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As part of the CAREC project
"Sustainable Landscape Restoration in the Kyrgyz Republic" (KG RESILAND)

ANALYTICAL REVIEW
on mudflows and floods in Central Asia
that have a transboundary nature

Central Asia – 2025

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Brief Summary
on floods and mudflows in Central Asia that have a transboundary nature

The Central Asian region comprises the Republic of Kazakhstan, the Kyrgyz Republic, the Republic of Tajikistan, Turkmenistan, and the Republic of Uzbekistan. The region covers an area of approximately 4 million square kilometers and has a total population of over 80 million people. The population density in the region is only about 20 people per square kilometer[1] .

From a geographical standpoint, Central Asia is an extremely vast subregion that includes mighty mountain ranges, such as the Tian Shan, as well as large deserts and steppe regions. *The* largest *transboundary rivers* in this region are the Amu Darya and the Syr Darya. The largest bodies of water include the Caspian Sea, the Aral Sea, and Lake Balkhash, which are part of the West-Central Asian closed basin.

Central Asia’s landlocked location within the Eurasian continent determines its sharply continental climate, with low and unevenly distributed precipitation. The region is characterized by a wide range of daily and seasonal temperatures, high solar radiation, and relatively low humidity.

Significant variations in geographic location and elevations ranging from 0 to 7,500 meters above sea level account for the diversity of microclimates. The mountains are located in the east and southeast and serve as the source of water resources and their runoff. Although this area often experiences moist winds, most of the moisture is absorbed by the mountains, leaving little precipitation for the rest of the basin. Temperature fluctuations are quite significant—ranging from -40°C to +40°C. Precipitation in the lowlands and valleys ranges from 80 to 200 mm per year, with most precipitation falling in winter and spring. Meanwhile, the foothills receive 300–400 mm of precipitation, and the southern and southwestern slopes of the mountain ranges receive 600–800 mm.

A sharp increase in population and the development of irrigation over the past 40 years have significantly increased the demand for land and water in the region. At the same time, more than 46% of the population lives in cities.

The region is characterized by vast areas of high seismic activity, with the potential for strong earthquakes measuring 7, 8, 9, or higher on the Richter scale, as well as *mudflows*, floods, *flash floods*, landslides, snow avalanches, flooding of low-lying areas, rising groundwater levels, strong and hurricane-force winds, and even tornadoes, desertification, dust and sandstorms, prolonged and torrential rains, hail, heavy snowfalls and blizzards, droughts, frosts, rockfalls and landslides, steppe, forest, and mountain fires, extreme temperatures, environmental, man-made industrial, and transportation accidents, explosions, major fires, epidemics, widespread infectious diseases affecting humans and animals, damage to agricultural crops caused by diseases, weeds, and pests, as well as the presence of artificial reservoirs and reservoirs at risk of breach, nuclear and chemical waste storage facilities, and facilities handling toxic and highly potent substances or involving hazardous technological processes.

Central Asia faces serious challenges in combating the adverse effects of climate change. In particular, the impact of climate change on *water-related disasters* in the region has been *recognized as one of the key threats*. For example, over the past 45 years, temperatures have risen by 1 degree in Kyrgyzstan, by 1.6 degrees in Turkmenistan, by 1.4 degrees in Kazakhstan and Uzbekistan, and by 0.7 degrees in Tajikistan.

One of the most significant consequences of global warming in Central Asia is the melting of glaciers and the associated formation of glacial lakes. The current rate of glacier retreat in the region is 0.2–1% per year. Due to glacial melting and the subsequent formation of glacial lakes, there is an increased risk *of flash floods* caused by glacial lake outbursts, which exacerbate water-related threats to mountain communities, their settlements, and livelihoods, and also threaten infrastructure located in river valleys and downstream areas.

[1] https://cesdrr.org/uploads/docs/2025/Региональная_характеристика.pdf

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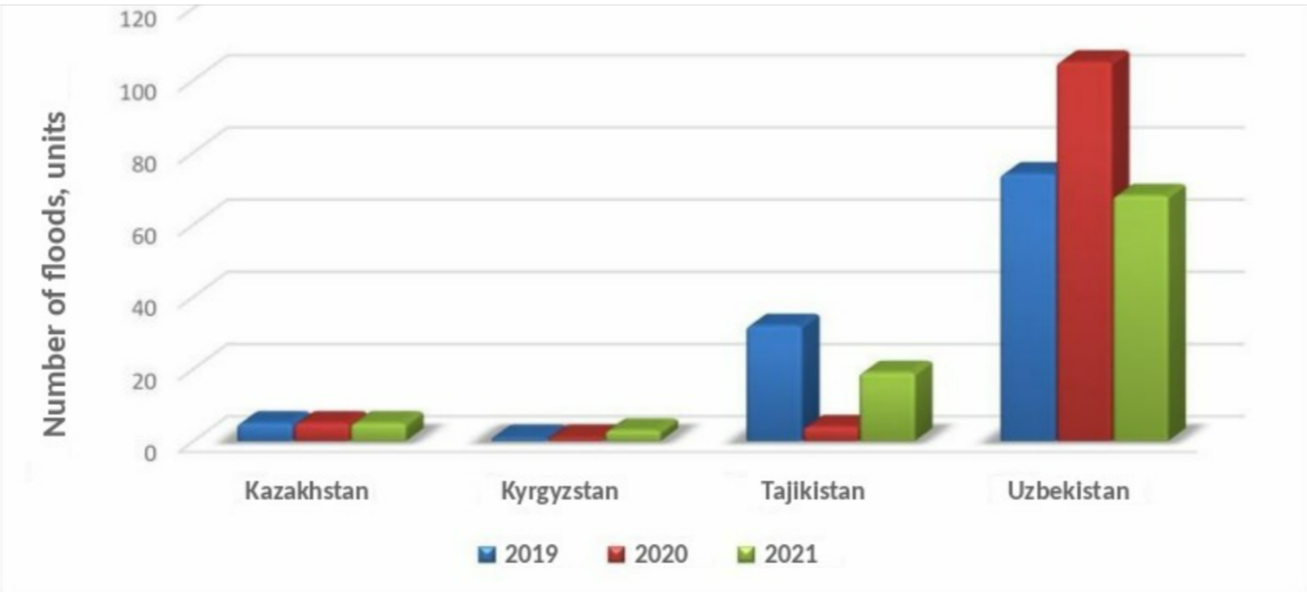
The threat of *mudflows, flash floods*, and floods is the second most significant hazard in Central Asia. The region features a mountainous terrain and is crisscrossed by several hundred large and small rivers and their tributaries. Floods, *flash floods, and mudflows* are the most frequent natural disasters in Central Asia, particularly in the basins of the region's largest *transboundary* rivers—the Amu Darya and Syr Darya—and it is these events that cause significant damage to housing, infrastructure, and agriculture, primarily in rural areas. Although the total volume of water resources remains fairly stable, annual and seasonal hydrological variability in the basins of these rivers has become more pronounced in recent years.

Since 2005, the number of years with high water levels has increased by a factor of 1.2 to 1.4, and the number of years with excessively high water levels has increased by a factor of 2.0 to 2.5. In recent decades, there has been an increase in the number *of mudflows*, the frequency of which is directly linked to cycles of rainy and dry years.

The mountains of Central Asia are home to thousands of lakes and artificial reservoirs. When their dams and embankments fail, floods, *mudflows, and flash floods* occur, triggered by the rapid melting of snow cover and the overflow of glacial lakes, which often result in damage to settlements and infrastructure in downstream areas. Due to the large volume of water released as a result of dam and levee breaches in glacial lakes and large reservoirs, floods, *flash floods, and mudflows* occur, often leading to *cross-border* emergencies.

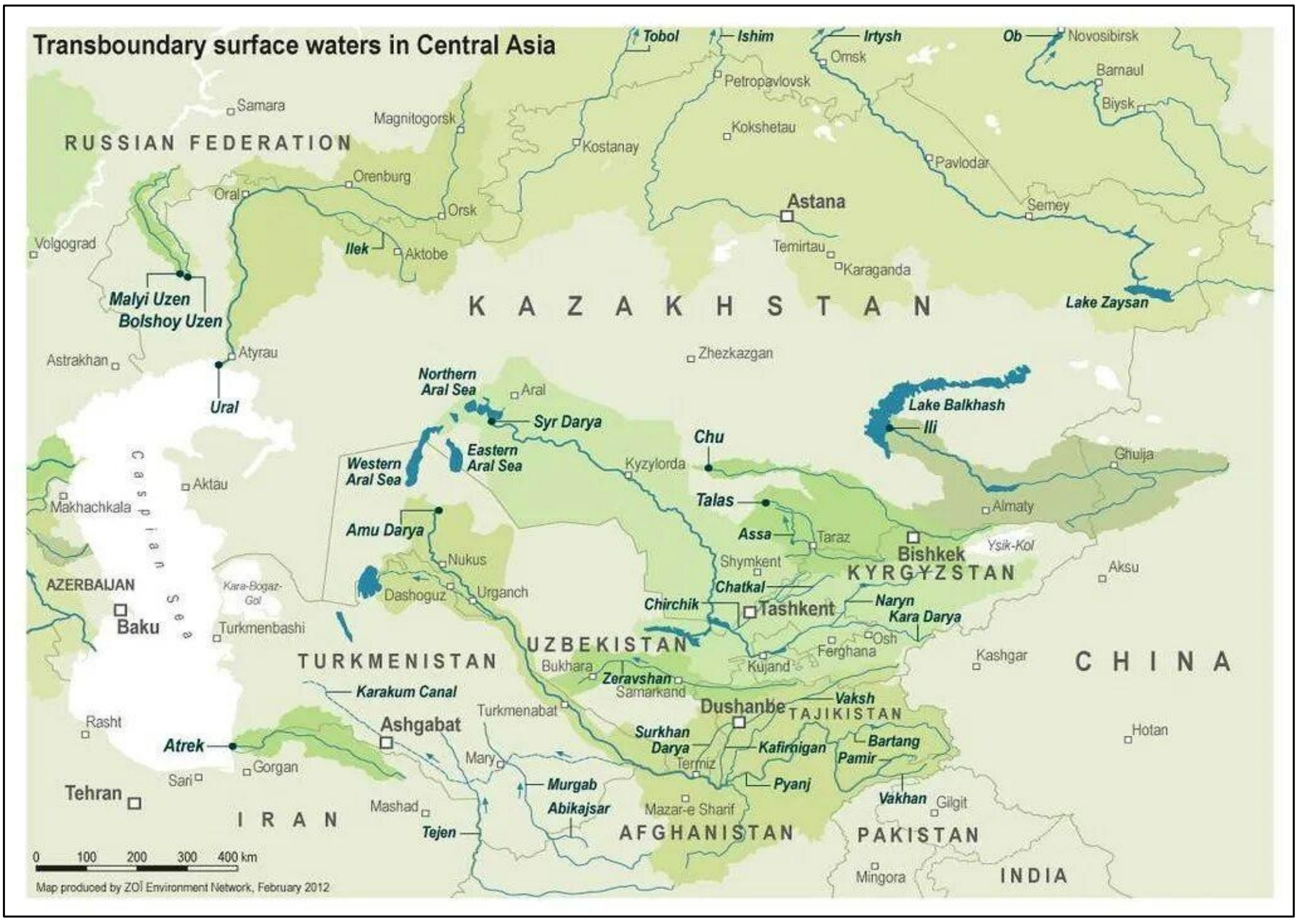


The figure shows the trends in snowmelt and rain-induced floods that occurred in Central Asian countries from 2019 to 2021.

The figure shows the dynamics of mudflows that occurred in Central Asian countries from 2019 to 2021.

<u>*Transboundary*</u> river waters belong to the territories of the bordering states and form part of those territories. The sovereignty of a riparian state extends to that part of a transboundary river located between the bank belonging to that state and the state border, which is generally established along the centerline of the river's main channel.

The countries of Central Asia (Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan) have numerous <u>*transboundary water resources*</u>—rivers that cross the territories of two or more states or flow across their borders.



This is due to the region's geographical location: the mountains in Kyrgyzstan, Tajikistan, and northeastern Kazakhstan have abundant reserves of snowmelt and glacial water, while Turkmenistan, Uzbekistan, and the central part of southern Kazakhstan have a sparse river network and limited water resources.

The Amu Darya, the region's largest <u>*transboundary*</u> river, originates at the confluence of the Panj and Vakhsh rivers; in its middle course, the Kafirnigan, Surkhandarya, and Sherabad rivers flow into it from the right, while the waters of the Kunduz flow in from the left. The river, which originates in Tajikistan and partly in northern Afghanistan, flows along the border between Afghanistan and Uzbekistan, then through the territory of Turkmenistan, and returns to Uzbekistan. Over the next 1,257 km, no other watercourses flow into the Amu Darya.

The Syr Darya, the second most important <u>*transboundary*</u> river in the region, originates at the confluence of the Naryn and Kara-Darya rivers, flows through the territories of Kyrgyzstan, Uzbekistan, and Tajikistan, and empties into the Aral Sea via Kazakhstan. In the river's middle course, the Akhangaran, Chirchik, and Keles rivers flow into it. The Arys is considered the last tributary to flow into the river.

With regard to the threat of transboundary mudflows and floods, the two largest river basins for the countries of Central Asia are *the Syr Darya and the Amu Darya*.

In addition to *the Syr Darya and Amu Darya* rivers, the following river basins pose a threat of transboundary mudflows and floods to the countries of Central Asia:

1) For Kyrgyzstan and Kazakhstan—*the Chu (Shu) and Talas, Karkara, and Aspara river basins…*
2) For Kyrgyzstan and Uzbekistan—*the Isfayram-Say, Ak-Suu–Shakhimardan, Soh, Karavshin-Isfara, Leylek-Ak-Suu, Kara-Darya, and Naryn river basins…*
3) For Kyrgyzstan and Tajikistan: *the Isfara River basin...*
4) For Kazakhstan and Uzbekistan: *the Ugam River basin...*
5) For Tajikistan and Uzbekistan: *the Zaravshan River basin...*

This Analytical Review of Transboundary Mudflows and Floods in Central Asia *provides an overview and analysis of the 13 largest river basins*, along with a brief description of each, including statistics, trends, the areas affected, and the impact (including on landscape degradation) of transboundary mudflows and floods, the consequences of which have extended or may extend beyond the official borders of states, causing damage and affecting people's living conditions.

Key Terms and Definitions Used in This Analytical Review

In this *Analytical Review*, with regard to transboundary mudflows and floods in Central Asia, *the* following *key terms and definitions* are used:

- **Transboundary waters**[2] - *means any surface or groundwater that marks, crosses, or is located on the boundaries between two or more States; where transboundary waters flow directly into the sea, the limits of such transboundary waters are defined by a straight line crossing their mouth between the currents located at the low-water line on their banks.*
- **Transboundary Impact**[3] - *means any significant adverse effects resulting from a change in the condition of transboundary waters caused by human activities, the physical source of which is located wholly or partly in an area under the jurisdiction of one Party, on the environment in an area under the jurisdiction of the other Party.*

  Such environmental effects include effects on human health and safety, flora, soil, air, water, climate, landscape, and historical monuments or other tangible objects, or the interaction of these factors.
- **Potential sites at risk of mudflows and flooding:**
  - ✓ *These include rivers, reservoirs, high-altitude lakes, and other water bodies—such as river basins—located in the transboundary territories of Central Asian countries, where there is a real threat of mudflows, floods, or transboundary emergencies.*
- **Transboundary emergencies** *(including transboundary disasters related to mudflows and floods)* **are:**

[2] https://www.un.org/ru/documents/decl_conv/conventions/watercourses_lakes.shtml

[3] https://www.un.org/ru/documents/decl_conv/conventions/watercourses_lakes.shtml

- *natural emergencies (natural disasters) whose consequences extend beyond a country's national borders or affect its territory, caused by natural phenomena occurring abroad;*
- *an emergency situation associated with a natural disaster (mudflow, flood) that either occurs within the territory of one country but whose consequences extend to another, or occurs abroad but affects territories near the border;*
- *emergencies whose consequences may extend beyond the official borders of states, causing damage, affecting people's living conditions, and requiring international cooperation for their resolution.*

▪ **Flash flood:**

- *a flow consisting of a mixture of water and solid components, the damage caused by which is due to the solid components moving under their own potential energy (definition in the Republic of Kazakhstan);*
- *a flow with a very high concentration of mineral particles, stones, and rock debris (up to 50–60 percent of the flow's volume), which occurs suddenly in the basins of small mountain rivers and dry ravines and is typically caused by torrential rainfall or rapid snowmelt (definition in the Kyrgyz Republic);*
- *these are powerful mud-and-rock flows that form in mountainous areas due to heavy precipitation, intense snowmelt or glacial melt, as well as other factors leading to rapid saturation of the aquifer; they are characterized by high density and destructive power (definition from the Kyrgyz Republic's National Action Plan through 2030);*
- *a rapid channel flow occurring in mountain rivers and ravines, usually due to heavy rains, snowmelt, or glacial melt (definition in the Republic of Tajikistan).*

▪ **Flood:**

- *This is a phase of a river's hydrological regime that may recur repeatedly throughout the year; it is characterized by an intense, usually short-term increase in discharge and water levels and is caused by rainfall or snowmelt during thaws (definition in the Republic of Kazakhstan);*
- *this is a phase of a river's hydrological regime involving a relatively short-term and non-periodic rise in the river's water level caused by increased snowmelt, glacial melt, or heavy rainfall (definition in Kyrgyzstan);*
- *These are short-term rises in water levels in rivers, reservoirs, and other watercourses caused by heavy precipitation, snowmelt, or glacial melt (definition from the Kyrgyz Republic's National Action Plan through 2030).*

▪ **Breach of dams in high-altitude natural lakes:**

- *a mudflow or flood surge with destructive force that overlaps the natural phases of the water regime of a river or temporary watercourse as a result of the complete or partial destruction of the dam structure (definition in the Kyrgyz Republic).*

▪ **Breach of dams, embankments, locks, weirs, and other structures:**

- *a formed mudflow or flood flow possessing destructive force that overlaps the natural phases of the water regime of a river or temporary watercourse as a result of the complete or partial destruction of the structure of a dam, embankment, sluice, bridge, or other structure (definition in the Code of Rules).*

PART 1:
Overview of transboundary mudflows and floods affecting Kazakhstan and Kyrgyzstan

1. Chu River Basin: Overview of transboundary mudflows and floods affecting Kazakhstan and Kyrgyzstan

Source [4]

1) The Chu River has a drainage basin area of 62,500 km² and a total length of approximately 1,067 km.
2) *The first 115 km are located in the Kyrgyz Republic*, and *for the* next *221 km, the river serves as the border between the Kyrgyz Republic and Kazakhstan*. This upper watershed receives most of the precipitation, mainly in the form of snow in winter.
3) *The final 731 km, the lower basin, are located in Kazakhstan* and flow through arid and semi-arid regions that rely heavily on the river's flow to meet the needs of the population and agriculture.
4) A significant portion of the Chu River's flow is regulated by the Orto-Tokay Reservoir. The main unregulated source of water supply is the Chon-Kemin River.
5) The flow regime in the Chu River basin is significantly altered by several reservoirs and irrigation systems, and flooding does not pose a significant threat. Neither the EM-DAT database nor the GLIDE database *contains any catastrophic events associated with this river channel.*
6) However, reduced flow and the presence of reservoirs are *disrupting the sediment balance in some sections, and in certain areas, bank erosion is becoming a problem*. This is of particular concern *along the 221-kilometer border between the Kyrgyz Republic and Kazakhstan*, where river channel migration could lead to territorial disputes.
7) Historical photographs suggest that Kazakhstan has gradually reinforced the river's northern bank with an elevated road, which also functions as a levee; for example, near the village of Vasilyevka (Kyrgyz Republic), an elevated road along the riverbank was constructed between 2008 and 2010.
8) As a result of the construction of this embankment*, the river has recently been flowing mainly southward, where there are no physical constraints on the evolution of the floodplain*; this general trend is clearly evident in GSWE2, which analyzes Landsat images for water transitions over the past 40 years. The image shows that the pink areas *(converted from seasonal water to solid soil)* predominate on the northern *(Kazakh)* side, while the green areas (solid soil converted into new seasonal water) are on the southern *(Kyrgyz)* side of the border.
9) Even with a lower average flow, *the Chu River will still be capable of generating flood events* and will undoubtedly continue to carve out new meanders on the southern bank, a process driven more by specific events than by a continuous process. This will undoubtedly result in damage, primarily the loss of agricultural land.
10) River floods, defined as large-scale processes occurring over several days—as opposed to flash floods and landslides—can occur only in the middle and lower reaches of the Chu River.
11) *The* most severe *floods are associated with bank erosion* caused by changes in the river's course due to sediment imbalance resulting from the reservoir in the upper reaches and reduced discharge.
12) In recent years, there have been isolated *cases of erosion along the Chu River on the border between Kazakhstan and the Kyrgyz Republic*, resulting in the destruction of some farms and the shifting of the border territory. This is reported annually in the reports of the Department of Natural Disaster Monitoring of the Kyrgyz Republic.

Source [5]**:**

1) *Bank erosion is actively occurring along the left bank of the Chu River* in the Kemin, Chuy, Issyk-Ata, Alamudun, and Sokuluk districts.

[4] https://cesdrr.org/uploads/docs/2025/Final_Report.pdf
[5] https://www.mchs.gov.kg/ru/kyrgyz-respublikasynyn-aimagyndagy-korkunuchtuu-processterge-zhana-kubulushtarga-monitoring-zhurguzuu - Book by the Ministry of Emergency Situations of the Kyrgyz Republic: "Monitoring and Forecasting of Hazardous Processes and Phenomena in the Kyrgyz Republic"

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2) At risk are the bypass highway, cemeteries, protective levees, power lines, a gas pipeline, farmland, and other facilities.

3) In 2013, the design and survey company "RiR" developed the Master Plan "Protection Against Erosion of the Left Bank of the Chu River on the Section from the City of Tokmok to the Village of Kamyshanovka." According to the plan, *the* natural *erosion processes of the Chu River mainly manifest as lateral erosion* with intense undercutting and destruction of the banks; anthropogenic factors—clearing and burning of floodplain forests, the operation of construction material quarries in the river channel, and long-term unilateral regulation of the river channel and floodplain by Kazakhstan. As a result of these processes, the dynamic axis of the flow has shifted toward the left bank over a total stretch of up to 65 kilometers.

4) *In the event of a breach of the tailings ponds in the village of Ak-Tuz and the city of Orlovka*, tailings could be carried into the Chu River basin, *contaminating not only the territory of the Kyrgyz Republic but also that of the Republic of Kazakhstan*.

5) Within the Chui Region, there are *more than 210 sections of erosion along the left bank of the Chui River, with a total length of approximately 45–70 km*, depending on the volume of water flow during flood-prone periods.

Source [6]

The safety data sheet for the Zhambyl Region states the following:

1) The Shu River originates in the mountains of Kyrgyzstan. Its total length is 1,186 km, of which approximately 850 km is within Kazakhstan.

2) There are *38 sections* in the Shu River basin that *are at risk of mudflows and flash floods*.

3) The Shu River valley consists of layered alluvium, in places overlaid by thin layers of loess-like loam and clay. Climatic factors have a particularly significant influence on the formation of the soil cover.

4) Hydromorphic soils *(meadow, meadow-marsh, and marsh soils)* with varying degrees of salinity are common in the floodplain of the Shu River and its lower reaches.

2. **The Talas River Basin:** An Overview of Rivers and Floods with Transboundary Characteristics for Kazakhstan and Kyrgyzstan

Source [7]

1) The Talas is a river flowing through Kyrgyzstan and Kazakhstan. The river is 661 km long, and its drainage basin covers an area of 52,700 km².

2) The river is fed by glacial and snowmelt runoff. It is formed by the confluence of the Karakol and Uch-Koshoy Rivers, which originate in the Talas Ala-Too glaciers of Kyrgyzstan. Along its course, the Talas River receives many tributaries, the most substantial of which are the Urmaral, Kara-Buura, Kumushtak, Kalba, and Besh-Tash. In its lower reaches, the river disappears into the sands of Moyinkum.

3) On the left bank of the river lies Talas, the administrative center of the Talas Region of Kyrgyzstan, and further downstream is Taraz, the administrative center of the Zhambyl Region of Kazakhstan.

4) The river features the Talas, Temirbek, Zhiyembet, and Uyuk hydroelectric complexes. The Kirov Reservoir is also located on the river.

5) The flood season lasts from late April to early September. The average discharge in the upper reaches (555 km from the mouth) is 15.7 m³/sec, and upstream of Taraz (444 km from the mouth) it is 27.4 m³/sec.

6) There is one left tributary—the Asy River.

[6] Safety Data Sheets for the Zhambyl, Kyzylorda, and Turkestan Regions
[7] https://ru.ruwiki.ru/wiki/Талас_(river)

Source [8]:

1) In the Talas River basin, mudflows and flash floods are most likely to occur. During periods of intense, locally concentrated precipitation, flash mudflows and areas of flash flooding may occur.
2) Along the Talas River near the villages of Pokrovka, Jiyde, and Uch-Korgon, there are areas of bank erosion posing a threat of flooding to adjacent territories. Along the Kyrgyz-Kazakh border on the left bank of the Talas River, areas of erosion covering approximately 35 hectares have been observed.
3) Based on forecast data indicating a possible increase in mudflows and flooding on the Talas River from the Ministry of Emergency Situations of the Kyrgyz Republic, the following locations are at risk:
   - In the Manas District: the village of Pokrovka, Sadovaya Street, Proletarskaya Street, the village of Jiyde, the village of Uch-Korgon, and the village of Chon-Kapka;
   - In the city of Talas: residential buildings and other structures, the "Zhashtyk" stadium, and more than 150 residential buildings and other structures along 50 Years of Kyrgyzstan Street;
   - In the Talas District: more than 200 residential buildings and other facilities in several potentially hazardous areas.

Source [9]: *According to data from the Emergency Situations Department of the Zhambyl Region:*

1) In the Zhambyl Region, six settlements are located in an area at risk of flooding. All of them are situated along the Talas River. In 2025, 260 million tenge were allocated for flood prevention measures. These funds were directed toward bank reinforcement work and the dredging of canals.
2) The Chon-Kapka Reservoir, located in Kyrgyzstan, is 86% full, according to the Zhambyl Region Administration. Every day, 33 cubic meters of water are released from this reservoir into the Talas River. With the arrival of snowmelt, the discharge volume could increase significantly, potentially causing the river to overflow. As a result, residential areas could be at risk of flooding.
3) Bank reinforcement work along the Talas River is being carried out for good reason. Just 100 meters from the reservoir are about 500 homes located in a potential flooding zone. To protect them, a two-meter-high dam up to 10 meters wide is being built here. Officials from the Emergency Situations Department of the Ministry of Emergency Situations of the Republic of Kazakhstan conducted a survey in the Zhambyl Region and identified six potentially hazardous areas where flooding could occur during the spring flood season. Four of these are on the Talas River in the Bayzak District, and the rest are in Taraz.
4) Consequently, since January, water bodies have been cleared and their banks reinforced. In Taraz, two areas have now been identified where flooding is possible during the spring flood season. Therefore, these areas are undergoing bank reinforcement, and the riverbed is being deepened. A total of 485 pieces of equipment, 1,927 personnel, 132 motor pumps, and 19 watercraft have been prepared, and 88 temporary shelters have been set up.
5) Since 2016, bank reinforcement work has been carried out along a 25-kilometer stretch of the Talas River. Flood control measures are carried out annually. Bank reinforcement work is currently underway at six sites. Another one was discovered on the border with Kyrgyzstan. There, the channel was widened using heavy equipment. As of today, we are also conducting mechanical dredging and bank reinforcement over a stretch of up to 3 kilometers in the region.

Source [10]: *According to the Emergency Situations Department of the Zhambyl Region:*

1) In the Zhambyl Region, as part of preparations for the spring flood season, specialists are conducting joint surveys to prevent the risk of flooding.
2) The Zhambyl Region branch of the State Enterprise "Kazhydromet," the Zhambyl branch of the state organization "Kazselezashchita," the Shu-Talas Basin Inspectorate for the Regulation, Protection, and Use of Water Resources, the Zhambyl branch of the State Enterprise "Kazvodkhoz," and representatives

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[8] https://www.mchs.gov.kg/ru/kyrgyz-respublikasynyn-aimagyndagy-korkunuchtuu-processterge-zhana-kubulushtarga-monitoring-zhurguzuu - Ministry of Emergency Situations of the Kyrgyz Republic publication "Monitoring and Forecasting of Hazardous Processes and Phenomena in the Kyrgyz Republic"
[9] https://24.kz/ru/news/social/694046-berega-reki-talas-ukreplyayut-v-zhambylskoj-oblasti
[10] https://www.gov.kz/memleket/entities/emer-zhambyl/press/news/details/942061?lang=ru

Reservoir operators in the Zhambyl Region have organized efforts to monitor the flow and water level of the Talas River.

3) The main goal of this measure is to promptly identify changes in the river's water level, assess potential threats, and implement necessary preventive measures. Joint measurements make it possible to accurately determine the volume of water in the river channel, coordinate the operation of hydraulic structures, and ensure public safety.
4) There is a risk of flooding in populated areas and economic facilities in the Zhambyl Region due to rising water levels in the Shu, Talas, and Asa rivers, as well as from snowmelt and rainwater in the foothills.
5) The 2024 flood season may be complicated by a sharp rise in ambient temperatures, which could lead to intense snowmelt in the region's mountainous areas.
6) There is a risk of potential flooding during the flood season in 42 settlements in the Zhambyl Region.

Source [11] *The Zhambyl Region Safety Report states the following:*

1) The Talas River valley consists of layered alluvium, in places overlaid by thin layers of loess-like loams and clays. Climatic factors have a particularly significant influence on the formation of the soil cover.
2) In the Talas River floodplain and its lower reaches, hydromorphic soils *(meadow, meadow-marsh, and marsh)* with varying degrees of salinization are widespread.
3) The Talas River originates in the mountains of Kyrgyzstan. The total length of the river is 558 km, of which 444 km lie within Kazakhstan.
5) There are *16 areas* in the Talas River basin that *are at risk of mudflows and flash floods*.
6) The Shu River valley consists of layered alluvium, in places overlain by thin layers of loess-like loams and clays. Climatic factors have a particularly significant influence on the formation of the soil cover.
7) In the floodplain of the Shu River and its lower reaches, hydromorphic soils *(meadow, meadow-marsh, and marsh)* with varying degrees of salinization are widespread.

PART 2:
Overview of Floods and Floodwaters with Transboundary Characteristics for Kyrgyzstan and Uzbekistan

Source [12]

1) The valleys most at risk of major flooding, including that caused by lakes prone to bursting, are Isfayram-Say, Ak-Suu–Shakhimardan, Soh, Karavshin-Isfara, and Leylek-Ak-Suu. The most likely period for floods resulting from the rupture of high-altitude lakes is July–August (early September).
2) Torrential mudflows in this zone become more frequent from March through June, with the highest probability in the foothills of the Isfayram-Say, Shahimardan-Sokh, and Leylek-Ak-Suu river basins, as well as in the Sulyuktin Depression.
3) Glacial mudflows are most likely and dangerous in the valleys of the Isfayram-Say, Shahimardan, Ak Suu-Shahimardan, Soh, and Gavian rivers, in whose upper reaches there are high-altitude lakes at risk of bursting.
4) *During the period from 2029 to 2040, increased flow is expected on the Aravan Say River from March through May, on the Shahimardan River from May through September, and on the Isfayram-Say River from May through August*. During these periods, the following is observed

[11] Safety Data Sheets for the Zhambyl, Kyzylorda, and Turkestan regions
[12] https://www.mchs.gov.kg/ru/kyrgyz-respublikasynyn-aimagyndagy-korkunuchtuu-processterge-zhana-kubulushtarga-monitoring-zhurguzuu - Ministry of Emergency Situations of the Kyrgyz Republic publication "Monitoring and Forecasting of Hazardous Processes and Phenomena in the Kyrgyz Republic"

In the future, mudflow and flood activity in river basins will intensify due to torrential rainfall and the rapid melting of snow and glaciers, which may lead to torrential, mixed (snow-rain), or glacial mudflows. Flood peaks are also expected to occur earlier (one month earlier) or to occur in multiple peaks with higher discharge volumes than at present.

5) An assessment of river flow rates indicates the need for timely preventive measures aimed at protecting the population, economic facilities, and infrastructure from active mudflow and flood activity. It is also necessary to conduct public awareness campaigns and carry out engineering and technical work in sections of river basins at risk of mudflows and floods.

Source [13]

1) The risk of mudflows in each region can be assessed by the number of previous mudflow days in a year. For example, from 1950 to 1986, 180 days with mudflows were recorded in the Namangan Region, 119 in the Fergana Region, 116 in the Surkhandarya Region, in the Samarkand Region—115, in the Andijan Region—73, in the Jizzakh Region—63, in the Kashkadarya Region—74, in the Tashkent Region—55, and in the Navoi Region—16. In total, during this period, 662 days with mudflows were recorded in the foothills of Uzbekistan; 50% of these caused damage to economic sectors, and 25 % were catastrophic.

2) For example, the mudflow in April–May 1967 alone caused damage to the city of Andijan amounting to approximately 27 million rubles.

3. **The Shahimardan River Basin:** An Overview of Mudflows and Floods with Transboundary Implications for Kyrgyzstan and Uzbekistan

Source [14]

1) The Shahimardan River Basin is transboundary: it flows through the territory of Kyrgyzstan and the Uzbek enclave of Shahimardan.

2) The basin is located on the northern slope of the Alai Range and is characterized by the presence of modern mountain glaciation in the upper reaches of the rivers. Mudflows have occurred repeatedly in this basin, including some that were quite destructive, such as the 1977 mudflow. However, the interest in studying this basin stemmed from the fact that on July 8, 1998, a catastrophic mudflow occurred here, killing more than 100 people and causing enormous damage to the infrastructure and economy of the Uzbek enclave of Shahimardan. The causes of the mudflow were never fully determined, and no articles about it were published.

3) During fieldwork conducted in July 2014, we were able to determine the characteristics of the 1998 mudflow's movement (identifying the zones where material was accumulated and discharged, as well as the section where the mudflow transformed into a mudflow flood). We estimated its approximate volume, which turned out to be about 2 million m³. In addition, we collected the information necessary to analyze the causes of the event. We partially confirmed the conclusion of experts who surveyed the origin zone the day after the disaster: the mudflow was caused by the breach of a series of lakes cascading in the upper reaches of the Archa-Bashi River. The lake breach occurred as a result of water overflowing an ice bridge, which was rapidly eroded. The rapid accumulation of water was caused by high temperatures and the rapid melting of the glacier (weather data taken from the station "The Abramov Glacier," which is located in a neighboring valley. It is difficult to say whether there was precipitation or not, since there was—and still is—no weather station in the upper part of the Shakhimardan River basin, and the Abramov Glacier has a different aspect than the Archa-Bashi Glacier and the headwaters area.

4) The question of a possible breach of an intra-glacial cavity remains open (this hypothesis is based on interviews with local residents who witnessed the event). The collected field data and the results of satellite image interpretation allow us to conclude that the main factor contributing to the high degree of mudflow hazard in the Shahimardan River basin was

[13] https://cyberleninka.ru/article/n/selevye-yavleniya-v-uzbekistane/viewer
[14] 56-59.pdf MUDFLOW PROCESSES IN THE ALAI AND KYRGYZ RANGES (USING THE EXAMPLES OF THE SHAHIMARDAN AND AKSAY RIVER BASINS)

and the breakthroughs of lakes and intra-glacial cavities, which form under conditions of active dynamics of the moraine-glacial complex, remain. In this regard, a catalog of lakes in the Shahimardan River basin was compiled, and for each lake, an assessment of its risk of breakthrough was conducted using the methodology proposed in this study. An inventory of mudflow channels was conducted. Figure 2 shows the lakes and their numbers according to the catalog, as well as the mudflow channels.

Source [15]

1) Shakhimardan is a river in Uzbekistan and Kyrgyzstan, a left tributary of the Syr Darya. It originates in the Shahimardan region within the territory of the Shahimardan , an exclave of Uzbekistan, at the confluence of the Aksu and Koksu Rivers, which originate on the northern slopes of the Alay and Turkestan mountain ranges.
2) It begins in the Osh-Aravan Basin, cuts through the entire Adyr range, and carves through the intermountain plain east of the Katrantau Mountains (Katrang-Too). It has a permanent flow. It flows northwest, crossing the border between Kyrgyzstan and Uzbekistan. East of the village of Orozbekovo, it turns north, flows through Jiydelik, Kadamzhai, and Pulgon, crosses the border between Kyrgyzstan and Uzbekistan again, and enters the Fergana Valley at the village of Vualid. Downstream from Vualid, it is known as the Marg‘ilonsoy. The city of Fergana is located on the Marg‘ilonsoy River. The Marg‘ilonsoy crosses the city of Margilan and the Great Fergana Canal. The river's waters are entirely diverted for irrigation through the construction of numerous irrigation canals.
3) The river is fed by snow and glaciers, with its flood peak in June. From the east, the Marg‘ilonsoy (a continuation of the Shahimardan) is fed by the waters of the Isfayramsoy River via the Yangiaryk and Lovon canals; from the west, it is fed by the waters of the Soh River via the Soh-Shahimardan Canal. The drainage basin covers an area of 1,300 km². In turn, the waters of the Margilansay feed the Great Fergana Canal (via the Altyaryk diversion) and the Southern Fergana Canal (from the Margilansay outflow). Consequently, the river waters of the Margilansay within the Fergana Region mix with the waters of the Soh irrigation system, the Great Fergana Canal system, and the Southern Fergana Canal system, which naturally affects its water quality.
4) During the growing season, after the Shahimardan River exits Kyrgyzstan, the water at the "Vuadil" hydropower complex and at Hydropower Complex No. 6 on the Margilansay is completely diverted through irrigation canals for crop irrigation and other purposes. Downstream of "Hydraulic Structure No. 6" during the growing season, there is virtually no discharge of water into the Margilansay, and under these conditions, the river is fed by groundwater seepage, replenishment from canals, discharges from small collector-drainage systems and runoff from irrigated agricultural lands, as well as discharges during floods or outside the growing season, when there is no particular need for irrigation.
5) The average long-term water discharge is 11.6 m³/s, the standard discharge is 9.66 m³/s, and the average annual runoff is 304 million m³ (at the "Pavulgan" gauging station); in a year with average water availability, it is 275 million m³, which accounts for 1.5% of the Fergana Valley's runoff. During floods, the discharge reaches 64 m³/s.
6) The construction of major canals, such as the Great Fergana Canal, the Southern Fergana Canal, and the Great Andijan Canal, along with the implemented hydraulic engineering measures, have contributed to the integration of the entire irrigation system of the Fergana Region into a single system, where, depending on the water availability of the year and season, the Shahimardan-Margilan River, the Isfayramsay-Beshalyssay River, the Great Fergana Canal, the Southern Fergana Canal, and the Great Andijan Canal mutually replenish one another, and the irrigated lands are supplied by a combination of these systems.

Source [16]

1) One of the largest mudflow disasters of the past 20 years occurred in the Shahimardan River basin, located on the northern macro-slope of the Alay Range. In July 1998, a mudflow occurred there, killing more than 100 people in the Uzbek exclave of Shahimardan and causing significant damage to its infrastructure and economy.

[15] https://ru.ruwiki.ru/wiki/Шахимардан_(river)
[16] https://istina.msu.ru/conferences/presentations/11208275

2) Despite the catastrophic nature of the event, no articles have been published analyzing its causes or describing the key characteristics of the 1998 mudflow. In light of this, comprehensive studies of the Shakhimardan River basin were conducted, including summer fieldwork (July 2014) and a desk-based phase (analysis of aerial and satellite imagery taken at different times, topographic maps, and compilation of information on previous studies).

3) The field and desk studies led to the conclusion that there are two most likely hypotheses regarding the causes of the 1998 mudflow. The first is a breach in a group of three glacial lakes. These lakes formed on terminal moraines and dead ice in the upper reaches of one of the headwaters of the Shakhimardan River and, in the run-up to the disaster, were rapidly filling with meltwater due to persistently high temperatures and intense melting. Successive overflows and breaches of this group of lakes led to a cascade effect. A sufficient volume of water was generated, which set loose debris in motion. This hypothesis is supported by data from direct observations conducted the day after the disaster. There is also a second hypothesis, proposed based on an analysis of satellite images taken at different times. According to this hypothesis, the rock glacier located below the Archabashi Glacier (situated in the upper reaches of the river of the same name—one of the headwaters of the Shahimardan River) shifted and significantly narrowed the river channel. As a result, by the summer of 1998, the river channel had been blocked, and a lake had formed at the edge of the glacier, which quickly overflowed. The lake then burst its banks, and the water flow, eroding loose sediments further down the valley, transformed into a mudflow.

4) The Shahmardan River basin continues to face a high risk of mudflows, due to the possibility of future mudflows and the presence of settlements and infrastructure facilities within the affected zone.

Source [17]

1) Some insight into the nature of mudflow movement in Uzbekistan can be gained from the mudflow event *of May 4, 1927, in the vicinity of the village of Shahimardan*. That evening, a thunderstorm with hail lasted 42 minutes. About an hour later, a loud noise resembling artillery fire was heard. Twenty to thirty minutes later, a wall of mud and rock up to 15 meters high emerged from a narrow gorge located in the upper part of the village. The flow inundated the lower part of the village. At that time, there were over 100 carts loaded with sheep, bread, and the belongings of pilgrims who had arrived in Shahimardan. All the carts were swept away. Downstream from the village of Vualid (30 km away), the mudflow destroyed the reinforced concrete headworks of the Alty-Aryk Canal and flooded all the low-lying areas and structures located below, as well as cotton fields, orchards, and vineyards.

2) Early in the morning *of May 5, 1927, in the area of the village of Shahimardan*, separate streams of the mudflow reached the city of Fergana. The water overflowed the banks of the Margelansay River and flooded the city streets with a layer of water 1 meter deep. It destroyed 189 buildings and 12 km of embankments, ruined over 1,000 hectares of agricultural crops, and buried orchards under a mass of mud and rocks. Eight hundred head of livestock perished in the city. A total of 59 settlements were affected by the mudflow.

3) Mudflows *in the Shakhimardan-Sai River basin from May 29 to June 13, 1977,* destroyed 15 settlements settlements, 20 schools, 18 hospitals, and 1,300 km of irrigation canals.

4) A mudflow on *July 7, 1997, in Shahimardan* killed 116 people and injured 118.

5) The mechanism of dam failure was observed during the breach of lakes, which led to the formation of a catastrophic mudflow that swept *down the Shahimardan River in July 1998*; this event resulted from the breach of three moraine lakes draining into the Fergana Valley. As a result of the flood spreading out, the water discharge in the area around the city of Shahimardan reached 150–200 m³/s. This led to the deaths of more than 100 people and caused enormous damage to infrastructure.

   Examples include the mudflows formed as a result of the breach of Lake Yashinkul and *the powerful mudflow that swept down the Shahimardan River in 1998*.

[17] https://cyberleninka.ru/article/n/selevye-yavleniya-v-uzbekistane/viewer

6) On *March 23, 2002,* in the Guzar District of the Kashkadarya Region, a mudflow destroyed 56 houses, 3 automobile bridges, and 7.5 km of roads.

4. **The Kara-Darya River Basin:** An Overview of Mudflows and Floods with Transboundary Implications for Kyrgyzstan and Uzbekistan

Source [18]

1) Kara-Darya — a river in the Osh region of Kyrgyzstan and the Andijan and Namangan regions of Uzbekistan; it is a left tributary of the Syr Darya. It is one of the largest rivers flowing into the Syr Darya.

2) The Karadarya is 180 km long; together with its left tributary, the Tar, its total length is 318 km. The basin area is 30,100 km². The Karadarya is fed by snowmelt and glacial meltwater. The average annual discharge is 136 m³/s; the highest discharge recorded at this point was 265 m³/s (1969), and the lowest was 68.4 m³/s (1975). 55% of the annual runoff occurs between March and July[1]. The river has the highest water levels in June and the lowest during the winter.

3) The Karadarya River is formed by the confluence of the Tar and Kara-Kulja Rivers, which originate on the southeastern slope of the Fergana Range and the northern slope of the Alay Range. The source of the Karadarya is located at an elevation of about 1,150 m, near the village of Kenesh in the Osh Region of Kyrgyzstan.

4) The Karadarya flows generally westward. Up to the Andijan Reservoir, the Karadarya flows through a valley ranging in width from 0.5 to 4–5 km. Then the valley narrows sharply, forming the now-submerged Kampyrravat Gorge. Here, the river is dammed, forming the Andijan Reservoir. Downstream, the Karadarya enters the Fergana Valley, crossing into the territory of the Andijan Region of Uzbekistan.

5) The border between the Andijan and Namangan regions runs along the upper reaches of the Karadarya. Beyond the town of Balykchi, it joins the Naryn River at an elevation of 396 m. The Karadarya on the left and the Naryn on the right form the Syr Darya River.

Source [19]

1) Floodwaters from the Kara-Darya, Yassy, and Kurshab rivers cause significant property damage. After the Andijan Reservoir was put into operation, the riverbeds of these rivers began to rise due to the accumulation of boulders and gravel, and the lower terraces ended up below the floodplain levels, creating a threat of destruction to residential buildings in many settlements located along the riverbeds. To protect the residents of these villages, construction of protective levees is ongoing; however, these levees are also being damaged and require restoration.

2) During periods of intense, locally concentrated precipitation, flash floods and areas of storm flooding may occur.

3) For example, since the Andijan Reservoir on the Kara-Darya River was put into operation in 1975, the process of erosion along the developed riverbanks has been proceeding intensively. During the flood season, turbulent water flows carry large amounts of loose debris, which, due to a loss of flow velocity, is deposited in the riverbeds. This leads to river channel migration, bank erosion, and flooding. The same process can occur upstream of constricted sections of river channels.

4) In total, there are more than 10 sections along the Kara-Darya riverbed that are potentially at risk of mudflows and flash floods, which could affect several settlements, agricultural lands, and other facilities.

Source [20]

[18] https://ru.ruwiki.ru/wiki/Карадарья
[19] https://www.mchs.gov.kg/ru/kyrgyz-respublikasynyn-aimagyndagy-korkunuchtuu-processterge-zhana-kubulushtarga-monitoring-zhurguzuu - Book by the Ministry of Emergency Situations of the Kyrgyz Republic, “Monitoring and Forecasting of Hazardous Processes and Phenomena in the Kyrgyz Republic”
[20] https://cyberleninka.ru/article/n/selevye-yavleniya-v-uzbekistane/viewer

1) In the Namangan Region, a dam failed to withstand the water pressure on the Karadarya River. As a result, large areas of cropland were flooded, causing 11.5 million rubles in damage.

2) In the Denau District of the Surkhandarya Region alone, 15,000 hectares of cotton crops were flooded overnight on May 2, 1987. Cases of crops being swept away by mudflows of varying intensity over areas ranging from 60 to 200 hectares were observed quite frequently.

5. **The Naryn River Basin:** An Overview of Mudflows and Floods with Transboundary Implications for Kyrgyzstan and Uzbekistan

Sources [21][22]

1) River Naryn flows through the territory of the Issyk-Kul, Naryn, and Jalal-Abad regions of Kyrgyzstan and the Namangan region of Uzbekistan. The Naryn is 807 km long, and its drainage basin covers an area of 59,900 km². It is formed by the confluence of the Bolshoy Naryn and Maly Naryn rivers, which originate in the glaciers of the Central Tien Shan.

2) It flows through an intermountain valley, at times through narrow gorges. The average discharge at the mouth is 480 m³/s, the maximum discharge is 2,820 m³/s, and the suspended sediment load is 760 kg/s. The river is fed by glaciers and snowmelt. The flood season lasts from May through August, with maximum discharge occurring in June and July.

3) The Naryn has many tributaries. The largest of these are: (on the right) Kyökömeren, Kara-Suu, Uzun-Akmat, Chychkan, On-Archa, Torken, Kazhyrty; (on the left) At-Bashi, Alabuga, Kek-Iirim, Kara-Suu

4) The water is used for irrigation. The Great Fergana Canal and the Northern Fergana Canal originate from the Naryn. The river possesses significant hydropower resources. It is home to the Toktogul and Kurpsay reservoirs, as well as the Toktogul, Tash-Kumyr, Uchkurgan, Kurpsay, and Shamaldysay hydroelectric power plants; the Kambarati-2 hydroelectric power plant is under construction, along with the cascade of Upper Naryn hydroelectric power plants. The following cities are located on the banks of the river: Naryn, Tash-Kumyr, [and]Uchkurgan [3].

5) Beyond Toktogul, the Naryn River flows through Jalal-Abad before entering Uzbekistan, where it joins the Karadarya River to form the Syr Darya, which flows into the Aral Sea. The water flowing from Kyrgyzstan is crucial for Uzbekistan’s agriculture.

6) No information is available on floods or flash floods.

6. **Isfayramsay River Basin:** Overview of Landslides and Floods with Transboundary Implications for Kyrgyzstan and Uzbekistan

Sources [23][24]

1) The Isfayramsay River flows through Kyrgyzstan and Uzbekistan in the Syr Darya basin. The river is 122 km long, and its basin covers an area of 2,220 km².

2) It originates in the spurs of the Alay Range. The river is part of the Great Fergana Canal system. Near the town of Kuvasay, the 17th Party Congress Canal branches off from it, and several more canals branch off further downstream. East of the village of Kirguli, the river’s waters flow into the Southern Fergana Canal.

3) Its water supply is primarily from snow and glaciers. The maximum water volume occurs from May to August, and the minimum from December to February. The average discharge near the village of Uchkurgan in Kyrgyzstan (the start of the irrigation fan) is 21.1 m³/sec. The average discharge is 21.9 m³/s.

4) During the high-water period, mainly in summer, the Isfayram is a turbulent stream with chocolate-colored water due to impurities of sand and clay. The water is very cold. In some places along the banks, small tugai forests have survived, overgrown with jida (loha) shrubs, sea buckthorn, and others. In 1962 and 1973, on

[21] https://ru.ruwiki.ru/wiki/Нарын_(river)
[22] https://eurasia.travel/ru/kyrgyzstan/nature/rivers
[23] https://ru.ruwiki.ru/wiki/Исфайрамсай
[24] https://cyberleninka.ru/article/n/selevye-yavleniya-v-uzbekistane/viewer

Severe mudflows and rockfalls occurred in Isfayram, leading to the evacuation of the city of Kuvasaya and nearby settlements.

5) Lake Yashil-Kul was formed several centuries ago by a massive landslide that created a rocky dam, behind which about 15 million cubic meters of water subsequently accumulated. In June 1966, due to heavy snowmelt in the mountains, the water level in the lake rose rapidly, causing it to overflow and eventually breach the rock dam. A powerful mudflow burst through the breach, flowed down the Isfayramsay River—located downstream from the lake—and flooded a significant portion of the Fergana Valley, causing enormous damage to the region's agriculture. Not a trace of the lake remained.

PART 3: Overview of Transboundary Mudflows and Floods Affecting Kyrgyzstan and Tajikistan

7. **Isfara River Basin:** Overview of transboundary mudflows and floods affecting Kyrgyzstan, Tajikistan, and Uzbekistan

Source [25]

1) The Isfara is a river in the Syr Darya basin (though it currently does not flow into it) in the Batken Region of Kyrgyzstan, the Sughd Region of Tajikistan, and the Fergana Region of Uzbekistan. In its upper reaches, it is called the Ak-Suu; in its middle reaches, it is called the Karavshan.

2) The river is 130 km long. The basin area is 3,240 km². The river is fed primarily by snowmelt and glacial meltwater.

3) Downstream from the confluence with the Kindyk-Karavshan tributary, the river is 10 m wide; further downstream, it is 20 m wide; and downstream of Vorukh (after the first canal branches off from the river), it is 18 m wide. The depth downstream of the Kindyk confluence is 1.0 m; in the Vorukh area, it is 2.0 m, and the riverbed is firm. The current velocity near Vorukh is 2.0 m/s, and in the lower reaches, past the village of Nefteabad, it is 1.2 m/s.

4) The average annual water discharge near the village of Tashkurgan is 14.5 m³/s. 85–90% of the flow occurs during the flood season, which spans the period from May through September (according to other sources, from late April through October). In July, the average monthly discharge reaches 43.6 m³/s (according to other sources, the river is at its fullest in August [1]). March and April mark the low-water period, when the average monthly discharge drops to 3.5–4.0 m³/s. The highest recorded discharge was 150 m³/s (August 5, 1973), and the lowest recorded discharge was 0.050 m³/s (March 28, 1975).

5) *The Isfara is classified as one of the rivers most prone to mudflows*. Its average sediment discharge is 12 kg/s. On average, the Isfara carries 290 metric tons of sediment into the Fergana Valley each year.

6) The waters of the Isfara are used for irrigation. In Kyrgyzstan, the river's flow is regulated by the Torkul Reservoir, which has a capacity of 90 million m³ and irrigates an area of 9,000 hectares.

Source [26]

1) The Isfara River basin is part of the Syr Darya River basin and is located in the west of the Kyrgyz Republic and the north of Tajikistan. The runoff of the Isfara River basin is mainly fed by glaciers and snowfields in the Turkestan Range. The river flows along the administrative borders of the Batken Region of the Kyrgyz Republic and the Isfara and Kanibadam districts of the Republic of Tajikistan. Near the administrative territory of the city of Isfara, the Kyrgyz side diverts water from the Isfara River into the Tortgul Reservoir, which has a capacity of 91 million m³; 9 million m³ of this volume is allocated for water users in Tajikistan located in the Isfara and Kanibadam districts.

[25] https://ru.ruwiki.ru/wiki/Исфара_(river)

[26] https://riverbp.net/upload/iblock/dba/dbaf6dfc20e57def19bf582c075032f7.pdf

2) In the Kanibadam District of Tajikistan, at the “Ravat” water control structure, the water resources of the Isfara River are divided between Tajikistan and Uzbekistan. Through the left-bank canals “Kyrgyz,” “Kuchak,” “Kanibadam,” “Ravat-1,” and “Ravat-2” of the Kanibadam District Water Management Administration, water is supplied to irrigated lands in the Kanibadam District, while through the right-bank canals “Novy” and “Rapkan,” water is supplied to the Besharyk District of Uzbekistan. The interstate allocation of water resources in the Isfara River basin is carried out on the basis of mutually recognized documents from the Soviet period.

3) The Isfara River is fed by glaciers and snowmelt. The total area of glaciers in the river’s basin, located on the Turkestan Range at an elevation of more than 5,000 m above sea level, is 169.6 km², or 4% of their total area on this range.

4) The largest tributaries of the river are the Kshmish and Karavshan rivers, which converge in the Vorukh jamoat to form the Isfara River, which is 107 km long. The total length of all its tributaries longer than 10 km is 499 km.

5) *The Isfara River is considered one of the rivers in the Sughd Region most prone to flash floods*. As it flows into the Fergana Valley, river sediments form an extensive alluvial fan. The drainage basin area at the mouth is 3,240 km². Based on long-term data from the State Agency “Tajikhydromet,” the average discharge is 14.7 m³/sec, and the average sediment load is 12 kg/sec. The river’s average gradient is 31 m/km. The flood season lasts from late April through October, with peak flow occurring in July and August. According to data from the “Tangi Vorukh” hydrological station, the highest recorded water discharge occurred in July 1942 - 77.19 m³/sec; in June 2006—77 m³/sec. The minimum discharge rates were recorded in July and August 1918, at 23.6 m³/sec and 19.9 m³/sec, respectively.

6) According to information from the Isfara City Emergency Situations and Civil Defense Headquarters, the greatest damage caused by flash floods occurs in the “Lyakkan-1,” “Lyakkan-2,” and “Kholesan” floodplains, which originate in Kyrgyzstan.

7) The greatest danger is posed by silted-up mudflow channels in the areas of “Shurob-Baland,” “Chorkishlok-1,” “Chorvodoron,” “Takhtapul,” “Kuruk,” “Keh,” “Lochin,” “Dzhui-Dam,” “Oftobruy-Shurtang,” and “Guzlon” in the Isfara District, as well as the destroyed mudflow protection dams on the Isfara River near the city of Isfara.

8) The main problem is that these mudflow channels have not been cleared of sediment for a long time, and the protective dams have not been repaired due to a lack of funding. Consequently, the risks of negative impacts from mudflows on the population and infrastructure are increasing. The Kyrgyz and Tajik sides have repeatedly discussed this issue together and expressed their intention to seek donor funding. However, the issue remains unresolved.

9) A report by the Isfara City Emergency Situations and Civil Defense Headquarters notes that in the last three years alone (2010–2013), the economy and the sociocultural sector of this region sustained damages amounting to 18.9 million somoni (3.95 million U.S. dollars), equivalent to 54.5 % of the local budget. The Isfara District sustained the most significant damage from various natural disasters in 2012, amounting to 7.7 million somoni (US$1.61 million). In 2013, three natural disasters occurred in the Isfara District, causing total damage of more than 1 million somoni.

10) *Negative consequences and risks:* Degradation of the watershed surface and a lack of protective structures lead to widespread erosion, the scouring of riverbanks and riparian areas, and the destruction of structures and agricultural land located there.

11) For the city of Isfara and its surrounding settlements, the Tortgul Reservoir in Kyrgyzstan poses a potential danger due to its technical deficiencies. The reservoir was built in 1971, 12 km west of the Batken district center and 26 km southeast of the city of Isfara. The reservoir basin is formed by two earthen dams (consisting of homogeneous loam and crushed stone): the western dam, 34 m high, and the eastern dam, 20 m high. The length along the crest of the western dam is 1.094 km, with a width of 8 m; the eastern dam is 5.045 km long and 4 m wide. The slope gradients on the western dam are 3.5, 4, and 4.5; on the eastern dam, they are 2.3, 3, and 3.5. The maximum volume of the reservoir is 90 million m³ , and the usable capacity is 75 million m³. The water surface area is 657 ha, and the maximum depth is 35 m. The reservoir bed, covering an area of 657 ha, is lined with polyethylene film. The potential risk of a breach is confirmed by increased seepage at the pressure front of the structure due to suffosion processes within the dam body. Information regarding the presence of seepage was obtained through visual

observations, as the existing monitoring network has become inoperable. Modern means of continuous monitoring of the condition of both dams are needed to update the data, as well as an information system for transmitting this data to the Tajik side from Kyrgyz colleagues. Seepage through the pressure front of the Tortgul Reservoir occurred as a result of the formation of meridional cracks in the western dam following an 8.0-magnitude earthquake on the Richter scale that occurred on January 31, 1977. The anti-seepage measures implemented—including the sloping of the upper and lower embankments and the installation of a drainage well—had only a short-term effect, and seepage resumed. In 2002, in the northern part of the eastern dam, when the reservoir was filled to a volume 1 million m³ greater than the design capacity, a longitudinal crack up to 15 cm wide and 15 m long formed. As a result, seepage increased in the area of the eastern dam's tower spillway.

12) A complete failure of the western dam would lead to catastrophic flooding of the following settlements: Surkh; Chorkishlok; Zumradshoh; Kizil-Pilol, Arab-Kishlok, Honobod, Nefteabad, Yangiobod, Baland, Zarkhok, Zumrad, and Shahrak; and in the event of a partial collapse, the Muldon mahalla, the village of Zumrashokh, and the "Zumrad" sanatorium would be affected.

13) Complete destruction of the eastern dam would lead to catastrophic flooding of the settlements of Lyakkan, Bogiston, and Dahana.

14) Complete destruction of the eastern and western dams will cause extensive damage to infrastructure and result in the loss of human and animal lives. Over the past 10 years, the Isfara City Emergency Situations and Civil Defense Headquarters, in cooperation with UNDP,
the Red Crescent, ACTED, and other international and nongovernmental organizations, has conducted training for the population on responding to natural disasters. In collaboration with GIZ, the impacts of natural disasters in the Isfara River basin over the past 10 years have been analyzed. This information is used to respond to and mitigate potential risks.

PART 4:
Overview of mudflows and floods with transboundary implications for Kazakhstan and Uzbekistan

8. **Ugam River Basin:** Overview of transboundary mudflows and floods affecting Kazakhstan and Uzbekistan *(territory of the Republic of Kazakhstan)*

Source [27]

1) The Ugam is a mountain river in Kazakhstan and Uzbekistan and the largest right-bank tributary of the Chirchik River. The Ugam is 68.5 kilometers long, and its basin area is 869 km² . The river is fed primarily by snowmelt and, to a lesser extent, by rainfall. Water discharge: 20.9 m³/s (*during floods in certain years, it can reach 177 m³/s*).

2) The Ugam Range mostly does not exceed an elevation of 3,600 m. Elevations in the Ugam River basin range from 758 to 3,583 m above sea level. The Ugam flows eastward, and further upstream, it flows southeastward. The water yield of the left tributaries increases upstream due to the rising elevation of the Ugam Range and the associated increase in the number and thickness of watershed snowfields.

3) Administratively, the Ugam River basin covers an area of 890 km² and is located within two regions: the Tashkent Region in Uzbekistan (*Bustanlik District*) and the Turkestan Region in Kazakhstan (*Tolebi and Kyzygurt Districts*). The border between Kazakhstan and Uzbekistan runs across the river basin at a point where the river is confined to a narrow gorge with steep rocky slopes rising to the watersheds of the Karzhantau Range on the right bank and the Ugam Range on the left bank. In the Uzbek part, the basin widens continuously until the Ugam River flows into

[27] Descriptive Report of the Central Committee of the Soviet Union on field research conducted as part of the GIZ project: https://cesdrr.org/новости/в-рамках-проекта-giz-на-территории-узбекистана-проведены-полевые-исследования-трансграничных-рек

the Chirchik River, forming gentle slopes. In the Kazakh part of the basin, a narrow gorge continues upstream for approximately 10 km to the Buguchalpek tract.

4) Existing Risks: The transboundary Ugam River basin, located in Kazakhstan and Uzbekistan, plays a key role in supplying water resources to adjacent regions; however, this basin also faces numerous hydrological hazards that may pose a threat to local ecosystems, agriculture, and the population.

5) Within Kazakhstan, the level of mudflow risk in the Ugam River basin is assessed as high by civil defense authorities. The basin contains one area prone to mudflows and two moraine lakes. The settlement of Ugam (*18 residential buildings*), one school, a bridge, the akim's bathhouse complex, a private farm, an apple orchard, and a hunting lodge are all at risk of potential negative impacts.

6) There are 56 people living in the risk zone, and the potential affected area covers 130,000 m². Additionally, one landslide-prone area and one mudflow channel have been identified in the Ugam River basin, posing a threat to six structures (*four residential buildings, a school, and a hunting lodge*) where 11 people live or work.

7) Transboundary Risks: In terms of transboundary risks, flash floods and flooding pose the greatest threat in the Ugam River basin. This basin is prone to regular flash floods, especially in the spring, when there is intense snowmelt in the mountainous areas. Seasonal rises in river water levels can lead to the flooding of riparian areas in Kazakhstan and Uzbekistan, posing significant risks to agricultural land and populated areas. The highest probability of flooding occurs in the low-lying parts of the basin, where floodwaters accumulate, increasing the risk of inundation.

8) In the territory of Uzbekistan located within the Ugam River basin, the following settlements may be at risk of flooding during spring floods: Khumsan (*Tashkent Region*), Charvak (*Tashkent Region*), Gazalkent (*Tashkent Region*), and others.

9) In addition, the potential flood zone includes numerous recreational areas and private residential developments, as well as the following key economic and infrastructure facilities:

   - Agricultural land: Significant areas of agricultural land are located in the regions adjacent to Khumsan and Gazalkent. These areas, including croplands and pastures, are situated in low-lying areas and may be flooded, leading to the destruction of crops and soil degradation;
   - Irrigation systems: Important irrigation infrastructure, such as canals and reservoirs, is located in flood-prone areas, particularly in the Gazalkent and Charvak regions. Damage to these systems could disrupt water supply to agricultural areas, exacerbating the situation during the spring flood season;
   - The Charvak Reservoir: Although the reservoir serves to regulate water levels, the flood load on it may pose a risk to adjacent areas, including recreational zones and tourist sites. In the event of extreme weather conditions, the reservoir could overflow and flood downstream areas;
   - Road and bridge infrastructure: Bridges across the Ugam and Chirchik Rivers, as well as adjacent roads connecting settlements, may become submerged, disrupting transportation links and hindering access to the regions.

10) Field Research: From September 30 to October 8, 2024, as part of the Center and GIZ project "*Strengthening Capacity for the Safe Management of Transboundary Water Resources in Central Asia through the Application of Innovative Information and Communication Technologies*," a group of experts—comprising SRO expert V.V. Kuchkin, the Center's chief expert B.M. Ospanova, and the Center's system administrator A.G. Ospanova, conducted field research on the transboundary Ugam River, located in the Sairam-Ugam National Park in the Turkestan Region. Based on the results of the field research, a survey of the landslide-prone area near the village of Ugam was conducted, and a 3D model of the Ugam River basin, spanning more than 5 km, was prepared.

11) The research revealed that the hydrological stations of the State Joint-Stock Enterprise “Kazhydromet” and the State Agency
“Kazselezashchita” are equipped with a vertical water gauge with graduations, as well as outdated mechanical meteorological instruments, such as a rain gauge, thermometer, and barometer. Due to the lack of telephone service and internet access in the village of Ugam, the observer transmits hydrological data three times a day to the Kazygurt Production and Operations Branch of the South-Eastern Technical and Technical University (SUTETU) of the State Agency “Kazselezashchita” using a radio station. However, under adverse weather conditions in mountainous terrain, interruptions in data transmission frequently occur.

12) Expert Recommendations: To improve hydrological monitoring by eliminating the human factor and to subsequently establish a cross-border early warning system for hydrological hazards, experts proposed installing an automated monitoring station at the sites of existing hydrological stations operated by the State Agency
“Kazselezashchita” and the State Enterprise “Kazhydromet.” The station should be capable of transmitting data in real time to improve rapid response and be equipped with the following sensors:

   - Precipitation sensors (rain gauges or pluviometers)—to measure the amount and intensity of precipitation;
   - Water level sensors (water level gauges) — to measure the water level in the river;
   - Water flow sensors (flow meters)—to measure the flow rate and volume of water passing through a specific section of the river;
   - Soil moisture sensors—to measure the degree of soil moisture saturation. In mountainous areas, this is particularly important for landslide prevention, as oversaturated soil loses stability and can shift;
   - Meteorological sensors:
     - Temperature sensors: to measure air and water temperatures, which is important for assessing snowmelt and its impact on runoff volume;
     - Anemometers: to measure wind speed and direction. This is necessary for assessing evaporation and precipitation distribution.
   - Water pressure sensors (hydrostatic sensors)—to determine the hydrostatic pressure at the riverbed, which allows for an accurate assessment of changes in water level and possible sudden spikes;
   - Water turbidity sensors—to measure the concentration of suspended particles in the water. Increased turbidity may indicate the onset of a mudflow, especially when the flow velocity increases after rain;
   - Snow depth sensors—to measure the depth and moisture content of the snowpack, helping to predict the volume of meltwater that may enter the river;
   - Video surveillance cameras—for visual monitoring of the condition of the river and its banks;
   - Inclination sensors (inclinometers)—to monitor changes in slope angle, which helps in predicting landslides;
   - In addition, to verify the information received from the automated stations and ensure the prompt transmission of expert confirmations, it is proposed to equip the observation post with satellite internet and the necessary computer equipment.

13) Conclusion: Thus, the installation of an automated hydrological monitoring station on the Ugam River is a key element in establishing a transboundary early warning system, as it will enable the collection of real-time data, the timely identification of critical conditions, automatically process and analyze data, integrate with digital forecasting models, and transmit information to the servers of the State Enterprise “Kazhydromet,” the State Agency “Kazselezashchita,” and the Ministry of Emergency Situations of the Republic of Kazakhstan, as well as to warning systems via satellite internet.

14) Based on the results of processing data obtained during field studies, an interactive map will be prepared showing relevant attribute information for each site, which will be posted on the Center's website.

9. **Ugam River Basin:** Overview of Floods and High Water Events of a Transboundary Nature for Kazakhstan and Uzbekistan *(Territory of the Republic of Uzbekistan)*

Source [28]

1) From the perspective of transboundary risks, flash floods and flooding pose the greatest threat in the Ugam River basin. In the territory of Uzbekistan located within the Ugam River basin, the following settlements may be at risk of flooding during spring floods: Khumsan (Tashkent Region), Charvak (Tashkent Region), Gazalkent (Tashkent Region), and others. In addition, the potential flood zone includes several hundred residential buildings, 8 pedestrian and vehicular bridges, numerous recreational areas, as well as economic and infrastructure facilities such as agricultural land, irrigation systems, the Charvak Reservoir, and road and bridge infrastructure.
2) The length of the Ugam River within Uzbekistan, up to its confluence with the Chirchik River, is over 12 km; however, the hydrological station on the river is located practically at the confluence with the Chirchik River (the nearest station, "Khodzhikent," is 12 km from the border with Kazakhstan).
3) Currently, the Uzbek government is implementing a project to construct small hydroelectric power plants (mini-HPPs) and a water intake structure (dam) to distribute the water flow between the HPP's pressure pipeline and the river's main channel.
4) Expert Recommendations: Given the region's well-developed infrastructure (availability of electricity and cellular coverage) and the absence of a hydrological station, experts proposed installing an automated monitoring station at the site of the dam under construction to improve hydrological monitoring and establish a cross-border early warning system for hydrological hazards. The station should transmit data in real time and be equipped with the following sensors:
   - Precipitation sensors (rain gauges or pluviometers) to measure the amount and intensity of precipitation;
   - Water level sensors (water level gauges) to monitor water levels;
   - Water flow sensors (flow meters) to measure flow rate and volume;
   - Soil moisture sensors, which are particularly important for landslide warnings in mountainous areas;
   - Meteorological sensors, including temperature sensors (for measuring air and water temperature) and anemometers (for measuring wind speed and direction);
   - Water pressure sensors (hydrostatic sensors) for accurately measuring changes in water level;
   - Water turbidity sensors to monitor the concentration of suspended particles, which helps assess the onset of mudflows;
   - Video surveillance cameras for visual monitoring of river and bank conditions.
   - Installing such a station in Kazakhstan and subsequently integrating it with the station in Uzbekistan will enable the rapid exchange of hydrological data and risk information, while eliminating false alarms.
5) Experts also found that settlements along the Ugam River are not equipped with siren-and-voice warning systems (SVWS). To effectively alert the population, it is proposed to install approximately 10–15 SVWS along the Ugam River, taking into account its length, population density, and topography. In addition,

[28] Descriptive Report of the Central Commission for Civil Protection and Emergency Situations on Field Research Conducted as Part of the GIZ Project: https://cesdrr.org/новости/в-рамках-проекта-giz-на-территории-узбекистана-проведены-полевые-исследования-трансграничных-рек

it is recommended to use mobile applications to alert the public about hydrological emergencies.

PART 5:
Overview of cross-border mudflows and floods affecting Tajikistan and Uzbekistan

10. Zaravshan River Basin: Overview of transboundary mudflows and floods affecting Tajikistan and Uzbekistan *(territory of the Republic of Tajikistan)*

Source [29]

1) 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 the high mountain ranges—the Turkestan Range to the north and the Gissar Range to the south. The Zeravshan mountain range runs almost parallel between the Gissar and Turkestan ranges. The Tajik portion of the basin encompasses the mountainous areas where most of the water resources are formed, while the valley portion of the basin is located in neighboring Uzbekistan, where the river's flow is entirely diverted for irrigation, water supply, and other economic needs.

2) The water resources of the Zarafshan River are of great importance for water management in both Tajikistan and Uzbekistan, the territory of which is home to cotton crops that are vital to the region. The total length of the main canals alone that draw water from the Zarafshan is approximately 2,500 km, and the largest of these have a flow capacity exceeding the discharge of many rivers in Central Asia.

3) The Zeravshan glaciers are a vital source of water for the Zeravshan River, which originates in the mountains of Tajikistan at an elevation of 2,800 m and flows into Uzbekistan. The Zeravshan basin is home to 6 million people, and the river serves the ancient cities of Samarkand and Bukhara and provides water for the irrigation of 0.5 million hectares.

4) In Tajikistan, the Zeravshan flows naturally through the mountains with few water intakes, but in Uzbekistan, water demand is high, and the available water is fully utilized.

5) According to estimates by the Hydrometeorological Service of Tajikistan, the Zeravshan glaciers are retreating and have already shrunk significantly in size. Rising temperatures could increase climate-related risks to agriculture in the lower part of the basin in the densely populated Samarkand and Bukhara regions.

6) The Zeravshan's watershed covers an area of approximately 42,000 $^{km^2}$, and the river is over 800 km long. The river's name translates as "gold-bearing," and although there is little extractable gold left in the main channel, the Zeravshan's tributaries and geological formations are indeed rich in gold, and the region is home to the largest gold mining operations in Tajikistan and Uzbekistan.

7) The average annual precipitation in the Zeravshan River basin—500 mm—is unlikely to change significantly, but there will most likely be less snow and more rain. The current average annual temperature in the river basin, which is 5°C, is expected to rise to 8°C under moderate warming and to 10–12°C under strong warming. This significant warming will lead to a retreat of glaciers and a reduction in snow and ice cover in the basin.

8) The resulting decrease in the amount of meltwater entering the river will lead to a reduction in river flow. 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

[29] Descriptive Report by the Central Committee for the Study of the Sary-Darya River Basin on field research conducted as part of the GIZ project: https://cesdrr.org/новости/в-рамках-проекта-giz-на-территории-узбекистана-проведены-полевые-исследования-трансграничных-рек

the lower reaches of the basin, cotton yields are likely to decline unless water-saving technologies and other adaptation measures are implemented.

9) Existing Risks: The Zaravshan River basin in Tajikistan is highly vulnerable to various hydrological threats due to its complex mountainous terrain, intensive snow and glacier melt, and changing climatic conditions. The most common hazardous events are mudflows, landslides, and flash floods resulting from heavy precipitation, rapid snowmelt, or the bursting of moraine lakes. In the upper reaches of the river, where a large number of glaciers and potentially hazardous lakes are concentrated, there remains a high probability of glacial lake outburst floods (GLOFs), which can trigger destructive mudflows. During the spring and summer, floods fed by a combination of rain and snow are also frequently observed, leading to the flooding of populated areas and damage to transportation and engineering infrastructure.

10) Field Research: From July 29 to August 6, 2025, a group of experts from the Center conducted field research on the Zaravshan River in the Republic of Tajikistan with the aim of establishing a transboundary early warning system for hydrological disasters in Central Asia.

11) In terms of transboundary risks, mudflows and landslides pose the greatest threat in the Zaravshan River basin. In the upper reaches of the basin, which flows through the territories of Tajikistan and Uzbekistan, there are several moraine lakes that pose a potential risk of breaching. Their failure could trigger mudflows and floods, threatening the population and infrastructure located downstream.

12) In this regard, the expedition began by assessing the situation at the source of the Zaravshan River in the Gorno-Matchinsky District of the Sughd Region, in a remote and inaccessible area. Particular attention was paid to the village of Vodif, which is most vulnerable to natural disasters. Residents face the threat of mudflows every year: in July 2021, meltwater washed away the only road, damaged potato fields, and disrupted the operation of an irrigation canal, resulting in the loss of about half the harvest. Under such conditions, access to the outside world can be cut off for months.

13) A detailed survey was also conducted of the operational hydrological station near the village of Khudgif in the upper reaches of the Zaravshan River. Special attention was given to the village of Amondara, located 24 km from the district center of the Penjikent District in Sughd Province, with a population of over 3,000 people. It is one of the settlements in the district most vulnerable to mudflows. For example, in 2021, heavy rains triggered landslides that destroyed three houses, damaged 29 private plots, 10 hectares of farmland, and 10 km of rural roads. One person was killed.

14) Based on the results of field studies and with the aim of improving the hydrological monitoring system, experts proposed installing automated stations at the sites of the existing Dupuli and Khudgif hydrological stations.

15) Conclusion: Thus, the installation of automated hydrological monitoring stations on the Zaravshan River is a key element in establishing a transboundary early warning system, as it will enable real-time data collection, timely identification of critical conditions, automatically process and analyze data, integrate with digital forecasting models, and transmit information to the servers of the Hydrometeorological Agency of the Committee on Environmental Protection under the Government of the Republic of Tajikistan, as well as to the Committee of Emergency Situations and Civil Defense under the Government of the Republic of Tajikistan.

16) Based on the results of processing data obtained during field studies, an interactive map will be prepared showing relevant attribute information on the sites, which will be posted on the Center's website.

11. Zaravshan River Basin: Overview of landslides and floods with transboundary implications for Kazakhstan and Uzbekistan *(territory of the Republic of Uzbekistan)*

Source [30]

1) On the Zaravshan River, in the section between the border with Tajikistan and the city of Samarkand, there are hydrological risks such as flooding and mudflows. Samarkand, a major historical and cultural center, is at risk of flooding, especially during periods of sharp rises in the water level of the Zaravshan. Floods can affect the city’s infrastructure, including roads, buildings, and water supply systems. In addition, many small settlements near the river are at risk of flooding and flash floods. These settlements rely heavily on rivers for irrigation and water supply, and any hydrological disaster could disrupt water supply and damage infrastructure.
2) The Zaravshan River basin, which flows through Tajikistan and Uzbekistan, contains several moraine lakes that pose a potential risk of breaching. If a moraine dam were to fail, water from the lake could trigger mudflows and floods, threatening residents and facilities located downstream.
3) In the section between the border with Tajikistan and the city of Samarkand, there are also risks of transboundary flooding that could affect the city’s infrastructure, including roads, buildings, and water supply systems. Small settlements along the river depend on the Zaravshan for irrigation and water supply, and hydrological disasters could cause significant damage.
4) The existing hydrological station on the Zarafshan River is located downstream of the Ravatkhodja Dam on the border between Tajikistan and Uzbekistan. The station is equipped with the necessary monitoring equipment; however, some of the equipment requires modernization (*for example, submersible depth recorders from the German company Seba Hydrometrie and GR-64 remote hydrometric stations developed by the USSR*).
5) For comprehensive monitoring of hydrological risks, experts will recommend installing an automated station based on the existing station, which requires retrofitting with sensors for water level, flow velocity, precipitation, water and air temperature, turbidity, soil moisture, and meteorological parameters.
6) Since the river section from the border with Tajikistan to Samarkand is densely populated (more than 15 settlements within 38 km), experts also proposed installing siren and voice-announcement systems to alert the public to hydrological hazards. Additionally, it is recommended to use mobile applications to inform the public about the threat of hydrological emergencies.
7) The recommendations being developed as part of the GIZ project will aim to improve hydrological monitoring in the transboundary river basin, enabling the timely tracking and identification of hydrological threats. A key element of these recommendations will be the development and implementation of a transboundary early warning system, which will ensure the rapid exchange of data between countries and enable timely notification of potential hydrological risks, such as high water, flooding, mudflows, and sudden fluctuations in water levels.

PART 6:
Overview of Cross-Border Mudflows and Floods Affecting Turkmenistan and Uzbekistan

12. River Basin .....: Overview of transboundary mudflows and floods affecting Turkmenistan and Uzbekistan

[30] Descriptive Report by the Central Committee for Hydrometeorological Services on Field Research Conducted as Part of the GIZ Project: https://cesdrr.org/новости/в-рамках-проекта-giz-на-территории-узбекистана-проведены-полевые-исследования-трансграничных-рек

There is currently no information available for this section, except for information on the Amu Darya River, which originates in Tajikistan, flows along the border between Afghanistan and Uzbekistan, then crosses Turkmenistan, and returns to Uzbekistan, where it empties into the Aral Sea.

The world's longest canal, the Karakum Canal (1,445 km), diverts up to half of the Amu Darya River's total water flow (with a discharge rate of 600 cubic meters per second). It flows through Afghanistan, Tajikistan, Uzbekistan, and Turkmenistan. Major cities: Turkmenabat and Atamurat (Turkmenistan); Nukus, Termez, and Urgench (Uzbekistan). Regular shipping operates from Turkmenabat to the river's mouth.

At the same time, in order to develop an overview of cross-border floods and mudflows affecting Turkmenistan and Uzbekistan, it is planned—in consultation with the designated specialist from CAREC, the Deputy Head of the CAREC Expert Group— to address issues related to sending letters of inquiry from CAREC to the following government agencies:

- *Turkmenistan: Main Directorate for Civil Defense and Emergency Situations of the Ministry of Defense, Ministry of Environmental Protection;*
- *Republic of Uzbekistan: Ministry of Emergency Situations, Ministry of Ecology, Environmental Protection, and Climate Change.*

The purpose of sending these letters of inquiry is: to provide information about the project and coordinate matters related to their assistance in developing the RRM and IP for mitigating the effects of mudflows and floods by providing information, clarifying the list of necessary measures, the budget, and funding sources, participating in discussions, and offering remarks, comments, and suggestions, etc.

PART 7:
Overview of Transboundary Landslides and Floods in Central Asia

13. Amu Darya River Basin: Overview of Transboundary Mudflows and Floods Affecting Tajikistan and Uzbekistan

Source [31]

1) The Amu Darya is the largest river in Central Asia. Its length from the source of the Panj River is 2,540 km, and its drainage basin covers 309,000 km² (excluding the drainage basin of the Zeravshan River).
2) It takes the name Amu Darya when the Panj River flows into the Vakhsh River. Three major right-bank tributaries (Kafirnigan, Surkhandarya, and Sherabad) and one left-bank tributary (Kunduz) flow into the Amu Darya in its middle course. From there on, all the way to the Aral Sea, there are no tributaries. The river is mainly fed by meltwater; thus, maximum flow rates occur in the summer, and minimum flow rates in January–February.
3) This annual flow pattern is favorable for the use of river water for irrigation. As it flows across the plain from Kerki to Nukus, the Amu Darya loses most of its flow through evaporation, infiltration, and water withdrawals for irrigation. *The Amu Darya ranks first in the world in terms of sediment transport.*
4) The main flow of the Amu Darya is generated in Tajikistan (about 72.8%—excluding the Zerafshan River). The river then flows along the border between Afghanistan and Uzbekistan, crosses Turkmenistan, and returns to Uzbekistan, where it empties into the Aral Sea. About 14.6% of the Amu Darya's water originates in Afghanistan and Iran. About 8.5% of the Amu Darya's flow originates in Uzbekistan.

[31] https://unece.org/fileadmin/DAM/env/water/meetings/Assessment/Almaty%20workshop/pdf/breakout_session/surface/Amudarya_overview_rus.pdf

5) A key characteristic of the Amu Darya River basin is that most of the areas with favorable natural and economic conditions for irrigated agriculture are located far from the main river channel, and their water resources are very limited. These include areas such as the Karshin Steppe, the Bukhara region, and the southern part of Turkmenistan. To ensure the delivery of water for the development of these areas, unique canal systems were constructed.

Source [32]

1) The source of the Amu Darya is located at the confluence of the Panj and Vakhsh rivers at an elevation of 400 m. The river is 1,415 km long (2,336 km including the Panj; 2,556 km including the Panj and the Vakhsh); the water discharge in the upper reaches is about 2,000 cubic meters per second; and the drainage basin covers 309,000 square kilometers.
2) Major tributaries: Kafirnigan, Surkhandarya, Sherabad, and Kunduz. Currently, the mouth is located 200 km from the Small Aral Sea, since all of the river's water is diverted for irrigation via the Karakum, Amu-Bukhara, and other canals, along which cotton and wheat fields stretch.
3) The world's longest canal, the Karakum Canal (1,445 km), diverts up to half of the river's total water (with a flow rate of 600 cubic meters per second). It flows through the territories of Afghanistan, Tajikistan, Uzbekistan, and Turkmenistan. Major cities: Turkmenabat and Atamurat (Turkmenistan); Nukus, Termez, and Urgench (Uzbekistan). Regular shipping operates from Turkmenabat to the river's mouth.
4) Several hydroelectric power plants have been built on the Vakhsh River. The flow of the Amu Darya is regulated by the Tyuyamun and Takhiatash hydroelectric complexes. Several nature reserves have been established in the river basin—the Amu Darya Reserve (Turkmenistan), the Aral-Paygambar Reserve, and the Kyzylkum Reserve (Uzbekistan). Uzbekistan produces up to 20% of the world's cotton crop on its irrigated lands.

14. Syr Darya River Basin: Overview of Transboundary Floods and Mudflows Affecting Kyrgyzstan, Uzbekistan, Tajikistan, and Kazakhstan

Source [33]

1) The transboundary Syr Darya River is the second most significant source of surface runoff in the Central Asian region.
2) The Syr Darya river system belongs to the Aral Sea basin; it is formed by the confluence of the Naryn and Karadarya rivers in the Fergana Valley and encompasses the following countries: Kyrgyzstan (Batken, Jalal-Abad, Naryn, and Osh regions), Uzbekistan (Andijan, Jizzakh, Namangan, Syr Darya, Tashkent, and Fergana regions), the Sughd region of Tajikistan, and Kazakhstan (Kyzylorda and South Kazakhstan regions).
3) The Syr Darya's long-term average annual discharge is 40.8 km³/year. There are five reservoirs on the river: Toktogul, Andijan, Kayrakkum, Charvak, and Shardara.
4) In percentage terms, water withdrawal from the river is as follows: Kazakhstan 41.5%, Kyrgyzstan 0.82%, Tajikistan 7.44%, and Uzbekistan 50.24%.
5) The Syr Darya is formed by the confluence of the Kyrgyz rivers Naryn and Kara-Darya and receives runoff from rivers flowing down the southwestern slopes of the Fergana Range and the northern slopes of the Alay and Turkestan Ranges.
6) The Syr Darya is 2,860 km long, has a drainage basin of 136,000 km², and an average annual discharge of 37 km³/year. Annual discharge volumes range from 21 to 54 km³. The river flows through the territories of Kyrgyzstan, Uzbekistan, Tajikistan, and Kazakhstan.
7) It is formed by the confluence of the Naryn and Karadarya rivers in the eastern part of the Fergana Valley. Virtually all of the Syr Darya's runoff originates in the mountainous part of the basin. Its water supply consists primarily of snowmelt, with glacial and rainwater contributing to a lesser extent.

[32] https://proza.ru/2021/12/26/313
[33] https://cyberleninka.ru/article/n/ekologo-hozyaystvennaya-otsenka-basseyna-syrdari-s-primeneniem-geoinformatsionnyh-tehnologiy/viewer

8) The main contributors to the Syr Darya's runoff are the Naryn (36%), the Karadarya (11%), the rivers of the Fergana Valley (25%), and the Chirchik (20%). The flood season occurs in the spring and summer. Downstream of the city of Chardara, the river's flow is used for irrigation and is lost to evaporation in the floodplains. Upon exiting the Fergana Valley, the river crosses the Farkhad Mountains and then flows through the Golodnaya Steppe along a vast, sometimes marshy floodplain 14.7 km wide.

9) In its middle course (from the Farkhad Mountains to the Chardara Reservoir), the Angren (Akhangaran), Chirchik, and Keles rivers flow into the Syr Darya. The South Golodnaya Steppe Canal begins at the Farkhad Hydropower Complex. In 1958, the Zhanadari Canal was put into operation. The flow of many small tributaries of the Syr Darya is diverted for irrigation and does not reach the river itself.

10) In its lower course, the Syr Darya flows along the eastern and northern edges of the Kyzylkum Sands; the riverbed here is winding and unstable, and flooding is common during the winter and spring. The last tributary is the Arys. In the lower reaches of the river, along the stretch from the city of Turkestan to the district center of Zhosaly, there is a vast floodplain (10–50 km wide, about 400 km long), crisscrossed by numerous channels, overgrown in places with reeds and willow thickets, and widely used for agriculture (rice cultivation, melon and watermelon cultivation, vegetable farming, and, in some places, fruit growing). At its mouth, the Syr Darya forms a delta (near the city of Kazalinsk) with numerous channels, lakes, and marshes, which is used for melon and watermelon cultivation.

11) The Syr Darya previously flowed into the Aral Sea; however, due to the catastrophic drop in the sea's water level and its splitting into two parts (in 1989), the river now flows into the northern part of the sea (the so-called "Small Sea"). The waters of the Syr Darya are largely diverted for irrigation; as a result, the current discharge at the mouth has decreased more than tenfold (from 400 m^3/s to 30 m^3/s) compared to the quasi-natural period (prior to 1960).

Source [34]

1) The Syr Darya is formed by the confluence of the Naryn and Karadarya rivers at an elevation of 396 m in the eastern part of the Fergana Valley. It is 2,112 km long, with a discharge of about 500 cubic meters per second in its upper reaches and a drainage basin of 219,000 square kilometers. It flows through the Golodnaya Steppe and, in its lower reaches, bypasses the Kyzylkum Desert.

2) Tributaries: Angren, Chirchik, Keles, Arys, Karasu, and Khojabakirgan. It flows through the territories of Tajikistan, Uzbekistan, Kyrgyzstan, and Kazakhstan. Over the past 50 years, the river's discharge has decreased tenfold due to water diversions for irrigation via the Kyzylkum, Southern Golodnaya Steppe, and other canals. In some years, the river dries up 150 km before reaching the Great Aral Sea.

3) The largest reservoirs are the Kayrakkum Reservoir (Tajikistan), the Chardara Reservoir, and the Koksaray Reservoir (Kazakhstan). Settlements located along its banks include Kyzylorda, Turkestan, and Baikonur (Kazakhstan), Khujand (Tajikistan), and Bekabad (Uzbekistan). Two hydroelectric power plants have been built on the river: the Chardara Hydroelectric Power Plant (Kazakhstan) and the Farkhad Hydroelectric Power Plant (Tajikistan and Uzbekistan). Cotton, rice, melons and gourds, and grapes are grown in the irrigated fields. Fruit growing and vegetable gardening are well developed; fishing takes place in the reservoirs. Goats and sheep are raised.

4) The area of irrigated land increased from 2.3 to 3.3 million hectares between 1965 and 2000. Water withdrawal for irrigation rose from 13.5 to 30 km^3/year between 1932 and 1990; in the subsequent period, it averaged 14–16 km^3/year. Due to water withdrawal in the S. basin, the river's flow at the head of the delta (Kazalinsk) decreased on average from 15 km^3(1932–60) to 4.1 km^3(1961–2006); during the low-flow decade of 1981–90, it amounted ^{to} 2.$^{3\ km^3}$. The river's outflow desalinates the Small Sea (Small Aral), which is isolated from the rest of the Aral Sea. To the north (downstream) lie the cities of Kayrak-Kum, Khujand (Tajikistan), Syrdarya (Uzbekistan), Kzyl-Orda, Jalagash, Dzhusaly, Baikonur, and Kazalinsk (Kazakhstan).

Source [35]

1) The Syr Darya River is fed by snow and glaciers; maximum discharge occurs in May–June, and the flood season spans April–August. During the remaining months, water discharge is significantly lower.

2) Water Resources of the Syr Darya River Basin. The Syr Darya is the second-largest river in Central Asia in terms of water volume. The total discharge from the Syr Darya basin's catchment area is approximately 1,200 m^3/s.

[34] https://proza.ru/2021/12/26/313
[35] https://cawater-info.net/library/rus/chembarisov-rahimova-syrdarya.pdf

Surface water resources in the Syr Darya River basin are estimated at an average of 33.2 km³ and vary depending on the water availability in a given year. The Naryn and Chirchik Rivers are the most water-rich in the Syr Darya River basin

3) In the Syr Darya River basin, a cascade of reservoirs (Toktogul, Kairakum, Andijan, Charvak, and Shardara) makes it possible to fully regulate (up to 93%) the river's flow; that is, to achieve virtually complete regulation of the river's flow. However, since 1991, in the upper reaches, the largest reservoir, the Toktogul Reservoir, has been operating in power generation mode, sharply increasing outflows during the non-growing season and reducing them during the growing season (in years of low water). This operating regime of the Toktogul Reservoir reduces the extent to which the needs of irrigation water users in the upper and middle reaches of the river are met and leads to irrigation deficits in years of low water flow.

Source [36]

1) Mapping of hazardous enterprises in the Syr Darya River basin: 133 enterprises engaged in hazardous activities (74 in Kazakhstan, 20 in Kyrgyzstan, 27 in Uzbekistan, and 12 in Tajikistan) handle a wide range of chemical pollutants (ranging from petroleum products and heavy metals to agricultural treatment chemicals).
2) Mapping of tailings ponds:
   - 61 tailings ponds in the Syr Darya River basin, of which 9 are in Kazakhstan (downstream).
   - 30 in Kyrgyzstan (upstream).
   - 10 in Tajikistan (upstream).
   - 12 in Uzbekistan (downstream).
   - In the event of an accident, 33 tailings ponds could have a transboundary impact (19 of them in Kyrgyzstan, 10 in Tajikistan, and 4 in Uzbekistan).
   - Ranked according to the IRH international scale (very high—28, high—27, medium—6)

Source [37][38]

1) March 10, 2023 – A sharp rise in temperatures has caused the Syr Darya River to overflow its banks in Kazakhstan. In the Kyzylorda Region, the Syr Darya has burst its banks. In the village of Kyzyltam, the water washed away part of a bridge and swept away a road. The river level continues to rise. Nearly 800 cubic meters of water are flowing into the river every second. Ice and snow are melting rapidly. Evacuation centers have been set up in the region in case of flooding.
2) March 8, 2023 – In the Karmakshin District of the Kyzylorda Region, the Syr Darya River burst its banks at a hazardous section near the village of Kyzyltam. As a result, the regional highway between Zhalagash and Zhosaly has been temporarily closed.

Source [39]

1) The water regime of the Syr Darya River has always been plagued by water shortages during the summer for agricultural and domestic needs, as well as flooding during the spring high-water period, accompanied by enormous material damage. These problems in the river's lower reaches are caused by both natural and human factors. The severity of these natural problems has sharply decreased following the construction of a number of reservoirs in the river basin, particularly two strategically important ones: the Shardara Reservoir (1965) in Kazakhstan and the Toktogul Reservoir (1973) in Kyrgyzstan.

   The stabilization of flood issues during the spring flood season and low-water conditions in the summer is due to the fact that the regulation of the river's natural flow and the release regime from reservoirs was specifically organized to alleviate flood and low-water problems. Moreover, it was

[36] https://unece.org/sites/default/files/2023-02/Syr%20Darya%20project_KAZ_UZB%20meeting_.pdf
[37] https://mir24.tv/news/16544711/rezkoe-poteplenie-privelo-k-razlivu-reki-syrdari-v-kazahstane
[38] https://tengrinews.kz/kazakhstan_news/syirdarya-vyishla-beregov-trassu-zakryili-kyizyilordinskoy-493083
[39] https://cawater-info.net/syrdarya-knowledge-base/papers/shonbaeva.pdf

This may have been possible when Kazakhstan, Kyrgyzstan, and Uzbekistan were part of a single country, and the river's flow was managed from a single central authority.

2) Currently, the problems of flooding and low water levels have reemerged, and they are solely linked to human economic activity, even though this activity should, first and foremost, be aimed at reducing the risk to the entire population of the river basin. Floods on rivers in their natural state are, as is well known, associated with high-water periods, flood events, and a reduction in the river's free flow area during the winter months when log jams and ice jams occur. They often occur in the lower reaches and in river deltas, since during periods of peak high water and log jams, the water level in the river rises above that of the surrounding terrain.

   Floods have always occurred on the Syr Darya River under natural conditions, but those occurring in winter due to a narrowing of the river's effective cross-section were frequent and the most dangerous, since winter water levels in the river were higher than under conditions of an open, unobstructed river surface. Flooding was also exacerbated by the unique topographical position of the Syr Darya River, characterized by the fact that, practically starting from Tomenaryk, the river's floodplain merges with the surface of the adjacent plain, and floodwaters can cover a strip 20 km wide or more.

3) Under such conditions, frequent ice jams and sharp rises in water levels used to occur as the ice drift moved downstream; the nature of these events had the following characteristics:

   - at all stations except Shardara, the highest water levels are observed during the winter; - the highest water levels were also most frequently observed during river break-up, i.e., the ice drift;
   - the highest water levels at the Tomenaryk, Karaozek, and Kyzylorda stations were observed in the fall in some years—that is, during frosts—but these were rare;
   - High water levels at Zhosaly and Kazalinsk occurred when the river broke up during the ice drift. The most frequent high water levels also coincide with this period;
   - There is no correlation between the highest winter and summer water levels. - In November–December, the highest water levels are observed starting from Kyzylorda during the freezing period and after the ice cover has formed, i.e., this is an ice-related rise in water level;
   - In January, the highest water levels are observed during the ice-covered period, i.e., this is also a rise in water level caused by ice accumulation; - In February, high water levels are also observed during this period;
   - In March, during the ice break-up period, the frequency of high water levels increases from the beginning of winter to the end (50–72%) and from the upper reaches to the lower reaches. This is explained not by an increase in ice jams, high water levels, or a narrowing of the river channel due to ice formation, but by the fact that from fall to spring, the discharge in the lower part of the river increases due to the release of water previously retained in the river floodplain;
   - there is no correlation between the highest water level and the time of its occurrence;
   - at the Tomenaryk station, the highest winter level exceeded the summer level by 6–8 cm, while at the Kyzylorda station it exceeded it by 116 cm, and in Kazalinsk by 71 cm;
   - The correlation between the highest winter water levels at the downstream stations (Kyzylorda, Zhosalakh, Kazalinsk) and the discharge at Kokbulak (Shardara) is very weak; that is, it is not possible to reliably regulate the highest winter water levels at the downstream stations by releasing water from the Shardara Reservoir. For example, with a release of 600 m^3/s from Shardara, the level at the Kyzylorda station could be either 280 cm or 430 cm above the zero mark on the chart;
   - Under natural conditions, high water levels at gauging stations in the current month generally indicate that the following month will also see high levels, provided that ice conditions persist into the subsequent month. The freezing of river water, with the ice front moving upstream in the fall, causes water levels to rise in sections where ice cover has formed, while discharge decreases downstream of these sections—a phenomenon typically accompanied by a drop in water level. The transformation of water into ice somewhat exacerbates this decrease in discharge and drop in water level. The breaking up of ice in a river in the spring, as the ice front moves downstream, is accompanied by the release of trapped water back into the river, which increases downstream discharge with

a corresponding rise in water level. During the ice-covered period, a meaningful variation in average-decade water discharge is observed only at short distances between gauging stations, which characterizes the regular variation of hydrological processes along the length of the river. As the distance between gauging stations increases, this relationship becomes increasingly weak;

- the average water flow velocity under ice cover along the entire length of the river is taken to be 75 km/day, although calculations of this value based on long-term average monthly discharge during the winter ice-covered period yielded 50–60 km/day. It has been established that during the ice-covered period on the Karaozek–Kyzylorda section, both significant losses and inflows are observed, which reduces the ability to predict the discharge rate at one station based on the value measured at another, even though the distance between the stations is only 33 km. On the section upstream of Karaozek, when ice formation began in November and December, water discharge decreased by nearly half, and in the following months—January and February—it returned to its initial level. On the section from Karaozek to Kazalinsk, water losses are always observed, both during and outside the ice-cover period. In winter, as a rule, 55–60% of the water that passed through the Karaozek gauging station reached Kazalinsk;
- during the ice-covered period, as with discharge rates, the correlation between water levels at the gauging stations decreases as the distance between them increases.

4) According to data, over a 12-year period (1948–1960), 211 hazardous events were recorded along the river from Shardara to the mouth, of which 86 were floods that caused damage to economic facilities. Of the 86 floods, 62 were winter floods (caused by ice jams), and there were a total of 146 ice jams; that is, 42.5% of ice jams were accompanied by flooding that caused damage to economic facilities. During the same period, there were 65-year-return-period dangerous water level rises, 24 of which were accompanied by flooding that caused damage, accounting for 37%. Winter hazardous events occur 2.25 times more frequently than summer ones.

   On average over the 12-year period, there were 5 blockage-related floods and 2 annual floods resulting in damage. Over the 12 years, 60% of all floods resulting in damage occurred in three 100-km sections [(101–200) km; (601–700) km; (900–1,000) km] from the river's mouth. These are the areas of Kazalinsk, Kyzylorda–Terenozek, and Zhanakorgan–Shieli.

   All winter floods in the lower reaches of the river occurred when the discharge at Shardar exceeded 600 m³/s, and the risk of flooding generally decreases sharply when the discharge at Shardar is less than 475 m³/s during the winter. Under the river's current regime, floods occur only in winter and have the same causes as under the natural regime; however, anthropogenic impact plays a decisive role.

5) The flood problem has worsened in recent years due to a number of objective and subjective factors.

   First, the cause of modern-day flooding in the lower reaches of the Syr Darya River is the reduction in the river's effective cross-sectional area and the loss of its flow capacity in many sections of the river as a result of siltation during periods when river discharge was low. The most significant reduction in the river's effective cross-sectional area occurred during the prolonged low-water period of 1974–87, when releases downstream of the Kyzylorda hydroelectric complex were minimal, and downstream of the Kazalinsk hydroelectric complex, they were close to zero.

   The loss of the river channel's flow capacity was also exacerbated by the narrowing of the river floodplain due to its conversion into summer cottage plots and the construction of levees. And when winter discharge increased due to the Toktogul hydroelectric complex's transition to power generation mode, this restructuring of the river valley in the lower reaches could not handle discharges of 600–800 m³/s downstream of Shardara, leading to annual flooding.

6) In the spring of 2008, another flood in South Kazakhstan Region destroyed more than 3,000 homes and public facilities, resulting in costs to the state totaling $130 million. This finally prompted Kazakhstan to undertake the counter-regulator project. Construction of the reservoir began in 2008. The bulk of the work was completed in 2010. The counter-regulator is located in the rural districts of Akdala and Zadarya in the Arys District of the South Kazakhstan Region, 160 kilometers downstream from the Shardara Reservoir on the Syr Darya River, south of the village of Koksaray. The design capacity of the regulating reservoir is 3 billion cubic meters, the surface area of the water body is 46,745 thousand hectares, the discharge capacity of the concrete channel dam

is 1,800 cubic meters per second, and the flow capacity of the 16-kilometer-long intake canal is 500 cubic meters per second. The reservoir dam is 44.7 kilometers long with an average height of 7.7 meters; the outlet canal is 10.2 kilometers long with a flow capacity of 500 cubic meters per second. In early 2011, the counter-regulator accepted the first 2 billion cubic meters of water and spared southern Kazakhstan from unwanted flooding. The excess water collected during the high-risk period in the spring and summer will be released evenly downstream along the Syr Darya riverbed. As a result, lakes in the lower reaches will not dry up, which will have a positive impact on fish farming. Rice fields will receive regular irrigation. In addition, much-needed moisture will finally reach the drying-up Aral Sea.

7) From 2010 to 2013, more than 9 billion cubic meters of water from the Syr Darya River were stored in the Kokssaray counter-regulator basin, including 912.8 million cubic meters in 2010, 2,300 million cubic meters in 2011, 3,138 million cubic meters in 2012, and 3,015 million cubic meters in 2013. The accumulated water reserves are used annually to meet the needs of agricultural producers in the South Kazakhstan and Kyzylorda regions.

8) Observations on the Syr Darya River regarding the hydrological regime, floods, channel processes, characteristics of the winter regime, ice formation, the passage of ice drifts and ice breaks, and the nature of ice jams and blockages have revealed a number of water management issues, which have escalated into environmental issues due to the full utilization of river flow by various economic sectors. These issues consist of anthropogenic changes in the intra-annual distribution of flow—specifically, an increase in winter flow and a decrease in summer flow—which degrades the water supply to irrigated lands. Thus, this problem poses an obstacle not only to the ecological restoration of the river basin but also to the sustainable development of the region’s entire agro-industrial complex.