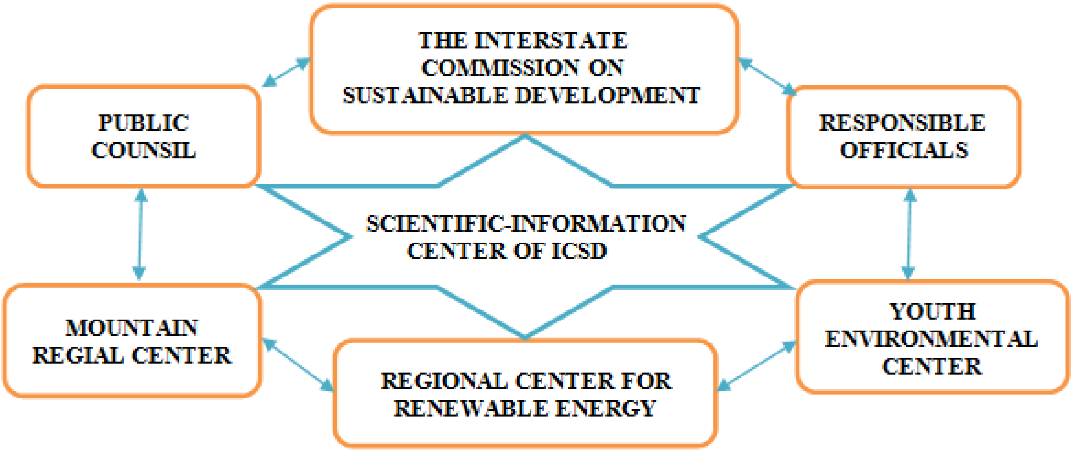

Figure 3 – Structure of the Interstate Commission on sustainable development/ Source «ICWC 20 years»

Scientific-information center of ICSD. Scientific-information center of ICSD was established in August 1995, when the Interstate Commission on sustainable development (IACSD) of the International Fund for Saving Aral Sea (IFAS). In accordance with the approved programme of work and SIC ICSD provides information, software, methodical and consulting support of IACSD.

The main purpose of SIC - establishment of an integrated information system for decision making at the regional and national levels and standardize the collection of socio-economic, scientific-technical and ecological data on the sustainable development of the Aral Sea basin countries.[14]

SIC is covering the following thematic blocks:

- organizational and institutional arrangements;
- carry out activities of ICSD;
- interaction with international environmental organizations;
- plans, reports, etc. documents on sustainable development of the region;
- communication with the public.

At first institutional mechanisms and bodies of water cooperation in Central Asia can be considered as well-balanced and covering all the issues concerning water. But while analyzing the organizational structure of joint institutional mechanisms in Central Asia we see that there are many weaknesses on regional, basin and bilateral levels of governance [15]. The main problems concern its organizational structure – not clear hierarchy system, misunderstanding in interrelations, rotational functioning of executive bodies and others.

There is a complex of problems with institutional character in water governance in Central Asia. The mechanism as a whole needs to be improved.

Conclusion. Central Asian countries, having the common historical background and strongly dependent from each other, is developing wide range of instruments and mechanisms for providing better bilateral and multilateral cooperation in all the spheres. Existing of transboundary rivers with the significant importance gives rise to the need to create joint mechanisms on managing shared waters.

All of the above-mentioned mechanisms for providing better bilateral and multilateral cooperation are very wide and general, without going into details. It happens because each case of joint management of water bodies by countries has its peculiarities and it is not possible to create unique rules applicable to each situation.

Analysis of current legal frameworks for establishing bilateral and multilateral mechanisms for cooperation in the region of Central Asia has shown the weaknesses of the system – existing bilateral and multilateral agreements seem to be not legally binding, although they are, and documents with recommendatory character remains “just beautiful words”.

Although it is possible to establish new joint bodies on water management in Central Asia (as it was proclaimed by Framework Convention on the protection of the environment for sustainable development in Central Asia, 2006), the system, regulating management of transboundary waters in Central Asia should be reformed as a complex. Joint bodies are not a panacea from all the problems, but they are the most important and efficient tool for better and transparent cooperation between countries on the common water objects. The number of agreements in Central Asia in comparison with the Agreements on establishment of Chu-Talas Commission has shown that only by creating joint executive mechanism the agreement provisions can be successfully implemented.

There is no doubt about the necessity to create joint bodies in Central Asia. All the problems, which cannot yet be solved by signing new document, will probably be resolved in the frames of the organization, involving all the riparian states and created by them.

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JOINT OWNERSHIP OF WATER INFRASTRUCTURE IN INTERNATIONAL LAW

Dams have often been viewed as instruments of development: they help to meet water and energy needs, foster industry and create jobs. Yet, dam construction and operation can also have serious negative impacts. They can divide aquatic ecosystems, alter natural water flow cycles and transform the biological and physical characteristics of both rivers and floodplains. They have an impact not only in the watersheds but also on the often complex ecosystems of river estuaries. Moreover, the creation of reservoirs associated with large dam constructed has caused the displacement of hundreds of thousands of people.

In November 2000 the World Commission on Dams (WCD) issued its report, *Dams and Development: A New Framework for Decision-Making*. Among the Commission's many findings was a clear articulation of the significant contribution to improved cooperation and conflict avoidance in relation to the implementation of dam projects that can be made concluding international agreements on shared watercourses. However, 16 years later, it remains difficult to identify common principles of international law related to the development of dam projects. Beyond the 1923 *Convention relating to the development of hydraulic power affecting more than one State* (Geneva), there are no universal treaties governing the construction and operation of dams. Numerous international agreements—bilateral, multilateral, regional—nonetheless exist that directly or indirectly regulate the potential impact of dams on shared watercourses. Examples are the 1963 Convention between France and Switzerland for the Development of the Emosson Basin and the 1986 Lesotho Highlands Water Project between Lesotho and South Africa.

The presentation will explore some examples of international agreements dealing with the management and protection of water infrastructure. In so doing, the focus will be on current trends of international regulations highlighting the examples of joint water infrastructures. For example, the Convention on the Legal Statute of the Common Infrastructures in the Senegal River of 1978 (*Convention relative au statut juridique des ouvrages communs*) establishes that member States of the OMVS (i.e. Guinea, Mali, Mauritania and Senegal) hold the common ownership of the Diama and Manantali dams. Beyond some agreements on specific water infrastructures such as those in the Senegal, Senqu/Orange and Paranà rivers, some universal agreements establish cooperative mechanisms on hydraulic works. This is the case of the UN Convention on the Law of the Non-Navigational Uses of International Watercourses of 1997 (articles 25-26) entered into force in 2014.

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WATER QUALITY STANDARDS: THEIR IMPLEMENTATION, THEIR MONITORING AND EFFECTIVE INTERVENTION

Water quality standards are determined based on data from human or environmental toxicology. They define either critical concentrations or permissible loads in order to safeguard water quality in surface or ground waters. In international river basins, water quality goals have been proven effective policy tools in order to agree on concerted actions: The aim to reduce nitrogen loading to the North Sea by 50%is an example. River basin commissions have become a standard institutional arrangement in order to implement water quality standards in international settings. They are in charge of harmonizing sampling and analysis protocols for effective water monitoring. Data generated in such networks can then be used to calibrate and run predictive hydrological models. Such models are specifically relevant to assess the effect of diffuse sources such as nutrient, salt, pesticides from agriculture on water quality. Results from monitoring and modelling are then used to prioritize policy interventions, i.e. to identify pollutant hot spots or critical sub catchments where water treatment or load reduction can significantly contribute to improving water quality for the downstream population.

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BY THE ESTABLISHMENT OF ECONOMIC OPTIMAL AND ECOLOGICALLY SAFE LEVEL WATER IN SYRDARYA BASIN

The article describes the background to the establishment of economically optimal and environmentally safe water level in the Syrdarya river basin.

Water resources of the Aral Sea were formed mainly from Syrdarya - 39 km^3 and Amudarya - 81 km^3. The irrigated lands in the Syr Darya basin amounted to 3.5 mln. hectares, and the upper reaches of the Syrdarya solved hydropower problems. The total capacity of 25 relatively large district and dozens of small hydropower plants accounted for more than 775 ths. kW of electricity. In addition, the 0.6 ... 0.8 km^3 of water per year used in the domestic economy, industrial and agricultural water supply. It should be mentioned that the use of water on the Syrdarya basin has uncoordinated appearance, and sometimes contradictory nature of both the countries located in the basin, and in the economy. Among the negative facts should be referred the reduction of mean values of flow and change its intra-distribution.

For an objective assessment of human activities, it is necessary to introduce a number of specific indicators to assess the level of water use, such as for hydropower purposes.

The level of influence on the flow of the river is usually more appreciated by indication of regulation (regulation degree or level of use) of the flow rate α

$$\alpha = P / Wo, \tag{1}$$

where P – the amount of water consumption for a given period (usually one year); Wo- annual flow (runoff rate).

However, this figure does not reflect the impact of energy use of the river flow and is not possible to take into account the impact on the flow of the energy use of the river regime (regulation of river flow). It should be noted that the use of water resources and the level of regulation for hydropower purposes up to 100% foreign. Therefore, it is proposed that a new indicator - the level of use of the river flow for hydropower purposes αe, type:

$$\alpha e = We.i. / We, \tag{2}$$

where We.i.- consumption of water for hydropower purposes (the volume of water regimes and sent for energy purposes); We - the volume of river flow for the natural period.

Accordingly, this value can be separately identified and during the winter and summer periods. During winter αe.w:

$$\alpha e.w = Ww.i. /Ww.e. \tag{3}$$

where Ww.i .; Ww.e.- respectively volumes of water distorted regulated flow (energy - water discharge modes through the turbine reservoirs) and natural river regimes for the winter.

Similarly αe.s for summer:

$$\alpha e.s = Ws.i. /Ws.e., \tag{4}$$

where Ws.i., Ws.e. - accordingly the volume of water distorted regulated flow (energy - water discharge modes through hydroelectric turbines) and the natural conditions of the river for the summer.

Accordingly it is possible to determine their absolute value, for winter and summer:

$$\alpha e.w = (Ww.e.- Ww.i.) /Ww.e. \qquad (5)$$

$$\alpha e.s = (Ws.e.- Ws.i.) /Ws.e .. \qquad (6)$$

In the same way, sets the values and their relative percentage.

For areas of the distorted flow regime of the river is necessary to determine the level of reduction of surface runoff for any analyzed alignment, such as the regulation of the flow rate

$$\alpha s.i = Wo.i.i /Wo.e.i, \qquad (7)$$

where Wo.i.i, Wo.e.i - accordingly the volume of river flow in the present i-th alignment between distorted and natural river regimes.

Then, the overall combined effect on the flow of the river (level of use of the river's flow, taking into account the energy) will be

$$\alpha ob.s.i = \alpha \cdot \alpha e \quad \text{or} \quad \alpha ob.s.i = (P / Wo) \cdot (We.i. / We). \qquad (8)$$

The decline of mean values of flow and change its intra-distribution should also be considered when establishing a secure and optimal water level.

Location of Syrdarya River Basin in the territories of four countries: Kyrgyz Republic, Republic of Tajikistan, Republic of Uzbekistan and the Republic of Kazakhstan, imposes certain complexity in the joint management of water and its resources. At the current level of the water resources of the Syrdarya river up 37.203 km^3. The level of water use for a long time already exceeded 100% mark, that is, from 59% in the 1931-60 years to 120% in the 1981-1985.

In this regard, appropriate alternative way to solve the problem of water management, where the basis for the rational use of water resources should be made optimal economic and environmental safety levels of water in the river basin.

The forecast of natural waters of Kazakhstan in terms of changes anthropo-genetic and environmental factors.

The decision in the field of natural resource management tasks, the priority is the approach in which problems are solved jointly, that is, problems of the economy are not detached from the problems of ecology. This should be based on the conditions that society prefers the issues of environmental protection.

At any level of use of the river's flow, it is necessary to establish siting water resources in the whole river basin. Under the siting of water resources are understood, the water resources of transboundary rivers less mandatory water consumption (water loss for additional evaporation, highly saline wastewater, etc.). Water loss by evaporation, to the territory of the above Kairakum reservoir at 1980 levels are 2.4 km^3. For Uzbekistan and Kazakhstan are 0.9 km^3. Including Uzbekistan and Kazakhstan 0.3 - 0.6 km^3. The same value is extended to the year 2000 -3.6 km^3 of water per year. Sanitary releases to 1980 equal to 1.6 km^3. This value is extended to the year 2000. Dimensions of sanitary releases on perspectives depend on the will of the peoples living in this basin. Is it acceptable, maintaining the present situation in the lower reaches of the Syrdarya River Basin - the preservation of the Northern Aral Sea (NAS) at the level equal to 42,0 m and possibly in the long term at the level of 46,0 m. To save the

NAS at the level of 42,0m and 46,0 m respectively requires 2.72 and 3.32 km3, an average of about 3.0 km^3 of water per year. For irrigation of fishery reservoirs in the lower reaches of the Syrdarya River is required, and about 3.0 km^3. Then for the Conservation of Nature in the lower reaches of the rivers, in the truncated version needed 6.0 km^3.

Table 1 – Water resources of Syrdarya River along the length of the watercourse, km^3

Rriver Land	State	Cross-sections	Water resources, km^3	Restoration of natural resources
1	2	3	4	5
Upper	China		0,75[1]	
	Kyrgyzstan, including:		25,9-26,8 (accepted 26,0)[9] 26,85[1] 27,52[6] 27,605[7]	28,4
		Naryn	14,544[7]	
		Karadarya	3,921[7]	
Average (From the confluence of the Naryn and Karadarya rivers to the border of Kazakhstan)	Tajikistan and Uzbekistan, including		8,9-10,4 (accepred 9,5)[9]	
	Tajikistan		1,00[1] 1,6 1,005[7]	1,0
	Uzbekistan		6,17[1] 5,66[6] 6,167[7]	10,2
Lower	Kazakhstan		2,1-2,6 (accepted 2,4)[9]	2,4
		Kokbulak	18,3[4] до 2000г.	
		Shardara HPP	13,6[4] до 2000г.	
		Tyumenaryk	15,6[4]до 1960г. 11,4[4] до 2000г.	
		Kyzylorda	21,2[4] до 1960г. 8,24[4] до 2000г.	
		Zhusaly	9,54[4] до 1960г. 8,24[4] до 2000г.	
		Kazalinsk	16,0[4] до 1960г. 9,95[4] до 2000г.	
		Karateren	5,41[4] до 2000г.	
Syrdarya river basin			36,9-39,8 (accepted 37,9)[9] 37,2[1] 36,6[6] 37,203[7]	42,0
1 - Korenistov etc .; 4 - Zaurbekov etc .; 6 - Bogolyubov, etc .; 7- The union of hydro water industry; 9 – The union water project				

Table 2 – Compulsory cost flow in the Syrdarya River Basin

Indicators		Years	Kygyzstan	Tajikistan	Uzbekistan	Kazakhstan	Syrdarya River Basin
Compulsory runoff costs km^3	Water loss through evaporation	1980*	1,8	0,3	0,3	0,6	2,4+0,9 (RUzb+RK) =3,3
		2000	2,0	0,4	0,5	0,7	3,6
		2020	2,5	0,5	0,6	1,0	4,6
		2050					
	Sanitary outflows	1980	1,6	1,6	1,6	1,6	1,6
		2000	1,6	1,6	1,6	1,6	1,6
		2020	6,0	6,0	6,0	6,0	6,0
		2050					
	Highly mineralized wastewaters	1980					-
		2000	0,1	0,1	2,0	0,3	2,5
		2020	0,2	0,2	2,5	0,4	3,3
		2050					
	Total	1980	3,4	1,9	1,9	2,2	4,9
		2000	3,7	2,1	4,1	2,6	7,7
		2020	8,7	6,7	9,1	7,4	13,9
		2050					
Excluding highly mineralized water		1980	3,4	1,9	1,9	2,2	4,9
		2000	3,6	2,0	2,1	2,3	5,2
		2020	8,5	6,5	6,6	7,0	10,6
		2050	8,5	6,5	6,6	7,0	10,6
Note: * -Syrdarya River Basin for 1980 [15]. Other data - expert assessments.							

Since the average annual flow of the river Syrdarya equal to 37.203 km^3 established for a period of two cycles of water availability years 1951-1974 cannot be regarded as a natural drain, due to the fact that they are established for the period the presence of human activity. The water resources of the Syrdarya River is : 30.4 km^3 of water in an average water year.

In the future (2020 -2050 years) mandatory costs flow in the Syrdarya river basin will be - 11.6 km^3. For the development of scientific and methodological foundations of rational use of water resources of the Syrdarya River, it is necessary to establish the natural water resources.

In turn, the methodology of study of social, environmental and economic performance and environmental protection measures carried out in two stages. In the first stage, based on the analysis of criteria for assessing the level of atmospheric pollution of air, water and soil is chosen the most common.

Implemented assessment of the level of pollution and environmental damage are determined. This assessment of the state of environmental pollution set by means of an integral criterion:

$$EPI = (WDI + WPI) + API + (0.2\text{-}0.5)\ SPI, \qquad (9)$$

where WDI – an index of water depletion; the rate of irreversible withdrawal of surface runoff, constituting 10 - 20% of the average annual value of natural runoff;

API – air pollution index;

SPI – soil pollution index.

At the second stage is chosen criteria of social - ecological - economic efficiency

$$SSER_i = I_i - D_i - C_i + EED_i, \qquad (10)$$

where $SSER_i$ - total income as i - th version of flow regulation (as i - th version of the integrated use of water resources of the river basin);

I_i - income sectors of the economy as i - th version of flow regulation (as i - th version of the integrated use of water resources of the river basin, taking into account the positive spillover effects);

D_i - damage from depletion and pollution of water sources as i - th version of flow regulation (as i - th version of the integrated use of water resources of the river basin, taking into account the negative spillover effects);

C_i - construction costs of water protection and water management facilities (as i - th version of the integrated use of water resources of the river basin, taking into account the negative spillover effects);

AEB_i - additional economic benefit arising from the increasing value of natural resources (as i - th version of the integrated use of water resources of the river basin, taking into account the negative spillover effects).

Produced technical and economic calculations for justification of social and ecological - economic efficiency of water management, water protection and water saving measures.

Principles of allocation transboundary rivers. Changing the water regime in one country inevitably affects the interests of other countries. Currently, water allocation and water allocation issues are resolved on the basis of interstate agreements, developed as early as the 90s of the last century. A feature of the regime of water resources of the Syrdarya River is the fact that more than 70% of the flow is formed on the territory of Kyrgyzstan. Basic arrays is suitable for irrigation of agricultural lands are concentrated in the lower reaches of these rivers - in Kazakhstan, Tajikistan and Uzbekistan. Moreover, the upper reaches of the rivers used for hydroelectric purposes, and downstream - for irrigated agriculture. Therefore, there are contradictions between the neighboring countries in the sharing of river runoff. Justification questions of economic sectors development and environmental issues are considered separately, in isolation from each other. Does not comply with the fundamental principle of the Declaration of Rio de Janeiro, nominated in 1992, which states that "in order to achieve sustainable development, protection of environment should become an integral part of the development process and can not be viewed in isolation from the him. "

A new principle of allocation flow of transboundary river basins, based on the preservation of the natural regime of water sources, or compliance with the agreed between neighboring countries mode releases from the reservoir and the water quality of the background. The main thesis of the proposed allocation of the principle of the flow of transboundary rivers - the "polluter-pays".

In international practice, there is a suggestion that the amount of water allocated to each state depends on the population living in this area. However, this thesis requires its improvement. Taking into account the international practice, the two variants of calculation can be identified.

I.Specific water consumption value for the whole river basin remains constant and is taken to the value of the corresponding period in 2015 or 2020.

II. Specific water consumption value for the whole river basin is taken in the context of differentiated states and the value equal to the corresponding period in 2015 or 2020. Limits of water allocated for conservation of natural complexes varies according to the hypothesis, and formed the development of industries in the territories of neighboring states.

The principal position to meet the requirements of natural systems can be of the following two options.

First option. All States shall take as a basis for the position that you want to save: all natural complexes, including the Aral Sea. In this case, also, two approaches: a) Saved in full natural complexes requirements b) natural complex requirements stored in the abbreviated form. (Conservation of Small North Sea in the Syrdarya river delta).

The second option. Natural systems requirements are not saved.

Modern views on the problems of the Aral Sea shows that: in the first stage in the Syrdarya river estuary to save small North Sea at 42,0-46,0m. Then, the inflow to the Small Sea approximately - 3.0 km^3 of water per year. Taking into account the amount of water to fill the system of delta lakes and water loss through seepage in the sections of the river in the Republic of Kazakhstan will amount to 3.0 km^3 of water per year. Further, this problem can be solved as follows. For example, in terms of average water content. Natural water resources of the Syrdarya River in the years of average water content - 42.0 km^3 of water per year. There remains small North Sea in the delta of the Syrdarya river (3.0 km^3) the requirements of natural systems in abbreviated form 3.0 km^3 of water per year. Loss of water from the reservoirs - 4.6, as well as the requirements of the lake Aydarkul-1.0 km^3 of water per year. Total costs of the mandatory runoff in the Syrdarya River basin - 11.6 km^3 of water per year. Install water resources, which must be distributed between the states (the siting of water resources: 30.4 km^3 of water per year. Determine the share of each State to water. Establishes requirements for the regime and the water volume of each state for the perspective period, table 3.

Table 3 – Social and water characteristics of the Central Asian states into modern and promising periods

Indicators	Years	Republic of Kyrgyzstan	Republic of Tajikistan	Republic of Uzbekistan	Republic of Kazakhstan	Syrdarya River Basin
Population, million people	2000	3,933	1,902	12,876	3,491	22,202
	2010	4,241	2,206	14,301	3,657	24,405
	2020	4,707	2,566	16,060	3,937	27,270
Water use, km3	2000	5,39	3,50	33,40	10,00	52,29
	2010	5,81	4,06	37,12	11,0	58,00
	2020	6,45	4,73	41,89	12,0	65,07
Mineralization of water, mg / l	2000	0,3-0,5	0,60	0,72	1,3	0,3-0,5 ... 1,3
	2010	0,3-0,5	0,65	0,80	1,6	0,3-0,5...1,6
	2020	0,3-0,5	0,68	0,85	1,8	0,3-0,5...1,8

Establish a stake in water use of each State of the total water volume in the river basin, table 4.

The analysis of Table 5 shows that both the modern and perspective periods, the share of water consumption of each state remains practically constant.

It determines the share of each state in km3 or million m3 of water resources of the Syrdarya River for each respective border alignment, Table 5. When establishing water use limits the development of measures to comply with them in each state will be on their own. For the rational and economical use of limited water resources depends on the further development of economic sectors and economic power of the state. And they would be interested in carrying out a water saving and other advanced water technologies. Because, already established levers or the same as the possibility to control the generated water, and the accuracy of the use of water resources in the region, or within a given state. If implemented, the new water-use technology, it will be an opportunity for the further development of industries in the states. In the future, the same way you can solve the allocated water resources, and other conditions of water availability in the Syrdarya River.

Table 4 – Percentage water use of each State as a percentage of the total water volume in the Syrdarya River Basin

Indicators	Years	Republic of Kyrgyz stan	Republic of Tajikistan	Republic of Uzbekistan	Republic of Kazakhstan	Syrdarya River Basin
Water use, km3	2000	0,10	0,07	0,64	0,19	1,00
	2010	0,10	0,07	0,64	0,19	1,00
	2020	0,10	0,07	0,64	0,19	1,00
	the average for 2000-2020	0,10	0,07	0,64	0,19	1,00

Table 5 – Water consumption limit and consequently skipped beyond each state and controlled the water resources in the Syrdarya River Basin during the average water availability km^3

Indicators	Years	Republic of Kyrgyzstan	Republic of Tajikistan	Republic of Uzbekistan	Republic of Kazakhstan
The accepted value of each State share	0,10	0,07	0,64	0,19	1,00
The generated amount of State Water	3,0	2,1	19,5	5,8	30,4
Sanitary releases	7,0	7,0	7,0	6,0	7,0
Compulsory costs of water	2,5	0,5	1,6	1,0	5,6
Natural water resources	28,4	1,0	10,2	2,4	42,0
Water skipped out of the State	22,9	21,3	10,4	6,0*	-
Controlled value of water resources, the underlying state	22,9	21,3	10,4	6,0*	-
Note: * Of these, 3.0 km3 in the delta lakes in the lower reaches of NAS and NAS 3.0 km^3. Water overlooked outside the state, must be greater than or equal to the sanitary releases.					

The only difference in the values formed by water at different water rivers and natural systems account requirements for the hydrological regime. Special conditions of water allocation in wet years and flood protection.

Selection of water facilities for interstate water resources management. You must select one or more of water facilities allow you to integrate to manage shared water resources of the river basin and to transfer them to the jurisdiction of ICWC. And do not disturb the activities of bodies formed by water resources of interstate management. Since, they are entrusted with and solve problems of water management in any water content of the year.

Underlying principles in controlling work mode "interstate facilities sharing" following.

- Preservation of the environment adopted in 1995, that the Aral Sea is the "sixth water user." Compliance with the requirements of international instruments for the rational use and protection of water resources.
- Compliance with the principles of allocation and subsequently develop the principles of allocation of cross-border rivers, taking into account water quality.
- Development of a methodology to monitor the formation of the drain and monitor the implementation of the adopted rules and allocation principles.
- Guide the principle that water resources of transboundary river basins belongs to all people living in the basin of the river.
- Monitoring the use of planning flow within the neighboring state and within its limit of water consumption.
- Assign the value of the water (water charges), taking into account all the positive and negative impacts on the river basin, taking into account their effect on the components of the biosphere, and in view of global climate change.
- Guidelines for the development of rules and methodologies for assessing the state of the environment and the principles of compensation for damages in case of violation of the rules of use and protection of water resources of the river basin.
- Improved scientific - methodological basis for the development of new criteria for the justification of the socio-environmental and economic efficiency of natural and water resources, including water availability at different river.

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