REPORT

On the project **«Strengthening the Capacity for Safe Management of Transboundary Water Resources in Central Asia through the Application of Innovative Information and Communication Technologies»**

Prepared by the Expert on promoting common approaches to hydrological models for water allocation and planning, reducing water-related climate risks, and providing support in the implementation of measures for establishing a transboundary early warning system

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Introduction

Central Asia (CA) stretches from arid desert and semi-desert areas to some of the highest mountainous regions in the world and is characterized by highly contrasting natural conditions. People living in this region face numerous natural processes and hazards such as earthquakes, landslides, rockfalls, floods, flash floods, mudflows, snow avalanches, and others, which occur more frequently than in many other regions of the world, causing loss of life and significant economic damage.

The experience of the past 50 years shows that residents of mountain settlements and tourists are most often threatened by sudden outbursts of high-altitude glacial lakes or floods originating from streams and rivers. Such phenomena are caused by the failure of natural dams in the mountains or rapid melting of snow and glaciers. These events can cause severe damage to infrastructure, destroy homes, and even lead to casualties among people living in mountainous areas.

Climate change in Central Asia has become particularly evident over the past 50 years. The Aral Sea played an important role in moderating cold northern winds in autumn and winter and reducing heat in summer. As the Aral Sea has dried up, summers have become hotter and drier, while winters have become colder and longer. Dust storms and flooding have intensified in western and northwestern Kazakhstan, while mudflows and floods have become more frequent in mountainous areas and along the rivers of the Tien Shan and Pamir regions.

Among the preventive measures, particular importance should be given to research and the development of territorial identity of regions, as well as the transboundary manifestation of hazardous natural processes and phenomena. Addressing this issue requires an analysis of a wide range of indicators for the optimal development of mountainous regions, including an assessment of the factors limiting such development.

Reducing the impact of hazardous processes and phenomena requires comprehensive study and the establishment of effective monitoring systems, which will form the basis for the creation of early warning systems (public alert systems). Such systems are especially important for transboundary rivers and territories.

Figure 1. Transboundary River Basins of Central Asia

Representative transboundary river basins have been selected as pilot areas: Ugam River: Kazakhstan – Uzbekistan, Zeravshan River: Tajikistan – Uzbekistan, Amu Darya River – Kerki: Turkmenistan – Uzbekistan, Khorezm – Dashoguz: Turkmenistan – Uzbekistan, A river basin in the territory of Kyrgyzstan – to be specified.

1. Criteria for Selecting Critical Sites

1.1 Criteria Directly Related to the Selection of Critical Sites (by Level of Importance)

Level I. Transboundary Nature of Risks

- Areas where potential flooding or drought affects multiple countries simultaneously, especially where actions in one country may influence conditions in another (e.g., dam management or water release).

Level II. Historical Data on Floods and Droughts

- Analysis of areas with the highest frequency or intensity of floods and droughts in the past. This may include data on major disasters, their impacts, and recurrence rates.

Level III. Population Density and Infrastructure Vulnerability

- Areas with high population density or significant concentrations of infrastructure (cities, dams, industrial facilities) should be prioritized for monitoring due to higher risks of damage and casualties.
- Areas where infrastructure is critically dependent on water resources (e.g., dams or canals).

Level IV. Hydrological and Climatic Parameters

- Geographical characteristics of the basin, distribution of water resources, and their importance for the region.
- Topography and land slope, which may contribute to rapid water runoff and increase the likelihood of flooding.
- Information on the availability and condition of hydrological monitoring systems at the national and local levels in Central Asian countries.
- Seasonal variations in river water levels and discharge.
- Precipitation levels, especially during high-risk seasons (mudflow and flood-prone periods).
- Snow cover reserves and their impact on flooding during melting periods.

1.2 1.2 Criteria Indirectly Related to the Selection of Critical Sites (by Level of Importance)

Impact of Climate Change

- Assessment of projected climate change and its impact on the hydrological regime in the basin, such as an increase in observed extreme weather events or higher precipitation intensity.

Data Quality and Monitoring Capacity

- Regions where monitoring infrastructure already exists (meteorological stations, hydrological posts) and where international data exchange protocols can be easily established.
- Areas where the quality of water resource data is insufficient but critically important for disaster prevention.

Anthropogenic Impact

- Areas experiencing significant anthropogenic pressure leading to soil and vegetation degradation.
- Areas affected by soil erosion (water or wind).
- Zones of infrastructure construction that may affect ecosystems in the future.

Risks of Water Pollution

- Areas where water contamination may occur in case of flooding (e.g., sites with industrial waste or agricultural runoff), which may complicate international disaster response efforts.

2. Zeravshan River Basin: Tajikistan – Uzbekistan

2.1 Geographical Characteristics of the Basin

The Zeravshan River basin is located in the central-western part of Tajikistan, between the Turkestan and Gissar mountain ranges. The Zeravshan Valley stretches from east to west between these high mountain ranges: Turkestan to the north and Gissar to the south. Between the Gissar and Turkestan ranges, the Zeravshan mountain range extends almost parallel to them. The Tajik part of the basin covers mountainous areas where water resources are primarily formed, while the downstream valley part is located in neighboring Uzbekistan, where the river flow is almost entirely diverted for irrigation, water supply, and other economic needs.

The water resources of the Zeravshan River are of great importance for both Tajikistan and Uzbekistan, particularly for Uzbekistan, where key cotton-growing areas are located. The total length of the main canals diverting water from the Zeravshan is about 2,500 km, with the largest canals having discharge capacities exceeding those of many rivers in Central Asia. Within Uzbekistan, the Zeravshan River flows through the Samarkand, Navoi, and Bukhara regions.

Since some districts of neighboring regions (Kasan, Mubarek, Jizzakh) also use the waters of the Zeravshan River, it is important to outline the administrative boundaries through which the river flows. The Samarkand region is located in the central part of Uzbekistan. To the north, it borders the Nurata district of Navoi region; to the northwest, the Khatyrchi and Karmana districts of Navoi region; to the west, the Kyzyltepa district of Navoi region; to the south, it borders the Kashkadarya region (including the Kasan, Mubarek, Kitab, and Chirakchi districts); to the east, it borders the Penjikent district of Sughd region in the Republic of Tajikistan; and to the northeast, it borders the Jizzakh region (Bakhmal, Gallaorol, and Farish districts). Some districts of neighboring regions (Kasan, Mubarek, Jizzakh) also use water from the Zeravshan River.

2.2 Distribution/Use of Water Resources in the Basin

The current length of the river is 877 km, while the length up to the Karakul oasis, where the Zeravshan splits into branches, is 803 km. The total basin area is 41,860 km², of which 17,710 km² corresponds to the mountainous part where runoff is formed. The long-term average water discharge measured downstream of the Mogiendarya confluence is 162 m³/s. The highest average annual discharge was recorded in 1973 (201 m³/s), and the lowest in 1957 (112 m³/s). The river reaches its highest water levels in July (250–690 m³/s) and its lowest in March (28–60 m³/s). The absolute minimum discharge was recorded on January 31, 1928 (24 m³/s), and the absolute maximum on May 31, 1964 (996 m³/s).

The natural flow regime of the Zeravshan River, unaffected by human economic activity, is studied at the Dupuli hydrometeorological station (with a basin area of 10,240 km² upstream of the station). According to data from the Dupuli hydrological post, the average annual runoff of the Zeravshan River is 4.86 km³/year. The basin upstream of the Dupuli station is located in Tajikistan, within Central Asia, and belongs to the Pamir mountain system. The elevation range in the Zeravshan basin within Tajikistan varies from 875 to 5,478 meters above sea level, with an average catchment elevation of 3,100 meters. The river length within this section is 781 km, and the catchment area is 12,300 km². Glaciation covers about 7% of the basin area.

High-altitude snow and glaciers play a significant role in feeding the Zeravshan River. The contribution of glacier melt to the annual runoff is about 18% at the Dupuli section and 56% at the Khudgif (near Dehavz) section. The flood period begins in the second decade of April, with intensive increases in discharge observed until July, followed by a decline from August to March. Significant interannual variability in river flow is observed, both during the flood period and within individual months.

Figures 2.2.1 and 2.2.2 show trends in average annual water discharge at the Dupuli (Tajikistan) and Khazora (Uzbekistan) hydrological stations. In the upper reaches of the river, data from the Dupuli station indicate an increase in average annual discharge by 0.11 m³ per year, whereas in the lower reaches, data from the Khazora station show a decrease in river flow by 0.97 m³ per year. In some years from the 1980s to the present, the river flow has been almost entirely diverted for irrigation.

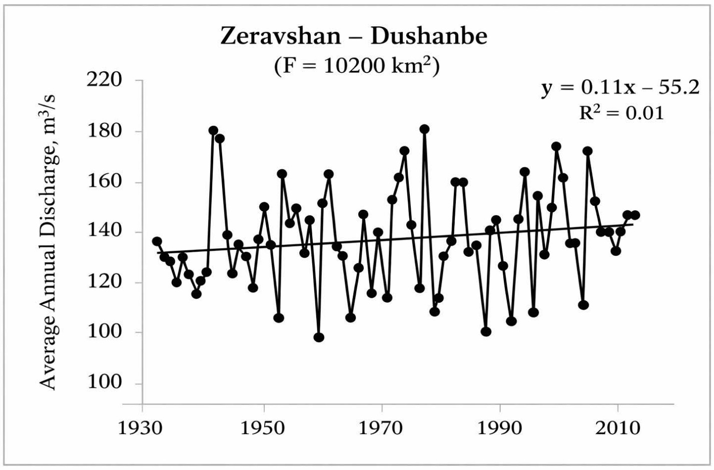


Figure 2.2.1. Average annual water discharge at the Zeravshan River – Dupuli hydrological station (Tajikistan) Source: Hikmatov F., Kalashnikova O., et al., "Water Resources of Central Asia and Current Trends in Their Use"

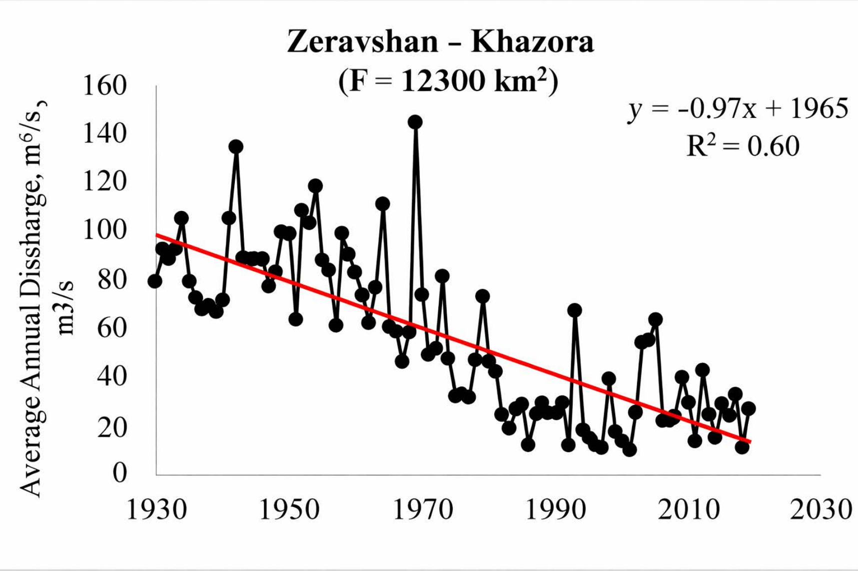


Figure 2.2.2. Average annual water discharge at the Zeravshan River – Khazora hydrological station (Uzbekistan) Source: Hikmatov F., Kalashnikova O., et al., "Water Resources of Central Asia and Current Trends in Their Use"

Calculations of the reliability (probability) of average annual water discharge are presented in Table 2.2.1 and Figure 2.2.3.

Table 2.2.1. Reliability (Probability) of Average Annual Water Discharge of the Zeravshan River – Dupuli

Coverage rate (%)	0.01	0.1	1	10	50	60	70	80	90	100
Average annual water discharge, m^3/s	236	222	204	182	155	149	144	137	129	94

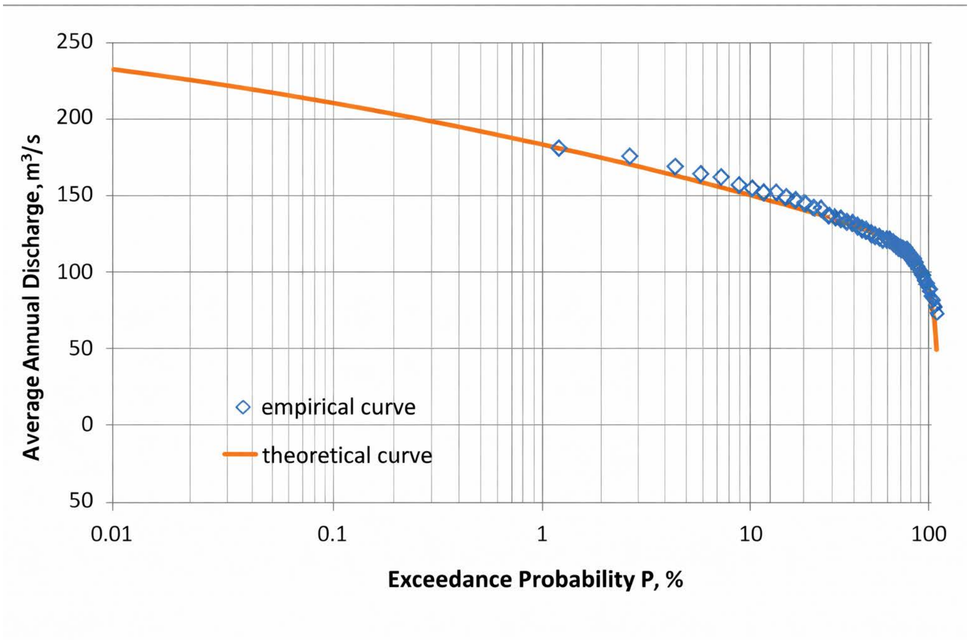


Figure. 2.2.3 Availability of average annual water discharge on the Zeravshan–Dupuli River

Materials from the State Water Use Accounting system show that **irrigated agriculture is the main water consumer in the Zeravshan Valley**. Its share in total water consumption in 2002–2003 averaged **93.1%.** Only 15.59 million m³, or 2.63% of the total water resources involved in use (224.603 million m³), is allocated for domestic and drinking purposes. Data on water use in the Zeravshan River basin are presented in Tables 2.2.2–2.2.5. There is no timber rafting in the Zeravshan River basin, no run-of-river hydropower plants have been constructed, and there are no reservoirs.

Table 2.2.2. Water Use in the Zeravshan River Basin for 2002, thousand m³

				Including for Needs:			Transferred to other consumers		
Names of districts	Total annual water withdrawal	Used in fact	Domestic/ Drinking	Industrial	Irrigation	Agricultural water supply	Without use	After use	Water loses
Penjikent	210131	185165	12691	0	172474	0	185165	0	24966
Aini	43215	40622	2844	0	37778	0	40622	0	2593
Total:	253346	225787	15535	0	210252	0	225787	0	27559

Table 2.2.3. Water Use by Sub-basins of the Zeravshan River Basin for 2003, thousand m³

				Including for Needs:			Transferred to other consumers		
Names of districts	Total annual water withdrawal	Used in fact	Domestic/ Drinking	Industrial	Irrigation	Agricultural water supply	Without use	After use	Water loses
Penjikent	205017	182893	12691	0	172474	0	185165	0	24966
Aini	45546	40526	2844	0	37778	0	40622	0	2593
Total:	250563	223419	15535	0	210252	0	225787	0	27559

Irrigation of land within the city and rural areas of Penjikent - is carried out through 6 irrigation canals with a total length of 135 km.

Table 2.2.4. Gravity-Fed State Canals in the City of Penjikent

#	List of channels	Year of commissioning	Source of irrigation	Area of land irrigated by channels (ha)	Length of channels (km)
1	Tuksan-Corez	1917	Mogien river	2427	29.4
2	Margedar	1962	Kishtudak river	4426	29.2
3	Eshon	1917	Mogien river	648	11.1
4	Xalifa-Khasan	1983	Mogien river	2082	48.0
5	Kishtudak	1974	Kishtudak river	303	11.0
6	Sarazm	1982	Zarafshon river	400	6.7
Total:		10286		10286	135.4

Table 2.2.5. Information on Irrigation Facilities of the State Department for Land Reclamation and Irrigation of Penjikent (GUMIP)

No.	List of pumping stations and channels	Source of irrigation	Year of commissioning	No. of units	Land area (ha)	List of jamoats
1	Yori - 1	r. Zarafshon	1970	4	1545	Yori
2	Yori - 2		1972	2	782	Amondara,
3	Dupula	r. Zarafshon	1969	8	1572	Suchina, Yori
4	Margedar -1	Margedar channel	1974	4	27	Voru
5	Margedar -3	Margedar channel	1987	4	555	Rudaki, Voru
6	Garibak	r. Zarafshon	1979	2	132	Khurmi
7	Rudaki	Margedar channel	1987	2	78	Rudaki
8	Leningrad - 1	r. Zarafshon	1974	4	450	Sarazm
9	Leningrad - 2	Sarazm channel	1986	5	570	Sarazm
10	Navobod	Margedar channel	1987	2	73	Voru, Rudaki
11	Nilufar - 1	r. Zarafshon	1990	3	23	Chinor, Sarazm
12	Nilufar - 2		1991	2	248	Chinor
13	Nilufar - 3		1992	3	372	Sarazm
14	Khumgaron-Bedak	C-l Kh.Khasan	2012	3	172	Kosatarosh
15	Urech	r.Urech	1993	2	51	Rudaki
16	Chomi	r. Zarafshon	1987	2	33	Amondara
17	Dashti kalon 1-2	C-l Chertuk	1988	4	120	Kosatarosh
	Total:			54	6782	

2.3 Importance of the Site for the Region

The glaciers of the Zeravshan are an important source of water for the Zeravshan River, which originates in the mountains of Tajikistan at an elevation of 2,800 meters and flows into Uzbekistan. About 6 million people live in the Zeravshan basin, and the river serves the historic cities of Samarkand and Bukhara, providing irrigation water for approximately 0.5 million hectares of land.

In Tajikistan, the Zeravshan flows naturally through mountainous terrain with relatively few water intakes, whereas in Uzbekistan water demand is high, and the available water is used almost entirely.

According to the Hydrometeorological Service of Tajikistan, the Zeravshan glaciers are retreating and have already significantly decreased in size. Rising temperatures may increase climate-related risks for agriculture in the lower parts of the basin, particularly in the densely populated Samarkand and Bukhara regions.

The Zeravshan basin covers approximately 42,000 km², and the river length exceeds 800 km. The name of the river translates as "gold-bearing," and although little extractable gold remains in the main riverbed, the tributaries and geological formations of the Zeravshan basin are indeed rich in gold. Some of the largest gold mining operations in Tajikistan and Uzbekistan are located in this region.

The average annual precipitation in the Zeravshan River basin is about 500 mm and is unlikely to change significantly; however, it is expected that there will be less snowfall and more rainfall. The current average annual temperature in the basin, which is around 5°C, is projected to increase to 8°C under moderate warming and to 10–12°C under more severe warming scenarios. This significant warming will lead to glacier retreat and a reduction in snow and ice cover within the basin. As a result, the volume of meltwater entering the river will decrease, leading to reduced river discharge. At the same time, disruptions in the hydrological cycle will increase both the variability of river flow and the frequency of potentially more destructive floods in mountainous areas.In the lower parts of the basin, cotton yields are likely to decline unless water-saving technologies and other adaptation measures are implemented.

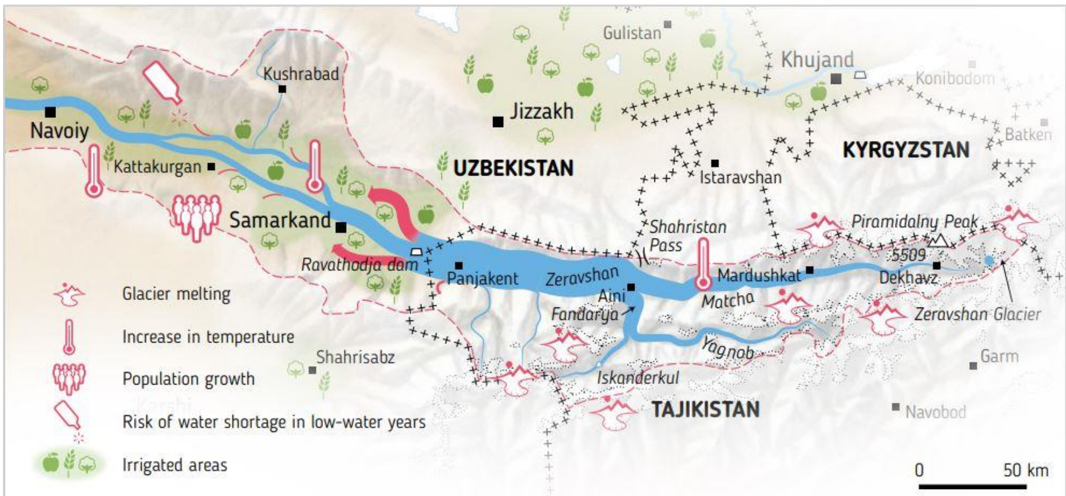


Figure 2.3.1. Use of Water Resources and Climate/Natural Risks in the Zeravshan River Basin
Source: Climate Change and Hydrology in Central Asia A Survey of Selected River Basins (Climate Adaptation and Mitigation Program for Aral Sea Basin (CAMP4ASB) sponsored by the International Development Association (IDA) of the World Bank has provided support for the process of developing methods, approaches, and tools for decision-making support and knowledge products on climate change in Central Asia.). 2019.

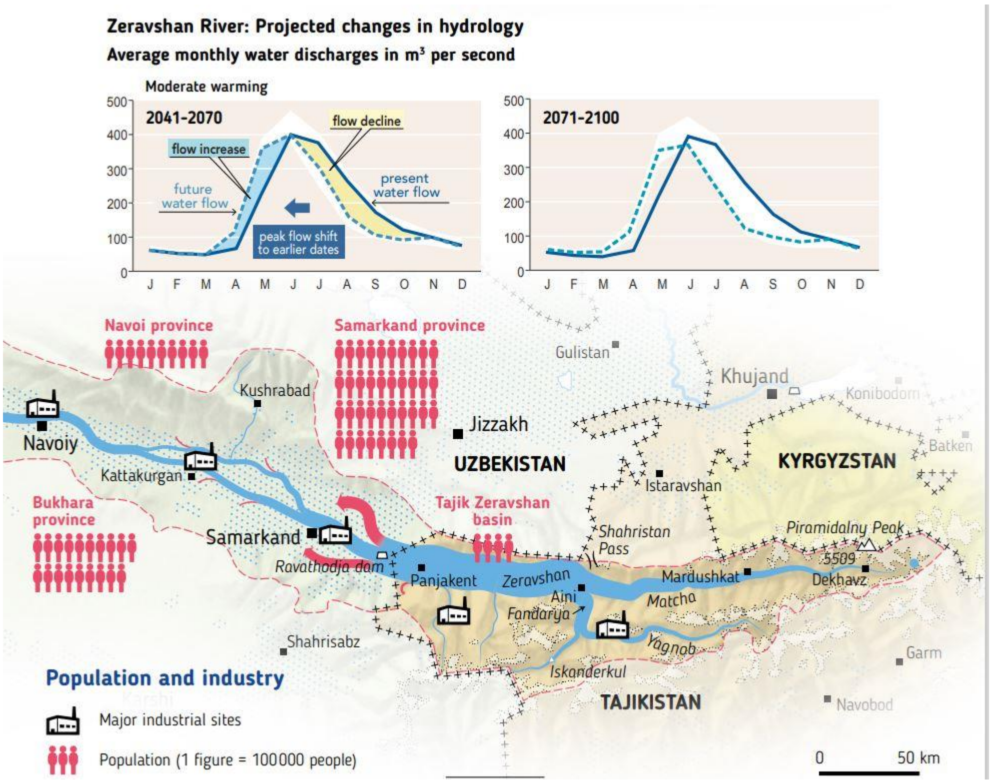


Figure 2.3.2. Distribution of Settlements and Population Density in the Zeravshan River Basin
Source: Climate Change and Hydrology in Central Asia A Survey of Selected River Basins (Climate Adaptation and Mitigation Program for Aral Sea Basin (CAMP4ASB) sponsored by the International Development Association (IDA) of the World Bank has provided support for

the process of developing methods, approaches, and tools for decision-making support and knowledge products on climate change in Central Asia.). 2019.

2.4 Water-Related Risks and Water Availability

These findings are further supported by research published in 2021 in *Journal of Hydrology: Regional Studies 34 (2021) 100779 «Central Asian rivers under climate change: Impacts assessment in eight representative catchments» Iulii Didovets et al.*

Representative Concentration Pathways (RCPs) describe possible future scenarios of greenhouse gas and aerosol emissions. RCP scenarios do not represent specific political, demographic, or economic futures; rather, they are defined by the level of radiative forcing by the year 2100. They are used to address uncertainties in future greenhouse gas concentrations and aerosol emissions.RCP.

4.5 is described by the Intergovernmental Panel on Climate Change (IPCC) as a moderate scenario in which emissions peak around 2040 and then decline. RCP 8.5 represents a high-emission baseline scenario in which emissions continue to rise throughout the 21st century.
Results based on Global Climate Models (GCMs) indicate an increase in average annual temperatures across all studied catchments by the end of the century. Under RCP 8.5, temperature increases in some basins may exceed 6°C. These findings are also supported by other studies (Gan et al., 2015; Ozturk et al., 2017). Rising temperatures lead to reduced snow accumulation during the cold season and increased total evaporation in summer. In some regions, these changes may be beneficial for agricultural production due to a longer growing season (Lobanova et al., 2021). On the other hand, an increase in potential evapotranspiration resulting from higher temperatures—while actual evapotranspiration remains limited by water availability—may lead to increased water demand in the region. A shorter period of snow accumulation during the year and a reduction in the volume of water stored as snow mean that less water will be available during the growing and irrigation seasons. The clear warming trend in a region where rivers are fed by snow and glaciers plays a significant role in potential changes in river runoff. In most studied catchments, significant seasonal changes in river discharge have been identified. A shift in peak discharge by approximately one month earlier has been projected, which has also been confirmed by other studies (Gan et al., 2015; Hagg et al., 2013; Reyer et al., 2015).

In the Zeravshan River catchment, except for a slight or moderate increase in spring months associated with the shift in peak flows, a decrease in river discharge is projected for the remainder of the season across all three time periods under both RCP scenarios. The greatest reduction is expected during the summer months and may reach up to 60% (Fig. 2.4.1). The variability of modeling results for future periods in most catchments remains at a level similar to that of the reference period under both RCP scenarios (Fig. 2.4.2). However, for the Zeravshan basin, uncertainty is expected to increase toward the end of the century.

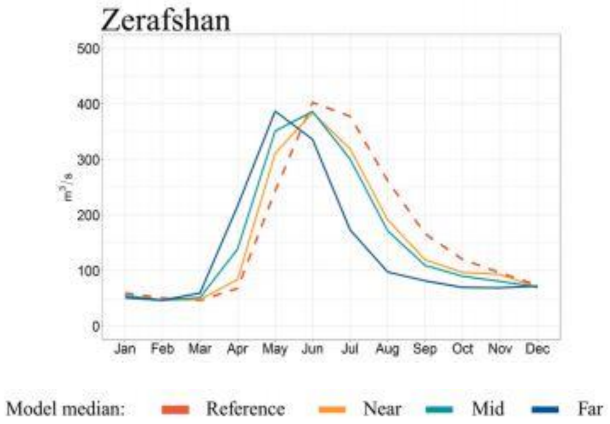


Figure 2.4.1. Multi-model median monthly river discharge for three future periods compared to the baseline period under RCP 8.5 (reference period). (Source: Journal of Hydrology: Regional Studies 34 (2021) 100779 «Central Asian rivers under climate change: Impacts assessment in eight representative catchments» Iulii Didovets et al.)

Figure 2.4.2. Graphical representation of simulated average annual river discharge for three future periods compared to the baseline period under RCP 4.5 and five climate scenarios. (The upper box lines indicate the 75th percentile, the lower lines indicate the 25th percentile, the middle lines indicate mean values, vertical lines represent minimum and maximum values, and dots represent outliers.) (Source: Journal of Hydrology: Regional Studies 34 (2021) 100779 «Central Asian rivers under climate change: Impacts assessment in eight representative catchments» Iulii Didovets et al.)

One of the main challenges for societies and economies in Central Asia is water availability. Climate change impacts pose both potential threats and benefits for socio-economic and environmental sectors. Changes in climatic conditions are already affecting agriculture by reducing productivity in water-dependent sectors (Perelet, 2007).

Climate projections indicate an increase in average annual temperatures across all catchments under both RCP scenarios by the end of the century. By the end of the century, temperatures are projected to increase from 3.3°C to 3.9°C under RCP 4.5 and from 5.3°C to 6.4°C under RCP 8.5.In mountainous catchments, results indicate a shift in peak river discharge by approximately one month earlier and a reduction in flow, mainly during summer and autumn. A shortening of the snow accumulation period and a decrease in the average annual snowmelt rate are also projected, particularly at lower elevations (Fig. 2.4.3).

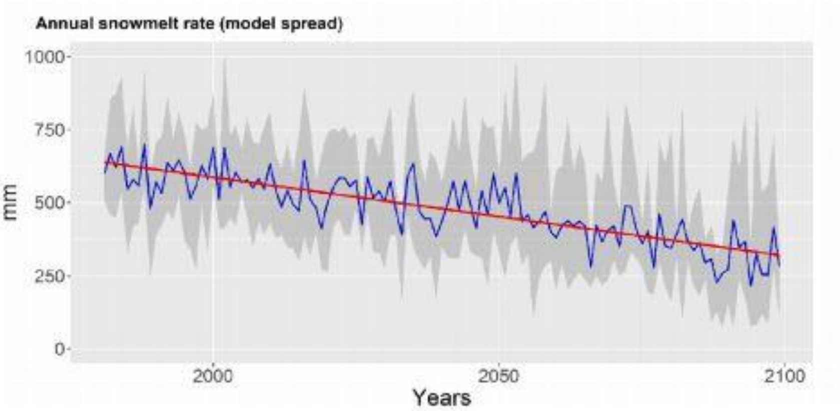


Figure 2.4.3. Average monthly snow cover during the winter months for the baseline and future periods (2071–2100) – upper panel; and the multi-model median annual snowmelt rate – lower panel, in the Kafirnigan catchment under RCP 8.5

2.5 Historical Data on Past Emergencies

According to data from the Monitoring Service for Hazardous Geological Processes of the Main Department of Geology of Tajikistan, three types of geological and exogenous processes have been recorded in the city of Penjikent: landslides, mudflows, and floods. During the period 2011–2014, six natural disaster events were recorded in Penjikent, including 4 mudflows and 1 frost event. *(Source:Interim Report Assessment of capacity needs in terms of climate and disaster risk management (water-related) of basin councils, water management organizations and local communities in the Zarafshan River Basin (Tajikistan) National Consultant of the GIZ (Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH) project "Climate Risk Management in Central Asia" Niyazov Jafar)*

Table 2.5.1. Information on Settlements Located in Hazardous and Highly Hazardous Areas

List of settlements in the city of Penjikent	Number of households	Number of population	Number of households in hazardous areas	Number of population in hazardous areas	Threatening process	Degree of danger	Availability of geological conclusion, yes or no
1. Rural jamoat Amondara							
01.v.Amondara	723	3511	30	123	mudflows	dangerous	no
02.v.Khucharib	259	1298	10	48	mudflows	dangerous	no
2. Rural jamoat Voru							
01.v.Voru	238	1318	16	85	landslide, mud-flows, rockfall	very dangerous	yes
02.v.Gazza	94	226	7	32	mudflows	dangerous	no
03.v.Guitan	148	524	12	68	mudflows	dangerous	no
04.v.Tagobi khalk	156	558	35	185	mudflows, flood	dangerous	no
05.v.Ven	92	492	17	90	mudflows	dangerous	no
06.v.Pagni	60	239	25	122	mudflows	dangerous	no
07.v.Kukhi	16	83	16	83	avalanches, mudflows	dangerous	no
3. Rural jamoat Shing							
01.v.Vagashton	71	307	63	295	landslide, mudf-flows, rockfalls	dangerous	yes
02.v.Shing	406	1777	367	1591	mudflows, rockfalls	very dangerous	yes
03.v.Badgokh	253	1136	175	1066	mudflows, rock-falls, landslide	very dangerous	yes
04.v.Khusher (Guldara)	33	237	18	108	landslide, mudflows	dangerous	no
05.v.Kievli	106	806	60	370	landslide	dangerous	no
06.v.Padrud	90	612	24	141	landslide, mudf-	dangerous	no
07.v.Rovadin	217	1057	70	342	llide, mudflows, rockfalls	very dangerous	no

List of setlements in the city of Penjikent	Number of households	Number of population	Number of households in hazardous areas	Number of population in hazard-ous areas	Threatening process	Degree of danger	Availability of geological conclusion, yes or no
08.v.Nofin (Raz)	50	304	7	47	mudflows, rock-falls, landslide	very dangerous	yes
09.v.Rashnai poyon	215	1350	82	529	landslide, flood risk	very dangerous	yes
10.v.Pani	51	360	51	353	rockfalls	very dangerous	no
11.v.Gijdarva	223	1256	70	434	rockfall, rockfalls, landslide	very dangerous	yes

4. Rural Jamoat Mogiёn							
01.v. Gezani poёn	296	1615	81	565	mudflows, landslides	dangerous	yes
02.v. Mogiёn	468	2857			landslides	dangerous	no
03.v. Zindovud	30	241	25	179	landslides, avalanches	dangerous	no
04.v. Rogich	56	534			landslides, rockfalls	very dangerous	no
05.v. Sor	627	3450			landslides, mudflows	very dangerous	no
06.v. Obi borik	210	1672			mudflows, flo-ods, landslides	very dangerous	no
5. Rural Jamoat Khurmi							
01.Ozodagon (Garibak)	770	3247	48	2845	collapse of mountain foot	dangerous	yes
02.v. Changal	221	888			mudflows, floods	dangerous	no
03.Zarfishon (Zarangbosh)	85	358			floods	dangerous	yes
04.v. Surkhob	94	317			floods	dangerous	yes
6. Rural Jamoat Ёri							
01.v. Dashti kozi	389	2058			mudflows	dangerous	no
02.v. Mingdona	473	1973			mudflows	very dangerous	no
7. Rural Jamoat Kosatarosh							
01.v. Chombulok	165	787	50	272	mudflows	dangerous	no
02.v. Kosatarosh	668	3889			mudflows	very dangerous	no
03.v. Novichomok	199	1274			mudflows	very dangerous	no
04.v. Filmandar	488	2961			mudflows, floods	dangerous	no
05.v. Chorbog	1262	6183	62	316	mudflows, floods	dangerous	yes
06.v. Khirskhona	103	500	68	293	mudflows	dangerous	yes
07.v. Khumgaron	150	761	15	70	mudflows	dangerous	yes
8. Rural Jamoat Khalipha Khasan							
01.v. Zebon	348	1851			mudflows	dangerous	no
02.v. Kushteppa	505	2817			mudflows	dangerous	no
03.v. Shurcha	613	3252			mudflows	dangerous	no
9. Rural Jamoat Rudaki							
01.v. Zeri Khisor	202	1070	144	720	landslides	dangerous	yes
02.v. Margedar	540	3257			mudflows	dangerous	no
03.v. Neknot	466	2512	123	665	collapse of mountain mass, mudflows	very dangerous	yes

List of settlements in the city of Penjikent	Number of households	Population count	Number of households in hazardous areas	Population count in hazardous areas	Threatening process	Hazard level	Presence of geological report, yes or no
04.v. Panchrud	545	3027			mudflows, floods, landslides	very hazardous	no
05.v. Shashkat	300	1421	54	1312	landslides	hazardous	yes
06.v. Artuch	493	3061	143	916	rockfalls, mudflows	hazardous	yes
07.v. Koshona	139	804	35	224	landslides, mudflows	hazardous	yes
08.v. Madovra	146	569	26	150	rockfalls	hazardous	yes
09.v. Yakkahona	149	645	25	112	rockfalls	hazardous	yes
			10. Rural jamoat Chinor				
01.v. Sharshara	355	1742			floods, mudflows	hazardous	no
			11. Rural jamoat Suchina				
01.v. Kumsoy	292	1572			flood risk		no
			12. Rural jamoat Loik Sherali				
01.v. Mazor	322	1443			mudflows, landslides	hazardous	no

To review the existing infrastructure related to emergency and disaster risks in the transboundary “Zeravshan” basin, several key aspects should be considered, as outlined in sections A, B, and C:

A. Hydrometeorological Infrastructure.

Meteorological stations: Analysis of the distribution of meteorological stations within the Zeravshan basin for monitoring weather and climate conditions, which supports the assessment and forecasting of natural hazards.

Hydrological posts: Identification of the locations of hydrological posts for monitoring river levels and water flow, which is essential for forecasting floods and droughts.

Meteorological stations in the Zeravshan River basin are located in the foothill and mountainous zones: Penjikent (1016 m), Sangiston (1505 m), Iskanderkul (2198 m), Madrushkat (2234 m), and in high-mountain zones: Dehavz (2561 m), Obburdon (2890 m), Shakhristan Pass (3143 m), and Anzob Pass (3373 m).

Hydrological posts in the Zeravshan basin are provided in the annex.

B. Communication and Early Warning Infrastructure

Communication systems used for rapid notification of the population and coordination of rescue operations (mobile networks, radio communication, and the Internet).

Communication and Information Environment. The population of three districts uses mobile networks provided by operators such as OJSC “Tojiktelecom,” “Tcell,” “Babilon,” “MLT,” “TK-Mobile,” “Telecom Technology,” “Megafon,” and others. An optical fiber line has been laid from the district center to the center of the Sughd region, connecting the central station with the regional center. This line is equipped with modern SDH digital equipment based on STM-4, enabling subscribers to access Internet services.

In 2013, a high-speed ADSL switch with a capacity of 48 ports was installed at the Penjikent station, and in 2014, an additional ADSL switch was installed and commissioned at the “Shelter” station located in a high-rise building.

Within the district, four national television channels (TVT, TV Safina, “Bahoriston,” and “Jahonnamo”) and two Russian channels (“RTR” and “Planeta”), as well as two radio programs of “Tojikiston,” are broadcast. A local radio station also operates in the district. Coverage of television programs such as TVT, TV Safina, and other national channels ranges from 80% (Gornaya Matcha) to 99.5% (Ayni district and the city of Penjikent). However, in the Gornaya Matcha district, due to the lack of receiving equipment, remote villages do not have access to these broadcasts.

In the city of Penjikent and surrounding villages, five television channels (TVT, TV Safina, Bahoriston, Jahonnamo, and TV Simo) and three radio programs of Tajikistan are broadcast. The limited liability public organization “Simo-TV” has been operating since 1992.

In Gornaya Matcha, the newspaper “Payomi Kuhiston” is published with a circulation of 500 copies. Due to the absence of a building and printing equipment, the newspaper is printed in the city of Khujand and is issued once a month. In the Ayni district, the newspaper “Mehnat” is published by the executive body of state authority with a circulation of 700 copies, and approximately 50% of the district’s population has access to it. This newspaper is printed in the city of Dushanbe.

C. Disaster Management Infrastructure.

Crisis management centers at local, regional, and national levels.

Evacuation points and temporary accommodation facilities to ensure the safety of people in emergency situations.

Early warning systems for emergencies (floods, landslides, earthquakes, and other hazards in the region). In the Sughd region, the Department of the Committee for Emergency Situations and Civil Defense operates. The Department carries out activities in the field of emergency management and civil defense, implementing a unified state policy for the protection and preparedness of the population, economic facilities, and territories against emergencies in both peacetime and wartime. During its operation, specialists of this institution have participated in emergency response and disaster recovery efforts in various cities and districts of the region, including Penjikent, Ayni, Gornaya Matcha, Devashtich, Spitamen, Shahristan, Asht, and Isfara.

Over the course of its activities, the personnel of the Department have taken part in responding to major accidents and emergencies in the Zeravshan basin, including:

- 2002–2003: relocation of residents from the villages of Vashan and Revat (Ayni district), Dashti Koni (Devashtich district), and Dashti Kozi (city of Penjikent) from hazardous areas to safer locations;

- 2005: relocation of part of the population affected by emergencies in the Shing jamoat (Penjikent) to the settlement of Sarazm;

- 2016: response to the consequences of a mudflow in the city of Penjikent;

- 2016: response to the consequences of a mudflow in the Ayni district.

At the regional Department, as well as in the divisions and sectors of cities and districts located in the potential flood zone of the Kayrakkum Reservoir and other areas exposed to possible emergencies, 19 ICOM radio stations operating on VHF frequencies, 2 ICOM radio stations operating on HF frequencies, and 1 repeater have been installed.

2.6 Information on the Availability and Condition of Hydrological Monitoring Systems at the National and Local Levels

A schematic map of hydrological and meteorological monitoring in the Zeravshan River basin is presented in Figure 2.6.1.

The Zeravshan River basin is relatively well covered by meteorological and hydrological observations. As of 1991, there were 9 meteorological stations and 15 hydrological posts located within the basin and along its boundaries.

Meteorological stations in the Zeravshan River basin are located in different geographical zones: in the plain zone – Samarkand; in the foothill and mountainous zone – Penjikent, Sangiston, Iskanderkul, Madrushkat; and in the high-mountain zone – Dehavz, Obburdon, Shakhristan Pass, and Anzob Pass.

Hydrological posts are mainly located in the runoff formation zone (Tajikistan), while in the downstream valley zone on the territory of Uzbekistan, hydrological posts are located at the downstream reach of the Ravatkhodja Dam, as well as at Khazora and Navoi.

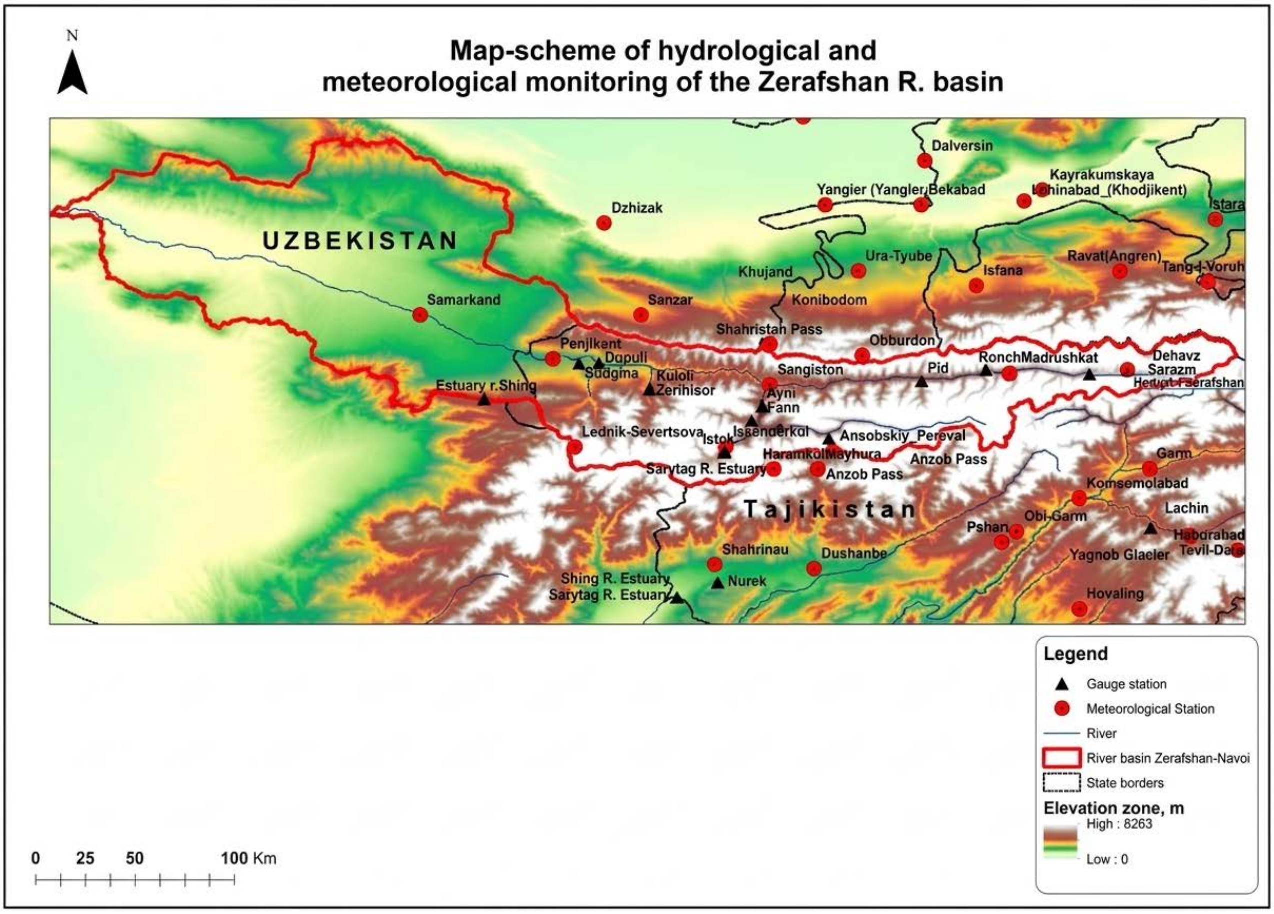


Figure 2.6.1. Schematic Map of Hydrological and Meteorological Monitoring in the Zeravshan River Basin in the Territories of Tajikistan and Uzbekistan

Table 2.6.1. List of Hydrological Posts, Observed Parameters, and Dates of Establishment in the Zeravshan River Basin in the Territory of Tajikistan (data as of 1991). (Source: Interim Report Assessment of capacity needs in terms of climate and disaster risk management (water-related) of basin councils, water management organizations and local communities in the Zarafshan River Basin (Tajikistan) National Consultant of the GIZ (Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH) project "Climate Risk Management in Central Asia" Niyazov Jafar)

No.	Water Object Name	Gauge Station Name	Measurement Parameters (H – water level, Q – water discharge)	Opening Date
1	Zeravshan River	Khudgif village	H, Q	12/11/1961
2	Zeravshan River	Dupuli Bridge	H, Q	1889
3	Samdjon River	Khudgif village	H, Q	12/11/1961
4	Guzi River	Pid station	H, Q	01/10/1964
5	Dashtioburdon River	Ronch station	H, Q	10/20/1964
6	Fandarya River	Pete village	H, Q	05/20/1964
7	Yagnob River	Takfon village	H, Q	10/07/1933 (09/01/1799)
8	Anzob River	Estuary	H, Q	04/16/1972
9	Iskanderdarya River	Source	H, Q	12/02/1929
10	Sarytag River	Estuary	H, Q	12/18/1929
11	Pasrut River	Pinyon village	H, Q	10/09/1932
12	Kshtut River	Zerihisor village	H, Q	11/01/1932 (04/11/1977)
13	Daryaurech River	Kuloli village	H, Q	11/01/1932 (11/01/1959)
14	Magiyandarya River	Sudjina village	H, Q	1889 (09/08/1983)
15	Shing River	Estuary	H, Q	01/01/1977

Table 2.6.2. List of Meteorological Stations Located at Different Elevations

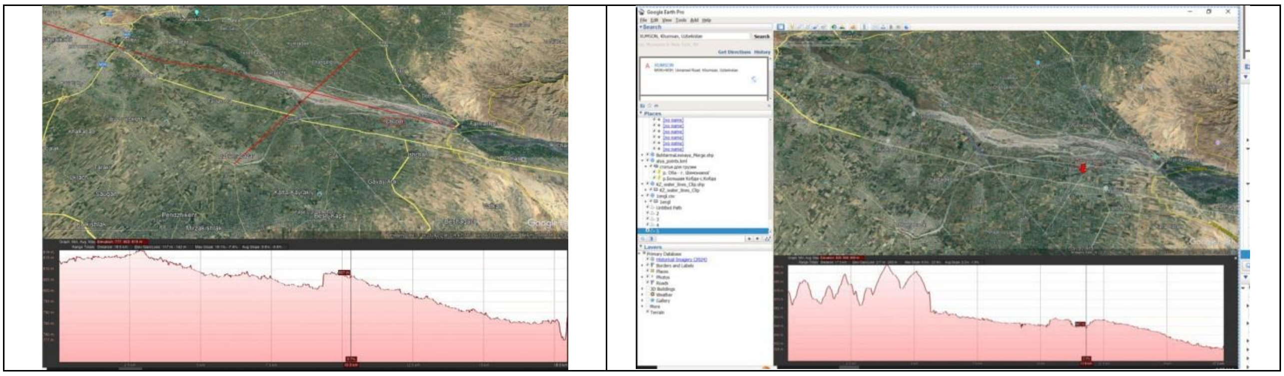
No.	Station Name (Meteo/Gauge)	River Basin	Elevation (m a.s.l.)
1	Dekhavz	Matcha	2564
2	Madrushkat	Matcha	2134
3	Sangiston	Zeravshan	1502
4	Iskanderkul	Fandarya	2204
5	Panjakent (Penjikent)	Zeravshan	1015
6	Shahristan	Zeravshan / Syr Darya	3143
7	Anzob	Zeravshan / Kafirnigan	3373
8	Dupuli	Zeravshan	1420

2.7 Proposals for Selecting Critical Sites for Fieldwork within the Project

The key site identified for the selection of a critical area is the Ravatkhodja Dam, located in the border region between Tajikistan and Uzbekistan. Water releases from the dam contribute to bank erosion and flooding of downstream areas, posing a threat to nearby settlements and residential houses, clearly visible in Google Earth images (Figs. 2.7.1 and 2.7.2). A hydrological post of the Uzbek Hydrometeorological Service ("Uzhydromet") is located on the Zeravshan River at the downstream reach of the Ravatkhodja Dam (39°32'27"N, 67°24'05"E), which is also indicated in Figure 2.7.1.

Figure 2.7.1. Location of the hydrological post "Zeravshan River – downstream reach of the Ravatkhodja Dam"

During discussions with the project expert group on the selection of critical sites for further fieldwork, proposals were supported for several areas downstream of the Ravatkhodja Dam, including the village of Chubot (Fig. 2.7.2).



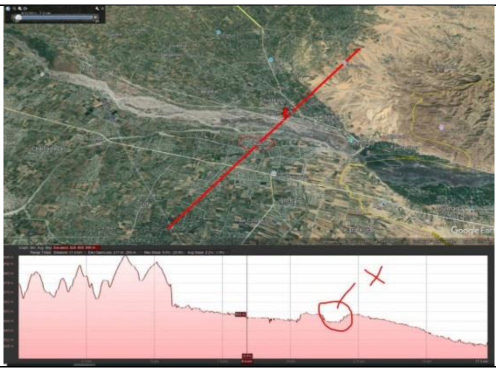


Figure 2.7.2. Explanation of the Selection of Critical Sites Downstream of the Ravatkhodja Dam (the village of Chubot, located in the risk zone, is marked with a cross).

3. Ugam River Basin: Kazakhstan – Uzbekistan

3.1 Geographical Characteristics of the Basin, Distribution of Water Resources, and Their Importance for the Region

UGAM is a mountain river in Kazakhstan and Uzbekistan, the largest right tributary of the Chirchiq River. Its length is 68.5 km, and the basin area is 869 km². The river is mainly fed by snow, with partial rainfall contribution. The average water discharge is 20.9 m³/s (during floods in some years it can reach up to 177 m³/s).

Water system: Chirchiq Syr Darya Small Aral Sea Large Aral Sea (Fig. 3.1.1).
The sources are located along the crest of the Ugam Range, in the Tolebi District of the South Kazakhstan Region, near the border with Uzbekistan. The Ugam River is formed by the confluence of several spring-fed streams. It flows into the Chirchiq River downstream of the Charvak Hydropower Plant. On its right bank is the settlement of Khojikent, and on the left bank is the settlement of Charvak.

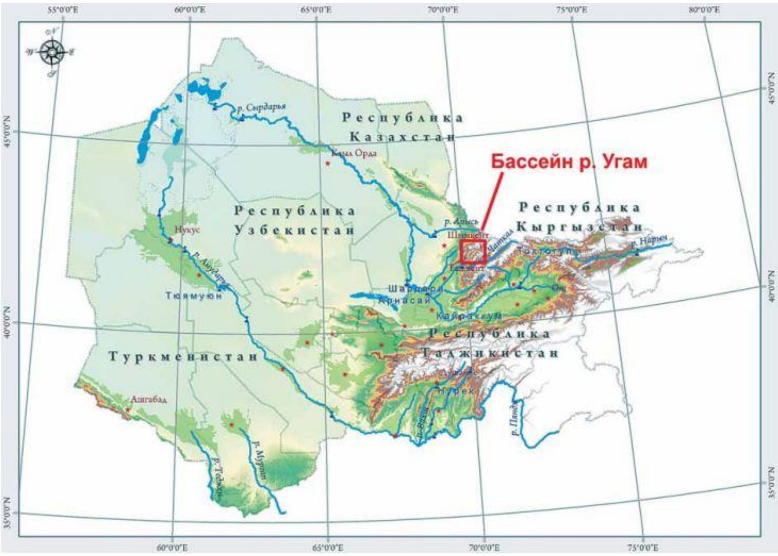


Fig. 3.1.1. Location of the Ugam River basin in the territory of CA

https://www.riverbp.net/library/publicationsatlas_basseyn_reki_ugam_/

he Ugam Range generally does not exceed elevations of 3,600 m. The elevation within the Ugam River basin ranges from 758 to 3,583 m above sea level (Fig. 3.1.2). The Ugam River has an eastward orientation, and in its upper reaches, a southeastward direction. The water content of the eft tributaries increases upstream, due to the rising elevation of the Ugam Range and the associated increase in the number and size of interfluve snowfields. Elevation differences within the described section of the basin range from 750 to 2,800 m above sea level. The terrain is mountainous, with slopes ranging from 15° to 40° in steepness (Fig. 3.1.3). The slopes are highly dissected by both temporary and permanent watercourses, resulting in a high variability of vegetation distribution, depending on slope orientation.

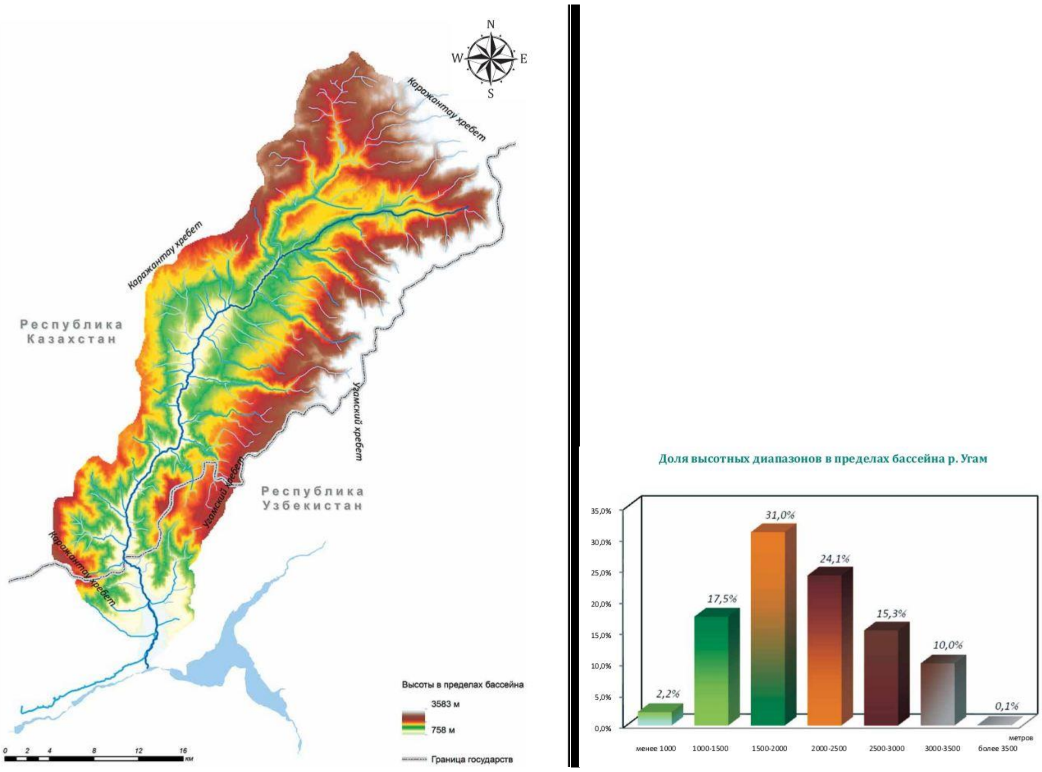


Fig. 3.1.2. Physical and geographical map of the Ugam River basin
https://www.riverbp.net/library/publications/atlas_basseyn_reki_ugam_/

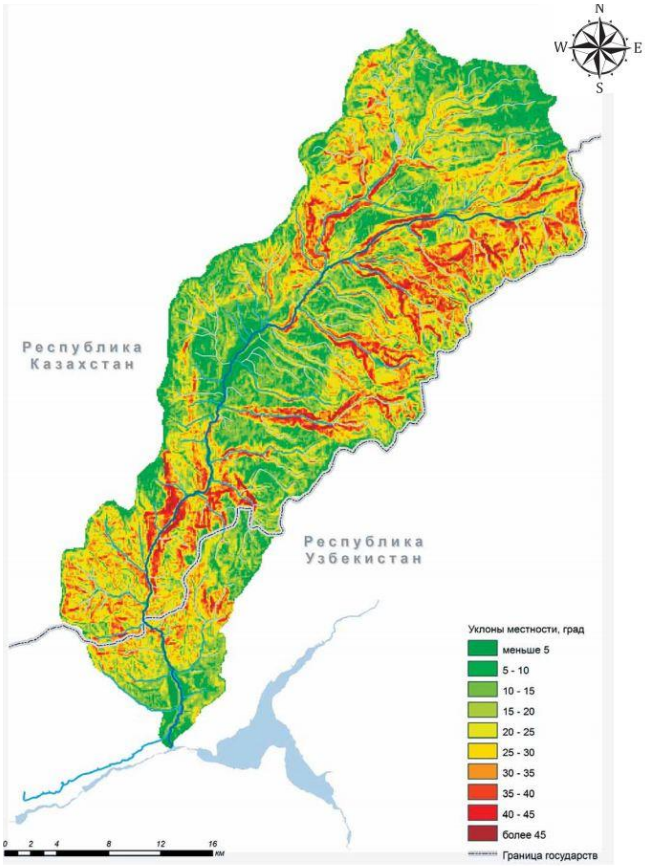


Fig. 3.1.3. Slope map of the terrain
https://www.riverbp.net/library/publications/atlas_basseyn_reki_ugam_/

3.2. Distribution / Use of Water Resources of the Basin

The Ugam River basin, in hydrological terms, belongs to the basin of the Chirchiq River, which in turn is part of the Syr Darya basin. The Ugam River originates from the Ugam Range and extends for more than 67.5 km from the northeast to the south, with about 32 main tributaries. The main water resources of the basin consist of the recorded surface runoff of the Ugam River. Runoff monitoring is carried out by the hydrometeorological service at a station near the village of Khojikent, located 2.7 km from the river mouth. Compared to other major tributaries of the Chirchiq River (such as the Pskem River and the Chatkal River), the Ugam River is characterized by a lower elevation, which leads to an earlier concentration of runoff. The Ugam River (known in its upper reaches as Akburkhan) is a transboundary river. It originates in Kazakhstan on the southern slope of the Talas Alatau (part of the Tian Shan). Within Kazakhstan, it has an average annual discharge of 18.7 m^3/s, accounting for 83% of the total river flow. The hydrological scheme of the Ugam River is shown in Fig. 3.2.1.

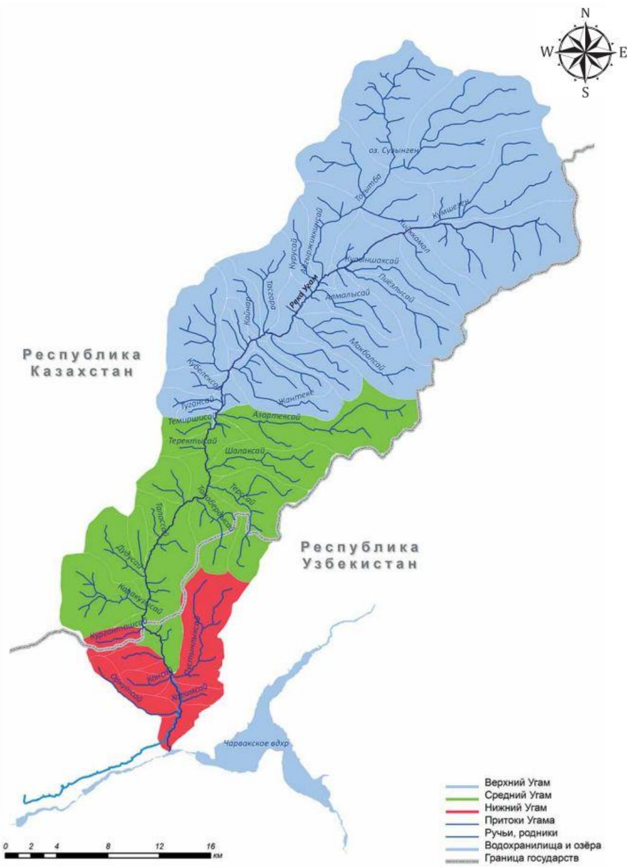


Fig. 3.2.1. River network and basins
https://www.riverbp.net/library/publications/atlas_basseyn_reki_ugam_/

The Ugam River is a small transboundary river flowing through the territory of Kazakhstan (upper and middle reaches) and Uzbekistan (lower reaches). It is the largest right tributary of the Chirchiq River. Its sources are located along the crest of the Ugam Range, in the Tolebi District of the South Kazakhstan Region. The river flows into the Chirchiq River in the Tashkent Region. The basin area is approximately 870 km². The annual runoff reaches up to 1.2 km³, while in an average water year it is about 0.684 km³. The total length of the river, according to various sources, ranges from 68.5 to 74 km.

Kazakhstan section: upper and middle reaches.

- Sources — the northern slopes of the Ugam Range (northwestern slopes of the Western Tian Shan). • The river is primarily snow-fed, with partial contribution from rainfall. •I t flows from northeast to southwest, toward the border with Uzbekistan. • Tributaries are of spring and rain origin: Kurusay, Almaly-say, Tasgora, Kaipar, and others. • Elevation drop: from 3,070 m above sea level at the source to 1,400 m at the state border. • River gradient: 34 m/km. • The water is ultra-fresh; according to the Water Pollution Index (WPI), it belongs to Class 1 — "very clean." • No hydrological monitoring stations are present on the territory of Kazakhstan. • Settlements: one settlement located in the middle course — Ugam Forestry, with a population of up to 200 people.

Uzbekistan section. Lower course.

The river enters the Chirchiq Valley (territory of the Tashkent Region) and flows into the Chirchiq River. The length of the river from the state border to its confluence with the Chirchiq River is 17 km. 3. River gradient: 17 m/km; 4. A hydrological station is located in the settlement of Khojikent; 5. Settlements along the river include Charvak.

Settlements along the river also include Khumsan and Boshut, as well as children's camps, sanatoriums, and recreation facilities. The Ugam River provides up to 20% of the total flow of the Chirchiq River into the Charvak Reservoir. The Charvak Reservoir (748 m above sea level) is one of the key water supply sources for the metropolis of Tashkent.

The main hydrographic and hydrological characteristics, along with acceptable error margins, are presented in Table 3.2.1.

Table 3.2.1. Geographical and hydrological characteristics of the Ugam River (based on the reference book "Surface Water Resources of the USSR").

https://www.riverbp.net/library/publications/basseynovyy_plan_reki_ugam_kazakhstanskaya_chast/

				Slope	, m/km	*Catchment*	characteristics	Average monthly discharge, m³/s	, Months										
River Name	Hydrological station number as per the reference manual	Location of the hydrological station	River length from source, km	average	weighted average	*Area, sq. km*	*Average elevation, m*	1	2	3	4	5	6	7	8	9	10	11	12
Ugam	294	Khodjikent	74	34	17	869	2030	6,88	7,78	15,5	42,8	51,7	47	29,7	15,4	10,1	8,41	8,33	7,64

Hydrological characteristics of the Ugam River (Hodzhikent village station)

Characteristics	Monitoring period, years		
	1935-1960	1960-2010	1935-201
Average annual water discharge, m³/s	21,1	23,3	22,5
Maximum annual discharge, m³/s	30	33	33
Minimum annual discharge, m³/s	12	14	12
Average runoff module, m³/s	23,7	26,3	23,4
Average annual discharge, m³/s for years:			
• 5% probability (exceptionally high-water)	29	33	33
• 25% probability (high-water)	27	27	27
• 50% probability (average)	19	23	22
• 75% probability (low-water)	17	18	18
• 95% probability (exceptionally low-water)	12	14	14

Irrigation network and water management facilities in the Ugam River basin

On the right bank of the Ugam River, below the Khojikent post, there is a water intake into the Ugam canal, which is part of the dispersion zone (irrigation network) of the Ugam River basin. The canal, operated by AVP Khujakent-Agro (Bostanlyk district), was put into operation in 1952. The length of the canal along the main channel is 19.7 km, the total length of the irrigation network is 31.5 km, the canal capacity is 2 m³/s. AVP Khujakent-Agro serves 30 farms with an area of 729 ha, including: 150 ha under wheat, 70 ha under vegetables, orchards and household plots 509 ha. Currently, the concrete lining of the canal is destroyed, the channel is silted up, and the delivery of water to irrigated lands is difficult. In order to reduce water losses and increase the channel capacity (up to 3 m³/s), reconstruction of the canal is planned, including works on cleaning and concreting the canal in separate sections.

The Ugam Canal is part of the Parkent-Korasuy irrigation system. The irrigation network and canals are shown in Fig. 3.2.2.

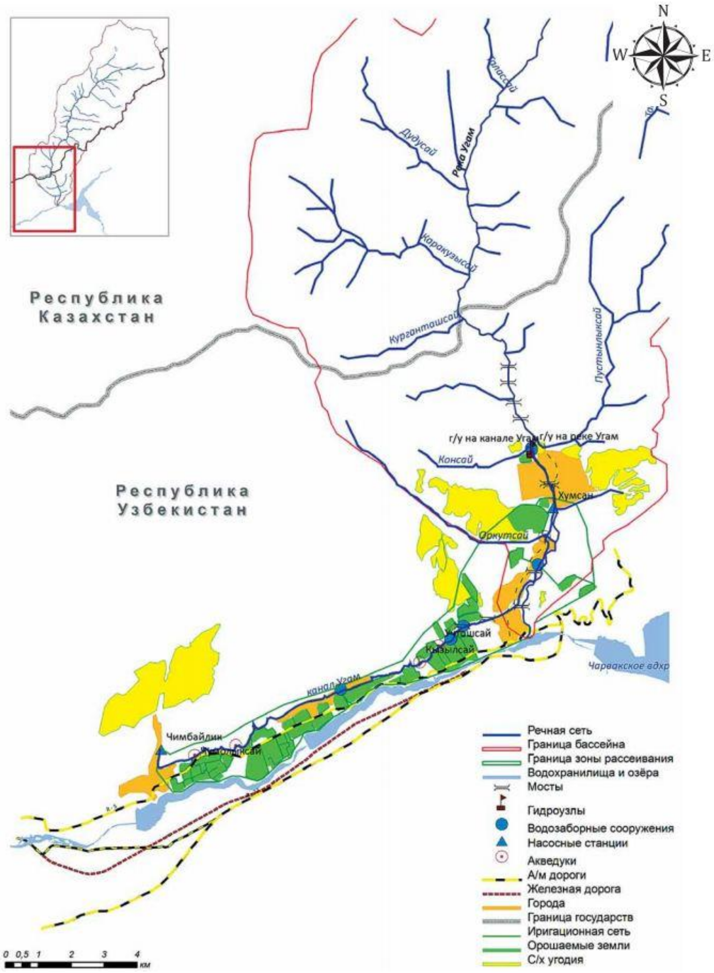


Fig. 3.2.2. Irrigation network and water management facilities in the Ugam River basin

https://www.riverbp.net/library/publications/atlas_basseyn_reki_ugam_/

3.3. Historical data on occurred emergencies. Water-related risks

Historical data on past emergencies are presented in Table 3.3.1.

Table 3.3.1. Information on past emergencies (Source: based on data from a local expert from Uzbekistan, Nodirbek Tolibov)

№	River Basin	Administrative District	Date	Cause of occurrence
1	Ugam	Bostanlyk District	21.04.2019	Heavy rainfall

2	Ugam	Khodjikent village	08.04.1959	
3	Ugam	Khodjikent village	20-21.04.1987	
4	Ugam	Khodjikent village	26.04.1996	

Explanatory note

to the Passport of mudflow-hazard areas

in the Ugam River basin and facilities (enterprises, residential areas, engineering structures, communications, etc.) located within their impact zones for 2023

Source: based on data from the Acting Head of DPES&ES, M. Userbayev.

During the passage of a mudflow in the Ugam River basin, 22 facilities in the settlement of Ugam fall within the impact zone, where 57 people live or work, including:

- 18 res. houses;
- 1 school;
- 1 road bridge;
- 1 ped. bridge;
- forest plantation (apple orchard).

Due to the short distance between the facilities, 5 sites are combined into 1 site with a total area of 130,000 m².

To the Passport of landslide-hazard areas

A site in the Ugam R. basin with a total area of 60,000 m². The potential impact zone includes 4 res. houses (Ugam settl.), a school, and a hunting lodge.

No. of residents: 11 ppl..

To the Passport of avalanche-hazard areas

In the Ugam R. basin – 1 site in the area of the Ugam settl. Under snow avalanche impact, 6 facilities are affected, incl.: 3 res. houses, a school, a hunting lodge.

No. of ppl living/working: 11 ppl, affected area: 60,000 m².

Table 3.3.2. PASSPORT of mudflow-hazard sites of the Ugam R. basin and facilities (settl., enterprises, res. areas, eng. structures, comm., etc.) located within impact zones

(Ugam R.: L – 86.5 km, F_{β} – 869 km²)

Mudflow Hazard level	Number of Hazardous Sites	Number of Moraine lakes	Impact Zone (area, m² / lenght, m)	Description of Facilities (residential buildings, social infrastructure, roads, power lines, etc,)	Number of Facilities within Impact Zone	Number of Residents/ Workers
relatively high	1	2	130 000	Ugam settlement: 18 residential houses,pedestrian bridge,	22	57

				road bridge, forest plantation		

Table 3.3.3. PASSPORT
of avalanche-hazard sites of the Ugam R. basin and facilities
(settl., enterprises, res. areas, eng. structures, comm., etc.) located within impact zones
(Ugam R.: L – 86.5 km, F_β – 869 km²)

Avalanche Hazard Level	Number of Avalanches	Impact Zone (area, m2 / lenght, m)	Description of Facilities (residential buildings, social infrastructure, roads, power lines, etc,)	Number of Facilities within Impact Zone	Number of Residents/ Workers	Remarks
Moderate	1	60 000	Settlement Ugam – 4 residential houses, a school, hunting lodge (1)	6	11	The number of people may be increased due to students.

Table 3.3.4. PASSPORT
of landslide-hazard sites of the Ugam R. basin and facilities
(settl., enterprises, res. areas, eng. structures, comm., etc.) located within impact zones
(Ugam R.: L – 86.5 km, F_β – 869 km²)

Avalanche Hazard Level	Number of Avalanches	Impact Zone (area, m2/ lenght, m)	Description of Facilities (residential buildings, social infrastructure, roads, power lines, etc,)	Number of Facilities within Impact Zone	Number of Residents/ Workers
	1	60 000	Settlement Ugam – 4	6	11

significant			residential houses, a school, hunting lodge		

3.4. Information on availability and condition of hydrol. monitoring systems at nat. and local levels

Runoff accounting of the Ugam R. – hydropost at Khojikent settl., located 2.7 km from the river mouth, is carried out by Uzhydromet. The Ugam R., compared to other (main) tributaries of the Chirchiq R. (Pskem, Chatkal), is characterized by lower elevation and earlier runoff concentration.
The Ugam R. (upper reaches – Akburkhan) is a transboundary river originating in Kazakhstan, where it has an avg. annual discharge of 18.7 m³/s (83% of total flow). The long-term avg. annual discharge (1932–2019) is 23.3 m³/s, and the max. is 347 m³/s, recorded on April 8, 1959. No meteorol. observations are conducted within the Ugam R. basin. A meteorol. station (Pskem) is located in the neighboring basin of the Pskem R.

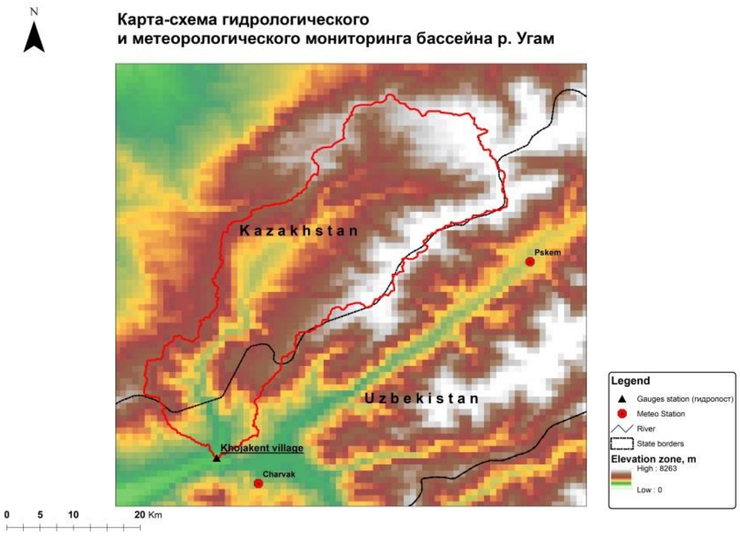


Fig. 3.4.1. Map-scheme of hydrol. and meteorol. observations in the Ugam R. basin

3.5. Proposals for selection of critical sites for fieldwork within the project

Within the discussion of critical sites in the Ugam R. basin, the settlement of Khumsan was identified as the most vulnerable to flooding from mudflow events. The selected area also includes recreation zones and private houses located at the foot of the slope (Tashkent Region, Uzbekistan). A section with a length of 5 km was selected (Fig. 3.5.1).

Fig. 3.5.1. Section prone to flooding near Khumsan settlement

4. Amu Darya R. basin – Kerki (Uzbekistan – Turkmenistan)

4.1. Geographical characteristics of the basin

The Amu Darya R. is formed by the confluence of the Panj R. and the Vakhsh R., and flows into the Aral Sea, forming a delta. In its middle course, three major right-bank tributaries (Kafirnigan, Surkhandarya, Sherabad) and one left-bank tributary (Kunduz) flow into the Amu Darya. Further downstream, up to the Aral Sea, it does not receive any tributaries, including within Turkmenistan.

The main flow of the Amu Darya is formed in Tajikistan (80%) and partly in northern Afghanistan. The river then flows along the border between Afghanistan and Uzbekistan, crosses Turkmenistan, returns again to Uzbekistan, and flows into the Aral Sea.

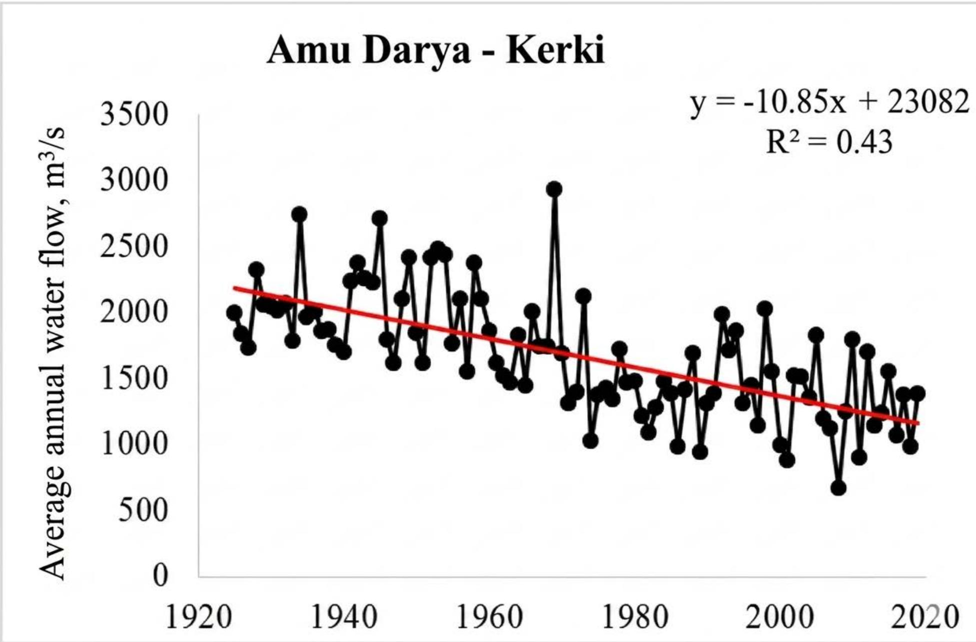
The city of Kerki is located in Turkmenistan along the Amu Darya R. The Amu Darya is the largest river in Central Asia, with a length of about 1,415 km. It flows through several countries, including Afghanistan, Tajikistan, Turkmenistan, and Uzbekistan. The area of its drainage basin reaches 309 thousand km² up to Kerki.

4.2. Distribution / use of water resources of the basin

The river is mainly fed by snowmelt and glacier waters, therefore the maximum discharge occurs in summer, while the lowest is observed in January–February. Flowing across the plain from Kerki to Nukus, the Amu Darya loses a significant part of its flow due to evaporation, infiltration, and irrigation. In terms of turbidity, the Amu Darya ranks first in Central Asia and one of the highest in the world.

Spring–summer floods, caused by melting snow and ice in high mountain areas, as well as a relatively stable inflow throughout the year, determine its hydrological regime. The flood period usually begins in late March – early April, and the maximum discharge is observed in July–August. The intra-annual distribution of runoff is favorable for agriculture. The river flow during the vegetation period of the main cultivated crops (May–August), when water demand is highest, accounts for 61.2% of the total annual runoff. The average annual discharge of the Amu Darya in the area of Kerki is 1,940 m³/s. The maximum value of the average annual discharge near Kerki can reach 2,540 m³/s, while the minimum can drop to 1,580 m³/s. At the same time, the maximum discharge can vary from 4,160 to 9,060 m³/s, and the minimum from 721 to 410 m³/s. The average annual runoff is 68.1 km³/year,, "According to the Analytical Review of the Water Sector of Turkmenistan (20), the runoff with 90% probability of exceedance is 55.2 km³/year." (Source: http://www.cawater-info.net/bk/water_law/pdf/tm_water_sector_assessment_ru.pdf)

HFigure 4.2.1 presents the trend of average annual water discharge, showing a decrease in runoff of 10.85 m³/s per year, which is associated with water withdrawals upstream of the gauging station, as well as infiltration and evaporation.



"Figure 4.2.1. Average annual water discharge at the Amu Darya River gauging station – Kerki (Turkmenistan). Source: Hikmatov F., Kalashnikova O., et al. 'Water Resources of Central Asia and Current Trends in Their Use.'

4.3. The Importance of Water Resources of the Amu Darya (Kerki) Basin for the Region The water resources of the Amu Darya are shared by five countries: Afghanistan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan. Turkmenistan's share, in accordance with existing transboundary agreements, amounts to 22 km³/year.

Approximately 80% of the Amu Darya's runoff is generated within the territory of Tajikistan. More than 35 reservoirs with a capacity exceeding 10×10^6 m³ have been constructed within the basin, with a total storage capacity of over 29.8 km³. About 17 km³ of this volume is attributed to reservoirs located directly on the Amu Darya, including the Tuyamuyun Reservoir (7.27 km³). In Turkmenistan, four reservoirs with a total capacity of 2.5 km³ are located along the Karakum Canal, and the Zeid Reservoir (3.2 km³) is currently under construction. Smaller reservoirs situated within complex canal systems—such as the Talimarjan and Tudakul reservoirs in Uzbekistan—serve primarily for seasonal water storage. The flow of the Vakhsh River is regulated by the Nurek Reservoir (10.5 km³), whereas the Panj River remains weakly regulated, resulting in frequent flooding in the section between the confluence of these rivers and the Tuyamuyun Reservoir. In the downstream plains, a portion of the Amu Darya's flow is lost due to evaporation, infiltration, and water withdrawals for irrigation

Irrigated agriculture accounts for approximately 90% of the total water consumption of the Amu Darya River. Cotton cultivation has somewhat declined, while the production of food crops has increased. Drainage waters from irrigation systems have a negative impact on water quality, leading to increased mineralization and higher concentrations of major ions from the upstream areas to the plains. Drainage waters contain, in particular, sulfates, chlorides, sodium, and pesticides, as well as nitrogen and phosphorus compounds. Water losses also occur within irrigation canals.

4.4. Information on the Availability and Condition of Hydrological Monitoring Systems at National and Local Levels

Hydrological and meteorological monitoring is primarily carried out within the territory of Tajikistan, in the runoff formation zone. It should be noted that there is a lack of monitoring data from the territory of Afghanistan. A schematic map of hydrometeorological monitoring in the Amu Darya River basin up to the Kerki section is presented in Figure 4.4.1.

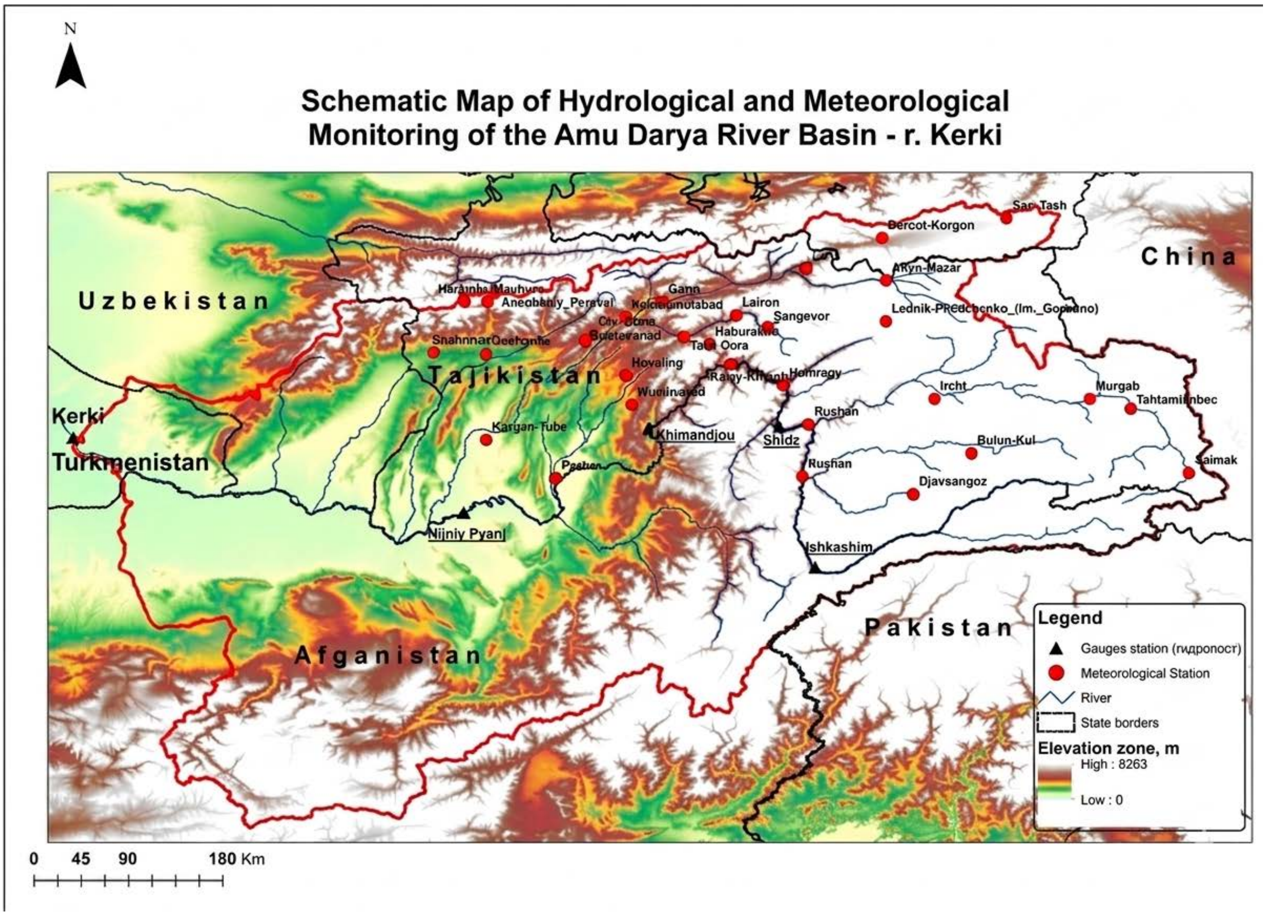
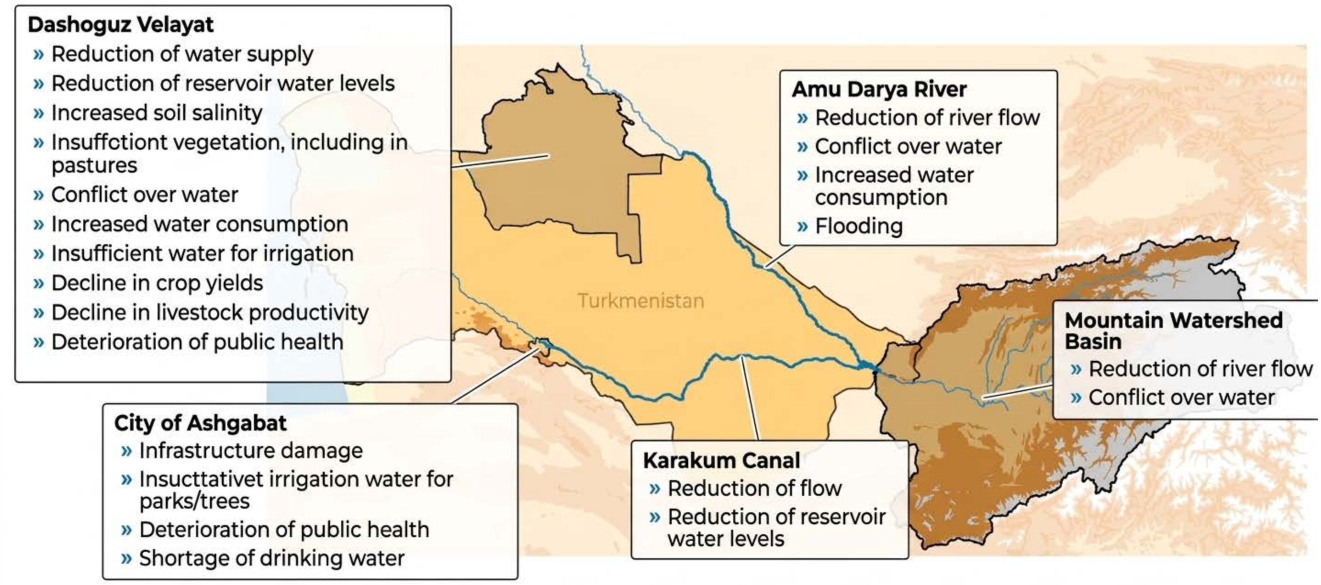


Figure 4.4.1. Schematic map of hydrological and meteorological monitoring in the Amu Darya River basin – Kerki.

5. Khorezm – Dashoguz Section: Uzbekistan – Turkmenistan

5.1. Geographical Characteristics of the Basin and Distribution/Use of Water Resources

The Khorezm–Dashoguz section is located within the territory of Turkmenistan, in the lower reaches of the Amu Darya River. In the Dashoguz velayat, the Tuyamuyun hydrosystem—a system of reservoirs fed by the waters of the Amu Darya—serves as the main source of water resources. The key climatic risks in the region include rising air temperatures and strong winds, which increase evaporation, while a high level of sediment deposition reduces reservoir capacity. The extensive irrigation network is under pressure due to significant water losses caused by infiltration and evaporation, posing a threat to agricultural water security. The location of the Dashoguz velayat within Turkmenistan and the main issues associated with climatic risks are shown in Figure 5.1.1. https://www.undp.org/sites/g/files/zskgke326/files/2024-08/undp-tm-policy-brief-2024.pdf



Source: Villner, Birkandt et al. *Climate Risks* for Water Resources and Agriculture in Turkmenistan – *Report on Climate Risk,* Vulnerability, Gender, and Vulnerable Group Assessment, 2024.

Figure 5.1.1. Location of the Dashoguz Velayat within the territory of Turkmenistan. Main natural risks of the region

One of the key transboundary issues is agricultural runoff (primarily formed by irrigation return flows), which negatively affects public health and reduces agricultural productivity in the Amu Darya River basin. Turkmenistan receives transboundary waters from several areas, including the waters of the Amu Darya and return flows from the Khorezm region of Uzbekistan. The quality of these waters, particularly return flows, is unsatisfactory due to their large volumes and the expected high levels of pollution. At present, Turkmenistan manages the disposal of these return waters, which, in turn, increases anthropogenic pressure and the risk of groundwater contamination.

5.2. Existing Monitoring and Information Storage Systems

http://www.cawater-info.net/bk/water_law/pdf/tm_water_sector_assessment_ru.pdf

At present, the following organizations are involved in water resource monitoring in Turkmenistan:
The State Committee for Hydrometeorology,
The "Amu Darya" Basin Water Resources Management Authority of the Interstate Commission for Water Coordination (ICWC),
The Ministry of Water Management,
The Environmental Monitoring Center (EMC) of the Ministry of Nature Protection,
The Sanitary and Epidemiological Service of the Ministry of Health and Medical Industry,
The State Concern Turkmengeology.

According to the Analytical Review of the Water Sector of Turkmenistan, the laboratories involved maintain sample collection logs, and those laboratories where chemical analyses are conducted keep corresponding analytical records. However, it should be noted that such records are maintained in a single copy, registered, and stored within the laboratories themselves. All data processing and calculations are carried out manually. In most cases, computer equipment is either completely absent, obsolete both morally and technically, or used only by administrative staff or accounting departments. The processing and aggregation of collected information are also performed manually due to the lack of appropriate computer equipment and software. The processed information is stored in reports, and electronic databases are not used for this purpose.

6. Development of Recommendations for Improving the Mechanism of Exchange of Hydrometeorological Information among the Hydrometeorological Services of Central Asian Countries

At the global and regional levels, as members of the World Meteorological Organization and the Interstate Council for Hydrometeorology of the Commonwealth of Independent States, the National Hydrometeorological Services of Central Asian countries ensure, through their hydrometeorological systems, access for the international meteorological community to data from national observation networks, and receive information from the National Hydrometeorological Services of other countries

7. Main Users of Hydrometeorological Information at the Regional Level

At the regional level, the primary users of hydrometeorological information are the National Hydrometeorological Services (NHMSs) of Central Asia. Bilateral agreements on scientific and technical cooperation, as well as cooperation programs in operational activities, exist between the NHMSs of Central Asian countries. These cooperation programs define the type, timing, frequency, and methods of information exchange. The exchange includes observed meteorological, aerological, hydrological, and agrometeorological data, as well as information products such as weather forecasts, river flow and reservoir inflow forecasts of varying lead times, storm warnings on hazardous hydrometeorological events, bulletins, reviews, and other materials.