Natural Disaster Risks in Central Asia: A Synthesis

Michael Thurman
UNDP/BCPR, Regional Disaster Risk Reduction Advisor, Europe and CIS
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Introduction

Central Asia is highly exposed and vulnerable to natural hazards. Both exposure and vulnerabilities have risen in the last few decades. In order to address risks posed by these two factors, governments and the international community have undertaken an increasing number of initiatives in the last decade. However, many of these efforts are based upon a limited understanding of disaster risks. The ensuing study attempts to synthesize the available data and studies of disaster risk in order to begin to fill this gap. It also highlights needs in risk assessment in the region.

The study has several objectives. Foremost, it offers a baseline analysis for identifying disaster risk reduction (DRR) and climate risk management (CRM) interventions in the region. For this purpose, it complements a capacity assessment undertaken for the Central Asia Center for Disaster Response and Risk Reduction, which is presently being established in Almaty.[1] Furthermore, it provides analysis to support to the 2011 meeting under *Central Asia Regional Risk Assessment (CARRA)*, which sought to analyze the "compound crisis" that emerged in Kyrgyzstan and Tajikistan in 2008.[2]

The study begins with a description of the sources and methodology employed. The ensuing section offers analysis of exposure to geophysical and meteorological hazards. Then the study covers vulnerabilities related to disaster impacts. The concluding section presents findings and implications for DRR initiatives in the region, and well as recommendations for further research and endeavors to strengthen risk assessment. Annex 1 contains additional maps and data that support the analysis.

Sources and Methodology

The study draws upon a wide range of data and sources. First and foremost among these are works devoted to specific hazards, including a drought management and mitigation assessment undertaken by World Bank and studies of earthquakes conducted under auspices of the Global Seismic Hazard Assessment Program and NATO.[3] Additionally, it draws upon primary data made available by DRR agencies in the region and studies devoted to disasters in individual countries.[4]

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[1] This is being done with support from DIPECHO under the UNDP project "Enhancing Disaster Risk Reduction Capacities in Central Asia."

[2] The CARRA and subsequent *Framework for Action* were discussed at a donor meeting in Almaty, Kazakhstan in July of 2008. Subsequently, a number of initiatives were taken to address the root causes of the crisis, as well as strengthen risk monitoring and assessment and preparedness and response.

[3] GeoHazards International, 1996, *Lessons for Central Asia from Armenia and Sakhalin: Strategies for Urban Earthquake Risk Management for the Central Asian Republics*; V. Ulomov and Working Group of GSHAP Region 7, 1998, "Seismic Hazard of Northern Eurasia," http://www.seismo2009.ethz.ch/gshap/neurasia/report.html; World Bank, 2006 *Drought Management and Mitigation Assessment for Central Asia and the Caucasus: Regional and Country Profiles and Strategies*.

[4] Komitet po cherzvychainym situatsiami i grazhdanskoi oboroni pri Pravitel'stve Respubliki Tadzhikistana, 2007, *Cherzvychaynye situatsii prirodnogo kharaktera, vozmozhnye na territorii Republike Tadzhikistana in ikh posledstviia;* ISDR Sub-Regional Office for Central Asia and the Caucasus, 2010, *In-Depth Review of Disaster Risk Reduction in the Kyrgyz Republic*; UNDP, Kazakhstan Ministry of Emergencies, and Kazakhstan Red Crescent Society, 2005, *Local Risk-Management in Earthquake Zones of Kazakhstan (LRM#00038518), Result 1 Report.*

A great deal of data from disaster management agencies in the region is available at www.ocha.kz and http://www.untj.org/country_context/coordination_mechanisms/disaster_management/resources_pages/.

Outputs of UNDP and other projects are also utilized, as well as a recent desk study conducted for the Central Asia and Caucasus Disaster Risk Management Initiative.[5] Finally, the ensuing study incorporates the findings of National Communications of the governments of Central Asia under the United Nations Framework Convention on Climate Change.

As this report is a synthesis of existing risk assessment studies, its methodology is largely conditioned by the quality of data and analysis related to hazard and vulnerability components of risk. The initial section of the study covers hazard exposure, for which data is much more readily available and reliable than for vulnerabilities to disasters. This is due mainly to the emphasis placed upon hazard analysis in the region and the strong capacity for it developed in the Soviet period. Although there is strong capacity for hazard analysis *per* se, there are two significant problems in this area. First, owing to the deterioration of monitoring networks in the last two decades, there are gaps in data. Moreover, analyses that once were conducted by specialists in the Soviet period, often with cooperation at the regional level, are now conducted mainly at national level. This has resulted in a loss of coherence in the analysis of regional hazards. This is true of analyses related to past patterns of hazard exposure, as well as projections of hazard related to climate change in the future. Where these issues present problems, the resulting uncertainties in analysis are highlighted below for various hazards.

Another section of this study is devoted to the analysis of disaster vulnerabilities, proceeding from disaster impacts. Data regarding disaster losses must be treated with some caution, as capacities in disaster needs assessment and vulnerability analysis remain weak. Data problems include the following:

- There are significant gaps in datasets, particularly for the immediate aftermath of the collapse of the USSR.
- Data is sometimes conflicting, and national datasets follow different standards.
- Global datasets (such as EM-DAT) have significant gaps and inaccuracies, for reasons explained below.

Owing to the lack of reliable data, this study can provide only a generalized assessment of disaster impacts. Proceeding from these impacts, it provides a qualitative analysis that seeks to attribute vulnerabilities to impacts in various sectors. A dedicated in-depth research effort is required at regional and national level, as well as within high-risk areas, to fully understand the critical vulnerability component of disaster risk. It is hoped that ongoing and future interventions in DRR will build adequate capacities to address this issue.

[5] UN ISDR, 2009, *Central Asia and Caucasus Disaster Risk Management Initiative (CAC DRMI): Risk Assessment for Central Asia and the Caucasus, Desk Review*.

Geophysical Hazards

Earthquakes

Central Asia is highly exposed to seismic hazards. The most recent seismic zoning map completed for the region, completed by the Global Seismic Hazard Assessment Program (GSHAP) in 1997, indicates that expected seismic intensity at the surface is higher than indicated from the previous map (developed in 1978).[6] The main seismic regions in Central Asia (shown in Figure 1 below) include the Pamir - Tien Shan (Region 2.1 in the map below), Iran-Caucasus-Anatolia (Region 1.1), and Central Kazakhstan (Region 3.1).

Seismic zones in Central Asia cross national boundaries. The seismic zones presented in Figure 1 contain not only several countries in Central Asia, but also neighboring countries in the Caucasus (in the case of Turkmenistan) and outside of the CIS (all countries). The same is true of most seismically active faults (see Figure 2). Transboundary seismic source zones are especially concentrated in the Pamir - Tien Shan region.

The seismic services of most countries register around 3,000 underground tremors of different intensity annually. All Central Asian countries have experienced devastating earthquakes within the last 150 years. Most impacts are felt within an area covering one or more provinces within the country. Some examples are provided below:

- In Kazakhstan, southeastern portion of the country is seismically active, with a few major earthquakes registered at magnitudes of seven to eight (Richter scale). Earthquakes in 1887 and 1910 leveled the city of Almaty. The northern Tien Shan mountain area is experiencing a phase of seismic activity. The more recent May 2003 Lugovskoy earthquake in this region killed 3 people, affected 36,626 people, and caused economic losses of around $105 million. The August 1990 earthquake on the Kazakhstan-China border killed 1 person and affected 20,008 people with an economic loss of $3 million.[7]
- Since 1970 Kyrgyzstan has been struck by 18 destructive earthquakes. The four most significant recent earthquakes (1992-2006) were in the range of magnitude five to seven. They resulted in 132 deaths, affected 150,930 people, and caused damages estimated at $163 million. According to the Institute of Seismology, the northern Tien Shan is presently the most seismically active region, with earthquakes expected of magnitude five to six and intensity of six to eight.[8] Another hotspot is in the south of the country near the Ferghana Valley and border with China.
- In the last century there have been three earthquakes in Tajikistan with a magnitude greater than seven and 500 greater than five. During 1997-2007 229 seismic events resulted in

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[6] For this reason, earthquakes in Armenia (Spitak, 1988), Kazakhstan (Zaysan, 1990), Georgia (Racha, 1991), and Kyrgyzstan (Suusamyr, 1992) were stronger than expected. See: V. Ulomov, et al, 1998, "Seismic Hazard of Northern Eurasia."

[7] UNDP, 2004, *Lessons from the Lugovskoy Earthquake of 23 May 2003 for Kazakhstan*; UNDP, 2005, *Local Risk Management in Earthquake Zones of Kazakhstan*.

[8] ISDR Sub-Regional Office for Central Asia and the Caucasus, 2010, *In-Depth Review of Disaster Risk Reduction in the Kyrgyz Republic*.

cumulative damages of $49 million. A magnitude 5.9 earthquake in 1985 affected 8,080 people and resulted in damages of over $300 million.[9]

- In the first quarter of the twentieth century there were around 80 earthquakes in Turkmenistan with intensity (on the MSK scale) of six to seven. Following a period of relative calm, an earthquake in 1948 (M = 7.3, MSK = 10) nearly razed the city of Ashgabat, reportedly killing around 50,000 people.[10] Districts outside the city, as well as parts of northern Iran, were affected. Since 1948 there have been 35 earthquakes of a magnitude higher than four.
- Since 1955 Uzbekistan has experienced 81 earthquakes above five in magnitude, of which 11 were above six. The eastern portion of the country, containing the cities of Tashkent, Samarkand, and Bukhara, as well as the Ferghana Valley, are subject to earthquakes with an intensity of seven or higher (MSK scale) every 50 years (or in the case of Tashkent, 25 years) . Tashkent was struck by an earthquake on 26 April 1966 that killed 10 people, affected 100,000 others and caused economic losses of $300 million.[11]

According to the GeoHazards International study conducted in 1996 (using the 1978 seismic intensity map), within the next 20 years there is a 40% probability that an earthquake with intensity of XI on the MSK scale (I-XII) will strike near one of the capital cities of the region.[12] The map of potential seismic intensity produced by GSHAP (Figure 3) indicates that it is very high in most of Kyrgyzstan and Tajikistan, as well as significant portions of Kazakhstan, Turkmenistan, and Uzbekistan.

Secondary effects of earthquakes can be potentially quite destructive. Seismic events can directly trigger or accelerate other hazards, including landslides, rockslides, mudflows, soil liquefaction, and formation of glacial lakes and outburst floods. Outside of urban areas these are responsible for greater damage that seismic event themselves. For example, the Khait earthquake of 1949 in Tajikistan caused a rockslide that buried the district center under 70 meters or rock and consequently blocked the river. The accumulated water eroded the dam, which eventually triggered a catastrophic mudflow. Owing to excessive irrigation water use and saturation of the water table in the Hissar region, an earthquake in 1989 activated a landslide and mudflow that killed 274 people.[13]

Exposure is heightened when the concentration of population within various zones of seismic intensity is considered. As shown in Figure 1 below, in most countries the overwhelming majority of population lives within areas of high or very high seismic hazard (Kyrgyzstan 99.9%, Tajikistan 88.3%, and Uzbekistan 80.4%), while on others a significant portion is within a moderate to very high hazard area (Turkmenistan 97% and Kazakhstan 43.6%). All of the capital cities lie within the high to very

[9] A.M. Babaev, A.R. Ishchuk, and S. Kh. Negmatullaev, 2005, *Seismic Conditions on the Territory of Tajikistan*.

[10] Cabinet of Ministers of Turkmenistan, Department for the Turkmenistan State Commission for Emergency Situations, 1994, *National Report: Work and Research in Turkmenistan in Connection with the International Decade for Natural Disaster Reduction 1990-2000*.

[11] Nadira Mavlyanov, Rashid Inagamov, Hirojillo Rakhmatullaev, and Nigora Tolipova, 2004 "Seismic Code of Uzbekistan," *13th World Conference on Earthquake Engineering, Paper No. 1611*.

[12] GeoHazards International, 1996, *Lessons for Central Asia from Armenia and Sakhalin*, p. 5.

[13] Babaev, Ishchuk, and Negmatullaev, 2005, *Seismic Conditions on the Territory of Tajikistan*, pp. 48-49.

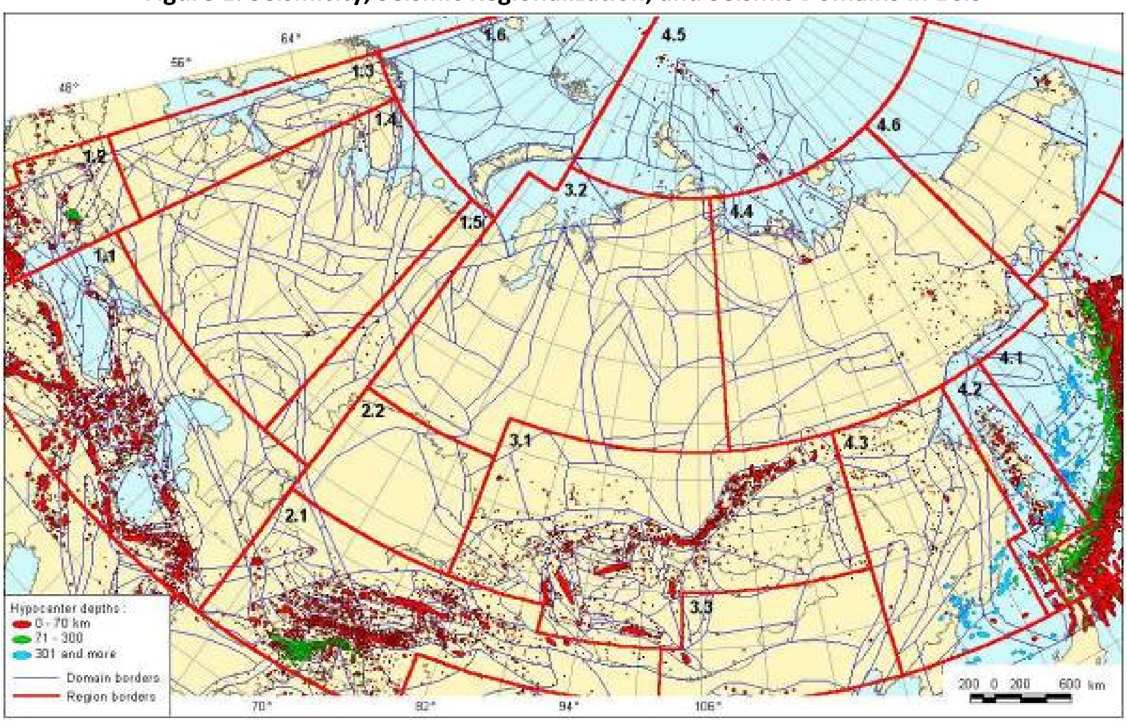
high hazard area. The most hazard-prone areas contain not only population centers, but also an inordinate amount of these countries' economic activity, particularly industrial output, services, and trade, as well as the national government of all countries except Kazakhstan.[14] Among rural areas, the densely populated Ferghana Valley (containing portions of Kyrgyzstan, Tajikistan, and Uzbekistan) is of particular concern, as it is also prone to mudslides and glacial lake outburst floods.

Table 1: Percentage of Area and Population of Central Asia in Seismic Hazard Categories

Country	Percentage Area In Each Category				Percentage Population In Each Category			
	Low	Moderate	High	Very High	Low	Moderate	High	Very High
Kazakhstan	86.3	8.7	1.8	3.3	56.4	14.2	8.8	20.5
Kyrgyzstan	-	0.5	6.6	92.9	-	0.1	3.2	96.7
Tajikistan	-	3.3	32.0	64.8	-	11.8	63.2	25.1
Turkmenistan	22.3	50.6	26.1	0.9	3.0	59.2	37.3	0.5
Uzbekistan	29.7	35.4	20.3	14.6	0.5	19.2	31.1	49.3

Source: UN ISDR, 2009, *Central Asia and Caucasus Disaster Risk Management Initiative (CAC DRMI): Risk Assessment for Central Asia and the Caucasus, Desk Review*, p. 72.

Figure 1: Seismicity, Seismic Regionalization, and Seismic Domains in ECIS

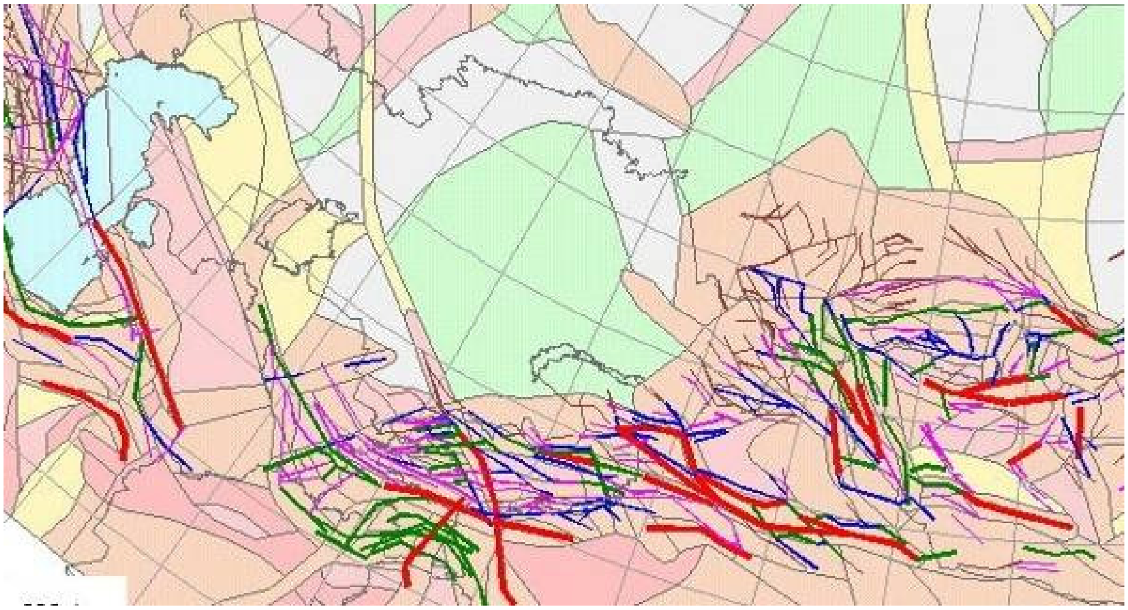


Source: V. Ulomov and Working Group of GSHAP Region 7, 1998, "Seismic Hazard of Northern Eurasia," http://www.seismo2009.ethz.ch/gshap/neurasia/report.html.

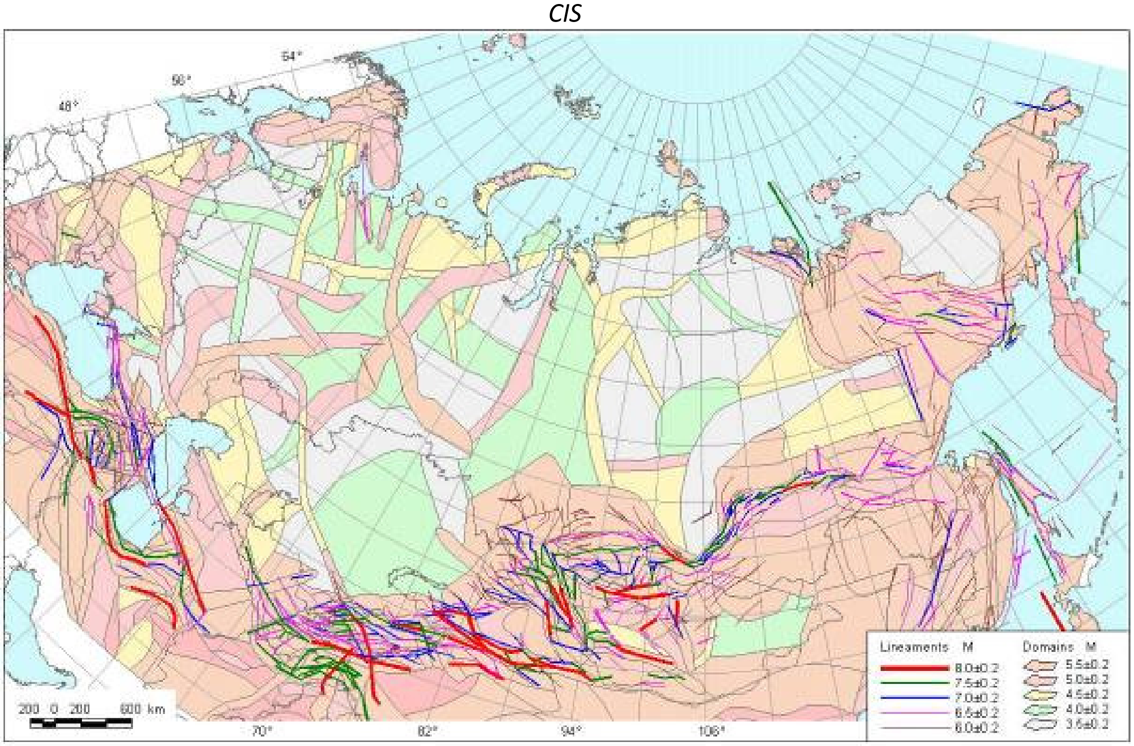
[14] For example, the Kazakhstan hazard area contains six million people, 27 cities, including the commercial center of Almaty (pop. 1.3 million), 400 smaller settlements, and more than 40% of the nation's industrial capacity. The city of Tashkent accounts for around 21% of Uzbekistan's GDP.

Figure 2: Seismic Sources Zones in the Central Asia and CIS

Central Asia



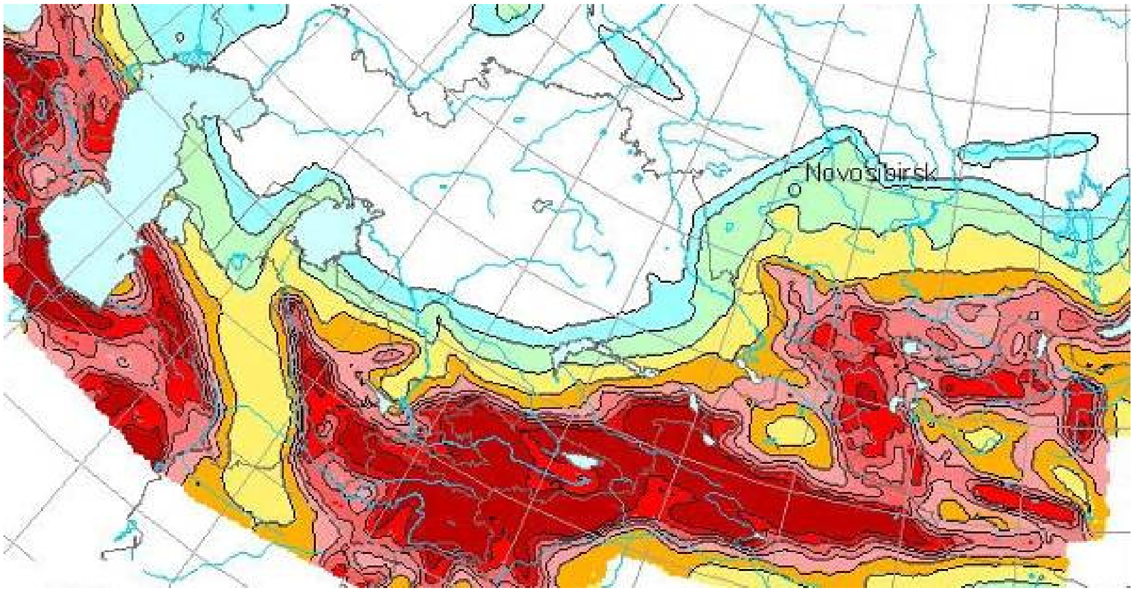
CIS



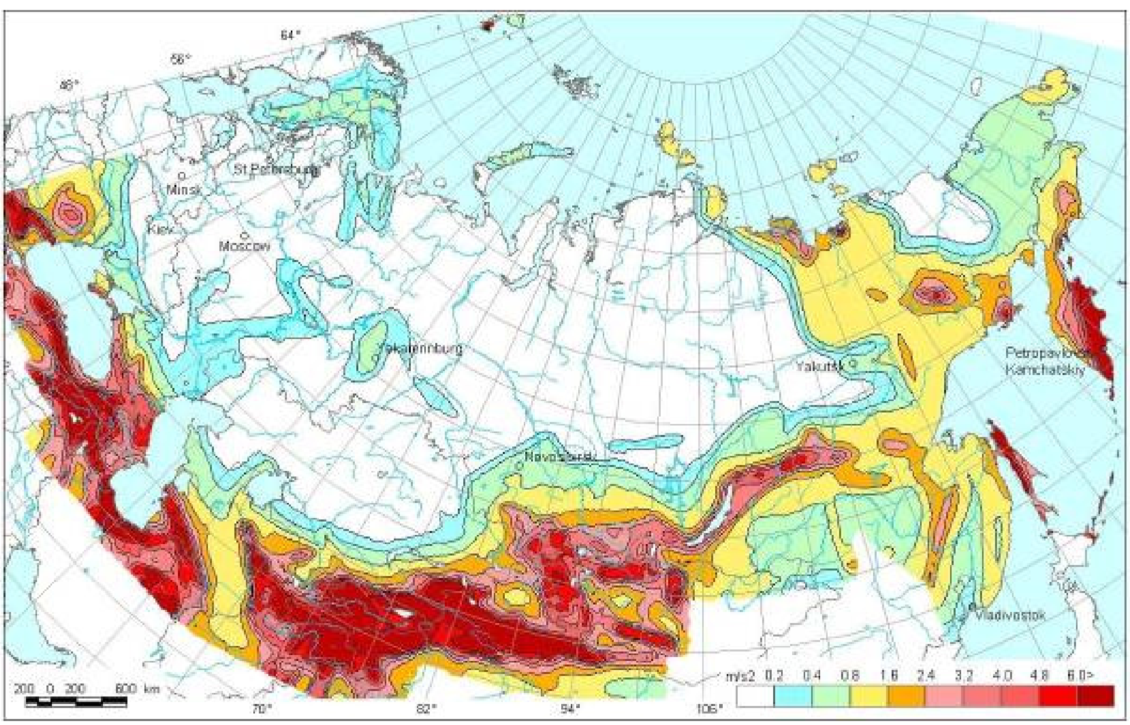
Source: V. Ulomov and Working Group of GSHAP Region 7, 1998, “Seismic Hazard of Northern Eurasia,” http://www.seismo2009.ethz.ch/gshap/neurasia/report.html.

Figure 3: Seismic Hazard in Central Asia and ECIS
(Peak Ground Acceleration; 10% probability of exceedance in 50-year period)

Central Asia



CIS



Source: V. Ulomov and Working Group of GSHAP Region 7, 1998, "Seismic Hazard of Northern Eurasia," http://www.seismo2009.ethz.ch/gshap/neurasia/report.html.

Seismic hazard monitoring and analysis has improved, but much remains to be done. Monitoring networks have not deteriorated to the same degree as those for hydrology (as described below), and there have been some upgrades to digital equipment. Improving hazard analysis remains a work in progress. The last coordinated seismic hazard map created for the region during the Soviet period was completed in 1978. This map underestimated seismic hazard, as the underlying analysis did not account for soft soil conditions, as became clear when subsequent earthquakes were larger than predicted. A new map was created in 1997, owing to the efforts of the Global Seismic Hazard Assessment Program (GSHAP), which brought together scientists from Kazakhstan, Kyrgyzstan, Russia, Tajikistan, and Uzbekistan. Nevertheless, a number of a number of areas require further attention, in particular improving identification of earthquake location, analysis of the crust and upper mantle structure, seismic attenuation models, and analysis of source physics. It is hoped that the ongoing Central Asia Seismic Risk Initiative can successfully address these issues.[15]

Landslides

Landslides are common in the mountainous areas of Central Asia. In this region, they are triggered by increasing steepness of slopes (owing to geological processes), seismic events, and meteorological and hydrological anomalies, as well as a variety of anthropogenic processes. Most landslides occur in foothill and mountain areas around 1000 to 2400 meters above sea level on slopes 19 degrees or steeper (depending upon soil type). They can be hundreds of meters in width and as thick as 20 meters. Slides often remain compact after falling, with an area anywhere between four and four hundred hectares.

Tajikistan contains around 50,000 landslide sites, of which 1,200 threaten settlements or facilities. Kyrgyzstan has at least 5,000 landslides, of which 3,500 at various levels of activity are located in the southern (Ferghana Valley) portion of the country. Significant portions of these countries lie in the moderate to high hazard categories shown in the map below (Figure 4). Almaty province in Kazakhstan, Tashkent, Samarkand, Surkhandarya, and Kashkadarya Provinces of Uzbekistan, and Ahal Province of Turkmenistan are also exposed to landslides, albeit not to the same degree.[16]

Landslides in the Ferghana Valley have greater transboundary implications than those in other areas. Here and elsewhere, landslides can trigger other transboundary hazards, such as glacial lake outburst floods and release of toxic substances in river basins (particularly in the Mayli Suu area of the Ferghana Valley, as analyzed below).

The number of landslides has grown in the past few decades, due to ongoing geodynamic movements, rising water tables, and increase in torrential rainfall, deforestation, and mining and excavation. Heightened groundwater infiltration from irrigation also contributes to landslide

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[15] GeoHazards International, 1996, *Lessons for Central Asia from Armenia and Sakhalin*; V. Ulomov and Working Group of GSHAP Region 7, 1998, "Seismic Hazard of Northern Eurasia;" Central Asia Seismic Risk Initiative, accessed 2011, http://casri.org/site/index.php?page=overview.

[16] Global Facility for Disaster Reduction and Recovery, 2009, *Disaster Risk Management Notes for Priority Countries 2009-2015, Europe and Asia*, pp. 48-49; Komitet po cherzvychainym situatsiami i grazhdanskoi oboroni pri Pravitel'stve Respubliki Tadzhikistana, 2007, *Cherzvychaynye situatsii prirodnogo kharaktera, vozmozhnye na territorii Republike Tadzhikistana in ikh posledstviia*, pp. 19-21; World Bank, 2006, *Natural Disaster Hotspots: Case Studies, Disaster Risk Management Series No. 6*.

formation. All those circumstances break the slope stability in mountain and foothill zones. Haphazard and unplanned settlement has increased exposure to them.

Hyrdometeorological anomalies play an important role in the beginning of landslide formation. On the basis of long tern data, scientists in Uzbekistan have show a strong correlation between landslide activation and four- to five-year cycles of wet and dry years. Absolute values of seasonal and annual precipitation, snow and glacial melt (with subsequent rapid groundwater recharge), and intense precipitation play a key role in mobilizing landslides. According to the available projections of climate change in the region, landslides will become more widespread, owing to the increasing prevalence of extreme rainfall events and more rapid melting of glaciers.[17] However, available analyses do not suffice to precisely locate these hazards.

Landslide monitoring and research has declined since the fall of the USSR in 1991. Even in countries such as Kazakhstan with greater resources to devote to hazard analysis, landslide surveys remain underfunded and adequate observation posts are lacking. Thus, the available hazard analysis of landslides in Central Asia is outdated and in need of increased support.[18] The need is particularly acute, given the increased anthropogenic pressures and likely impact of climate change.

Figure 4: Landslide Hazard Map of Central Asia and the Caucasus

Source: UN ISDR, 2009, *Central Asia and Caucasus Disaster Risk Management Initiative (CAC DRMI): Risk Assessment for Central Asia and the Caucasus, Desk Review*

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[17] R.A. Niyazov, 2002, “Climate Influence on the Initial Formation of Landslide Processes in Uzbekistan,” pp. 255-258 in Jan Rybar, Josef Stemberk, and Peter Wagner, eds. *Landslides: proceedings of the First European Conference on Landslides*; State Agency for Hydrometeorology of Tajikistan, 2009, *The Second National Communication of the Republic of Tajikistan under the United Nations Framework Convention on Climate Change;* State Agency on Environment Protection and Forestry under the Government of the Kyrgyz Republic, 2009, *The Second National Communication of the Kyrgyz Republic to the UN Framework Convention on Climate Change*, p. 144.

[18] For example, see: Kazakhstan Ministry of Emergencies, and Kazakhstan Red Crescent Society, 2005, *Local Risk-Management in Earthquake Zones of Kazakhstan (LRM#00038518), Result 1 Report*, p. 29.

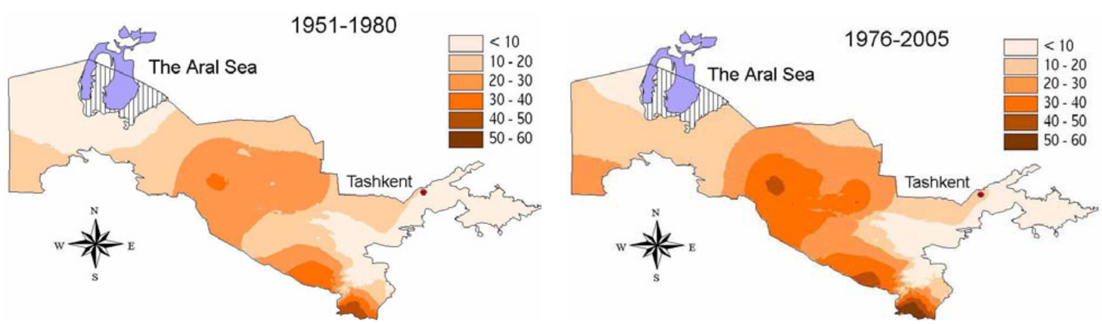
Meteorological Hazards

Meteorological hazards in Central Asia area primarily include floods of various types, drought, hail, strong winds, and temperature extremes. They occur with greater frequency than geophysical hazards, and at all scales, from small river basins (in the case of floods) to major river basins and large portions of the regions (in the instance of severe floods and droughts). Only meteorological hazards with regional impacts are covered below.

Climate Variability and Change

Exposure to meteorological hazards in Central Asia must be assessed against a backdrop of rising climate variability and change. First and foremost, the region's climate became noticeably warmer. In all countries, average annual temperature rose by 0.10^{o} to 0.31^{o} C every ten years.[19] This is much higher than the global trend (0.06^{o} C). The greatest increase was for the winter period (0.26^{o} to 0.44^{o} C per decade) in Kazakhstan, Kyrgyzstan, and Tajikistan, while in Turkmenistan and Uzbekistan the most significant changes were observed in the summer and autumn months. The frequency of extremely hot days (40^{o} C or above) has risen (as shown for Uzbekistan in Figure 5), while recurrence of low temperatures has diminished.

Figure 5: Number of Days in Uzbekistan with Temperatures over 38^{o} C, 1951-80 and 1976-2005

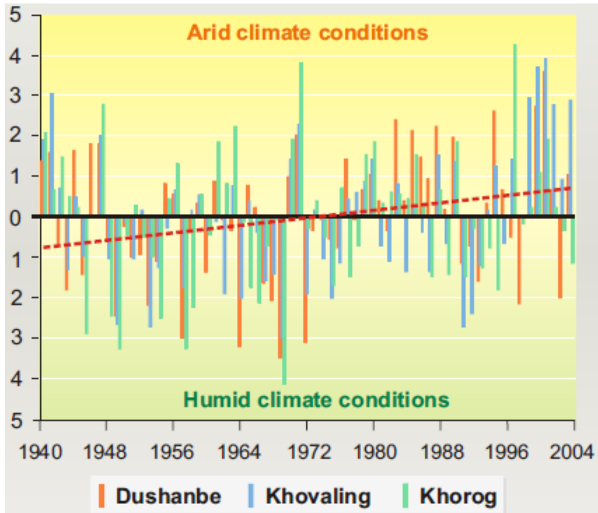


Source: Hydrometeorological Service under the Cabinet of Ministers of the Republic of Uzbekistan, 2009, *Second National Communication*, p. 68.

There is no clear trend in precipitation during the twentieth century, and there are significant variations among locales within countries. Typically, average annual precipitation has followed a cyclical pattern, with a series of "wet" years followed by "dry" years. Overall, owing to rising temperatures, aridity has increased, as shown in Figure 6 for various stations Tajikistan. Aridity has risen most sharply in the area surrounding the Aral Sea, owing to its desiccation.

[19] The time frame analyzed is 1936 to 2005 for Kazakhstan, 1930 to 2000 for Kyrgyzstan, 1940 to 2005 for Tajikistan, 1931-1995 for Turkmenistan, and 1878-2008 for Uzbekistan. See: Hydrometeorological Service under the Cabinet of Ministers of the Republic of Uzbekistan, 2009, *Second National Communication of the Republic of Uzbekistan under the United Nations Framework Convention on Climate Change;* Ministry of Environment Protection, 2009, *Kazakhstan's Second National Communication to the Conference of the Parties to the United Nations Framework Convention on Climate Change*; State Agency for Hydrometeorology of Tajikistan, 2009, *The Second National Communication*; State Agency on Environment Protection and Forestry under the Government of the Kyrgyz Republic, 2009, *The Second National Communication*.

Figure 6: Aridity Index for Tajikistan, 1940-2004



Source: State Agency for Hydrometeorology of Tajikistan, 2009, *The Second National Communication*, p. 35

The variability of precipitation, both among years and seasons, has increased. Intense rainfall events (15-20 mm or more per 24 hours) have become more frequent and irregular in countries for which data is available (Kazakhstan, Tajikistan, and Uzbekistan). This is particularly of true of mountain areas.

Climate change is projected to accelerate in Central Asia, owing to continued global warming. Projections for temperature, precipitation, and river runoff are presented in Table 2. Although the methods utilized by hydrometeorological services differ from country to country, there is general agreement that temperatures are expected to rise by 2030 by around one to two degrees Centigrade. Estimates of precipitation are often lacking. The available estimates indicate a correlation between rising temperature and heightened average annual precipitation. Where seasonal trends have been analyzed, a decline in precipitation is expected during the summer growing season. Individual precipitation events area projected to become more intense. Owing to the melting of glaciers, runoff is expected to remain stable through 2030, followed by a decline of 5-15% by 2030 (mainly in the Amu Darya River basin).

Table 2: Increase in Temperature (°C) or Percentage of Precipitation and River Runoff in Main River Basins Relative to the Base Period (1961-90)

Basin / Country	**Temperature 2030**	**Temperature 2050**	**Precipitation 2030**	**Precipitation 2050**	**Runoff 2030**	**Runoff 2050**
Amu Darya						
Tajikistan	0.2-0.4 °C	1.8-2.9 °C	n.a	95-126%	n.a	90-93%
Uzbekistan	1.1-1.2 °C	1.9-2.3 °C	114-116%	116-117%	~100%	85-90%
Turkmenistan	n.a.	n.a. (4.8-6.1 °C by 2100)	n.a.	n.a. (44-100% by 2100)	n.a.	n.a. (108-111% by 2100)
Zerafshan						
Tajikistan	0.2-0.4 °C	1.8-2.9 °C	n.a	95-126%	n.a	90-93%
Uzbekistan	1.1-1.2 °C	1.9-2.3 °C	114-115%	116-118%	98%	84%
Syr Darya						
Kyrgyzstan	~1.5 °C	~2.3 °C	n.a.	n.a. (98-102% by 2100)	~100%	~95%
Uzbekistan	1.1-1.2 °C	2.2-2.3 °C	115-117%	115-118%	~100%	95-98%
Kazakhstan	1.4 °C	2.7 °C	102%	104%	n.a.	n.a.

Source: First and Second National Communications to United National Framework Convention on Climate Change.[20]

Floods and Mudflows

River Flooding

Central Asian countries must manage a significant river flood hazard. River floods occur mainly in the spring and summer on the main rivers and their tributaries. Snow- and rain-fed rivers tend to flood in the spring and much more quickly those fed by snow and glacial melt, which flood in late spring and summer (as shown for Tajikistan in Figure A1 in Annex 1). Landslides during flood periods contribute to backwater through blocking channels, which when broken can sudden release significant surges.

River flooding occurs most frequently in the mountain areas of Central Asia. Areas of particular concern in Kyrgyzstan and Tajikistan are as follows:

- The largest floods in Kyrgyzstan usually affect the broad alluvial plain of the Chu River, where the cities of Bishkek and Tokmak are located. Other high-risk areas include the middle reaches of the Naryn River, the Talas River valley and the eastern and northern lowlands

[20] Uzbekistan, Kyrgyzstan, and Kazakhstan utilized the MAGICC/SCIENGEN program recommended by IPCC. For water resources, specialists of these countries selected the A2 ("middle-high" emissions) and B2 ("middle-low" emissions) families of scenarios as most likely to occur. The A2 scenario is presented above.

Tajikistan's Second National Communication notes the unsuitability of global circulation models for the local climatic dynamics created by its largely mountainous terrain. The Second National Communication does not provide specific projection. Therefore, figures from the First National Communication are utilized for temperature, precipitation, and runoff in 2050).

Turkmenistan has produced only one National Communication to UNFCCC, which provides projections to 2100. These are utilized for the table.

near Lake Issyk-Kul (including the city of Karakol). Altogether 182 towns and villages are at risk from river floods.[21]

- In Tajikistan, floods occur most frequently in the Zerafshan, Pyanj, and Vakhsh River basins (an average of over 70 events per year in this country).[22] On smaller rivers such as the Yakhsu, flows during flood periods can exceed the monthly average by a factor of five or more, while on larger rivers such as the Pyanj this figure is generally two or less.[23]

Mountain areas in downstream areas are also threatened. For example, the Terghap and Tedjen Rivers of Turkmenistan crested at three times their normal level during 1991-93 and inundated adjacent villages in the floodplain.[24]

River flooding in Central Asia has become more prevalent in the last 20-30 years in Central Asia. This is apparent from hydrographs of the largest river basins in the region, the Amu Darya and Syr Darya, which are presented in Figure 7. Availability of runoff in the rivers of Central Asia typically follows a cycle of high-water and low-water years in 15-20 year intervals. In the largest river basins of Central Asia, the Amu Darya and Syr Darya, hydrological extremes occur every 5-7 years. Although the overall amount of water resources has remained fairly stable, the annual (and seasonal) hydrological variability in these river basins has become more pronounced (as show in the hydrographs for these rivers, which are presented in Figure 4 below). When compared to the forty years preceding, in 1991-2007 high-water years became more frequent by a factor of 1.2-1.4 and extremely high-water years by 2.0-2.5.[25]

Transboundary river systems in Central Asia are highly regulated by a system of large reservoirs (of up to 19 km^3 in volume). Thus, flooding on most large rivers is as much a result of poor operations and maintenance as hydrological variability. Particularly threatened are the upper reaches of the Amu Darya River. Owing to the fact that among the Amu Darya's tributaries only the Vakhsh River is regulated, flooding frequently occurs between the headwaters of the Amu Darya in Tajikistan and the Tuyamuyun Reservoir in Uzbekistan.

The lack of consensus among Central Asian countries concerning operations and maintenance of transboundary waters has created severe flooding in downstream areas of the Syr Darya River. Due to greatly increased hydropower generation on the Toktogul Reservoir in autumn and winter, releases of water in these seasons increased from around 3.2 km^3 during the 1980s to an average of

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[21] "Natural Hazards in Kyrgyzstan," http://www.geomin.cz/index.php?menu=21&jazyk=en.

[22] Komitet po cherzvychainym situatsiami i grazhdanskoi oboroni pri Pravitel'stve Respubliki Tadzhikistana, 2007, *Cherzvychaynye situatsii prirodnogo kharaktera, vozmozhnye na territorii Republike Tadzhikistana in ikh posledstviia*, p. 28.

[23] Asian Development Bank, May 2007, *Republic of Tajikistan: Khatlon Province Flood Management Project. Technical Assistance Consultant's Report.*

[24] Cabinet of Ministers of Turkmenistan, Department for the Turkmenistan State Commission for Emergency Situations, 1994, *National Report*.

[25] UNECE, 2007, *Our Waters: Joining Hands across Borders - First Assessment of Transboundary Rivers, Lakes and Groundwaters*; V.A. Dukhovny, A.G. Sorokin, G.V. Stulina, 2008, *Should We Think about Adaptation to Climate Change in Central Asia?* Here low water is defined as 75% probablility of exceedance of the average, high water as 25% and extremely high water as 10%.

around 7.4 km^3 in the 1990s to km^3 in the 2000s. This exceeds the capacity of the river channel and infrastructure in downstream sections, resulting in the flooding of the Arnasay Depression (around 180,000 ha in Jizzakh and Navoi provinces of Uzbekistan) and the city of Kzyl Orda in Kazakhstan. Flooding in Kzyl Orda is also caused rainfall and snow melt on the steppe. Ice jams formed along course of the Syr Darya further exacerbate the situation. Meanwhile the water cannot be delivered to the Aral Sea. [26]

Higher temperatures owing to climate change will increase the duration of floods and shift the peak flow periods. Current projections are as follows:

- For rivers supplied by glacier and snow melt: increased duration by 30-50 days, with peak periods occurring 15-25 days earlier;
- For rivers supplied by snow and glacier melt: by 15-20 days, with peak periods occurring seven to 10 days earlier;
- For river fed by snowmelt and rainfall: by 8-10 days, with peak periods occurring 25-30 days.

Although there is a high degree of uncertainty in available outputs of climate and hydrological models linked to them, all analyses indicate that runoff and river levels during floods will be higher than at present.[27] Unfortunately, available analyses do not suffice to indicate which river basins will be most affected, and when.

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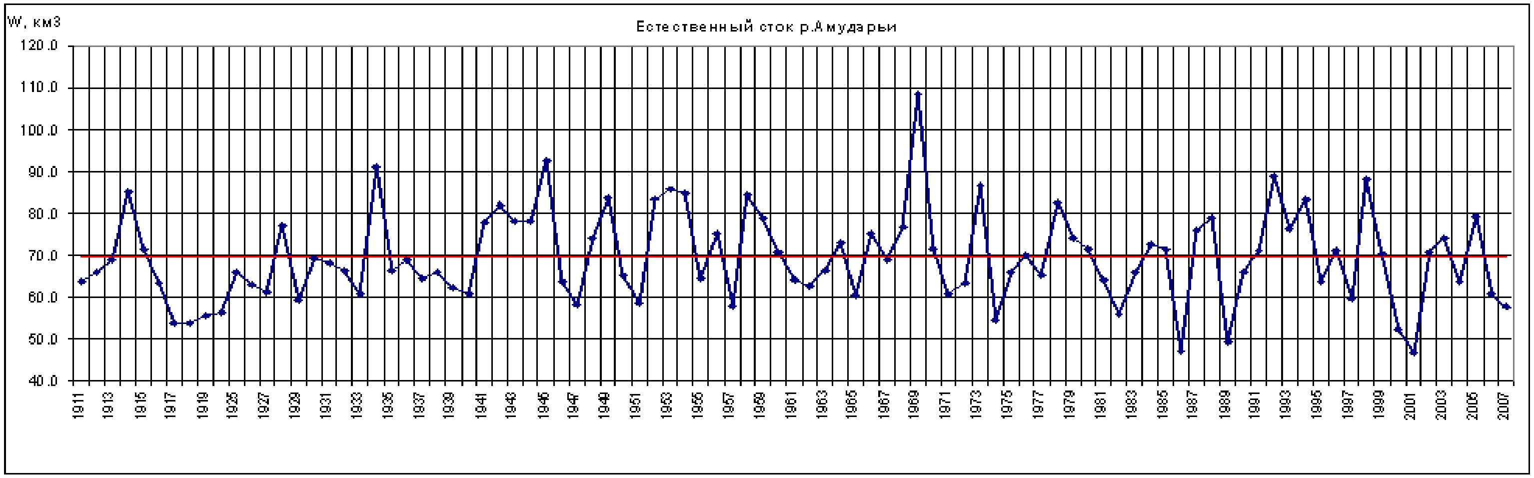
[26] World Bank, May 2001, *Republic of Kazakhstan Syr Darya Control and Northern Aral Sea Phase-1 Project, Project Appraisal Document, Report No. 22190-KZ;* V.A. Dukhovny, A.G. Sorokin, G.V. Stulina, 2009, *Should We Think about Adaptation to Climate Change in Central Asia?*
By the summer of 2003, the total area of the lake system formed in this way was 3,491 km2. The 180,000 ha included paddocks and pastures, sheep-folds and insemination stations, wells and mineshafts, roads, electric power lines, gas pipelines and other installations. The average annual damage caused by this flooding in Uzbekistan is estimated at $700 million. See: UNDP Uzbekistan, 2007: *Water: Critical Resource for Uzbekistan's Future*, p. 49

[27] Executive Board of the International Fund for Saving the Aral Sea, Regional Center of Hydrogeology, 2009, *Impact of Climate Change to Water Resources in Central Asia (Consolidated Report)*.

Figure 7: Hydrographs of Amu Darya and Syr Darya Rivers (km^3)



Source: V.A. Dukhovny, A.G. Sorokin, G.V. Stulina, 2009, *Should We Think about Adaptation to Climate Change in Central Asia?*

Flash Foods and Mudflows

Flash floods and mudflows are more common and widespread than more slowly forming river floods. Dozens occur throughout piedmont, foothill, and mountains areas of Central Asia. Within specific areas they tend to occur as often as every three years, although usually much less frequently than this. They are usually triggered by intense rainfall events and/or glacial lake outburst floods and tend to occur in steeply sloping valleys in mountainous areas where there is available loose sediment, gravel, and other debris to be mobilized. Most mountain areas have a high density of steep alpine streams, which deliver runoff and sediment rapidly to the valleys below. These events are most common in springtime (April to May), but they also occur with significant destructive potential in the summer.

The number of mudflows has increased in the last century, according to available records. The rate of frequency is strongly linked with cycles of wet and dry years (as shown for Uzbekistan in Figure A3). Owing to rising intensity of rainfall events, flash floods and mudflows have become increasingly problematic.

The areas in which flash floods and mudflows originate most frequently in Central Asia are listed below (by country):

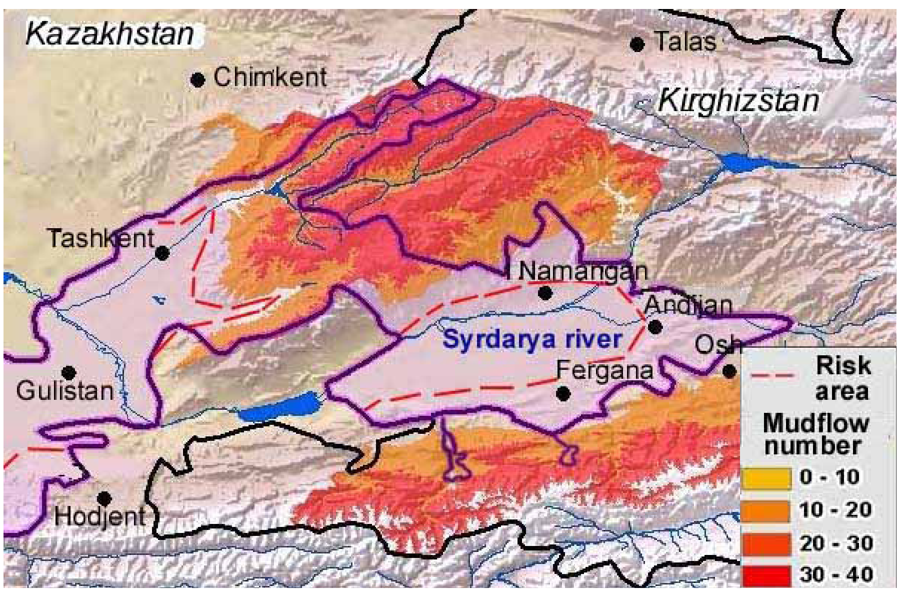
- Kazakhstan: Mudflows threaten around 13% of the country's area (the southeastern portion), containing over 26% of its population (including the entire city of Almaty, with a population of 1.2 million). During the last 150 years around 800 mudflows have been registered.[28]
- Kyrgyzstan: most of the country is exposed (with 1,153 settlements affected), most heavily in the southern and northern slopes of the Ferghana Valley, slopes of the Chu and Talas Valleys, middle and southern portion of Issiq Qol Province (see Figure A4). Around 850 flash flood and mudflows events were registered between 1990 and 2008 and another 92 in the first nine months of 2009.[29]
- Tajikistan: Hisssar and Karategin Valleys (around 50% of occurrences, affecting 466 settlements), Asht and Isfara areas of the Ferghana Valley, and Zerafshan Valley (where there are around 71 flash floods and mudslides per year). Figure A5 presents a mudflow hazard map of the country.[30]

[28] UNDP, Kazakhstan Ministry of Emergencies, and Kazakhstan Red Crescent Society, 2005, *Local Risk-Management in Earthquake Zones of Kazakhstan (LRM#00038518), Result 1 Report*, pp. 27-28.
[29] ISDR Sub-Regional Office for Central Asia and the Caucasus, 2010, *In-Depth Review of Disaster Risk Reduction in the Kyrgyz Republic*, p. 29.
[30] Komitet po cherzvychainym situatsiami i grazhdanskoi oboroni pri Pravitel'stve Respubliki Tadzhikistana, 2007, *Cherzvychaynye situatsii prirodnogo kharaktera, vozmozhnye na territorii Respublike Tadzhikistana in ikh posledstviia*, p. 28.

- Turkmenistan: The eastern and central sections of the Kopet Dagh and Kugitangau Mountains contain around 180 channels where mudflows occur. Catastrophic mudflows were registered here in 1963, 1968, 1972, 1981, and 1986.[31]
- Uzbekistan: On an annual basis there are around 22 flash floods and mudflows per year, formed mostly on the slopes of the Chirchik and Ahangaran River valleys, and in Surkhandarya. The high risk areas occupy around 12% of the country and contain around 16% of its population (see Figure A5).[32]

Mudflow hazard acquires a transboundary nature in the heavily populated Ferghana Valley. Here floods originating in mountain river areas of Kyrgyzstan and Tajikistan threaten foothill and lowland areas of Uzbekistan (as shown in Figure 8 below). There is a considerable population exposed, as the exposed area contains the cities of Ferghana, Osh, and Andijan, as well as rural areas in the southeast and northeast portions of the valley where population density is often 400 persons/km^2 or more.

Figure 8: Mudflow Number per Century and Mudflow Risk areas in the Uzbekistan Portions of the Ferghana Valley and Chirchik-Ahangaran Basin



Source: Hydrometeorological Service under the Cabinet of Ministers of the Republic of Uzbekistan, 2009, *Second National Communication*, p. 100.

Climate change will significantly increase flash flood and mudflow hazard in most areas of Central Asia, owing to the following factors:

[31] Cabinet of Ministers of Turkmenistan, Department for the Turkmenistan State Commission for Emergency Situations, 1994, *National Report*, p. 5.

[32] Centre of Hydrometeorological Service under the Cabinet of Ministers of the Republic of Uzbekistan, 2009, *Second National Communication of the Republic of Uzbekistan under the United Nations Framework Convention on Climate Change*, pp. 99-100.

- More intense rainfall events;
- Warming in winter resulting in rainfall occurring instead of snow, which will extend the seasons in which flash floods and mudflows occur;
- High rates of evaporation leading to increased soil aridity, with the result that the upper layer of soil will wash away more readily;
- Reduction of forest and other vegetative cover in some areas owing to greater aridity, which will accelerate erosion processes.
- Increased volume of moraines and groundwater in high mountain areas, owing to accelerated melting of glaciers

The hydrometeorological services of Kazakhstan, Kyrgyzstan, and Uzbekistan have attempted to model the occurrence of flash floods and mudflows owing to climate change. The results are as follows:

- A two-degree increase in temperature by 2050 will make mudflows triggered by rainfall 25% more frequent (as shown in Figure A6). The Northern Ten Shan region will be particularly hard hit. The Medeu mudflow dam (protecting the city of Almaty) may be entirely filled by 2030-40. If forests in foothill and piedmont areas disappear as projected, practically all rainfall will become mudflows.[33]
- Under the most likely climate scenarios (A2 and B2), the likelihood of mudslides, floods and outbursts of highland lakes will increase several times in the southern (Ferghana Valley) portion of Kyrgyzstan. By contrast their occurrence will be significantly reduced in the central and northern regions of the country.[34]
- Due to more intense rainfall events, the likelihood of flash floods and mudflows by 2030-50 is expected to rise by 19-24%, with another 12-13% by 2080. By 2030, the maximum discharge of mudflows owing to rainfall will increase by 30-35%.[35]

Glacial Lake Outburst Floods

There are thousands of lakes in the mountains of Central Asia. As a result of glacier recession, the adjacent moraines have become conducive to the formation of lakes. A network of glacial drainage channels is rapidly formed within the moraines and glacial melt water, if runoff is impeded, fills cavities to form glacial lakes. Movement of buried glacial ice can also cause cracks and fissures at the surface of moraines, which are filled in summer by glacial melt to form lakes. Other processes, such as thermokarst, soil fluction, and deposition of drift, contribute to the expansion of these lakes. These processes have accelerated since the monitoring of these lakes first began in the mid-1960s.

[33] Ministry of Environment Protection, 2009, *Kazakhstan's Second National Communication*, pp. 116-18. Increased mudflows would also accelerate the siltation of the Kapchagay water reservoir, as well as alter the aquatic ecosystems of the Ili river estuary and the lake Balhash.

[34] State Agency on Environment Protection and Forestry under the Government of the Kyrgyz Republic, 2009, *The Second National Communication*, pp. 145-46.

[35] Hydrometeorological Service under the Cabinet of Ministers of the Republic of Uzbekistan, 2009, *Second National Communication*, pp. 12, 70, 78.

Glacial lakes created in this fashion are dammed by moraine and other debris, which commonly are unstable and highly susceptible to erosion. Moreover, they are susceptible to landslides and debris flows into the lakes, which (together with other factors) can cause breeches in the dam. (As noted above, landslides and debris flows are often induced by intense rainfall or seismic events.) If the dam is breeched, glacial lake outburst flood (GLOF) is triggered, often resulting in large scale mudflows and consequent damage to settlements and infrastructure in the areas below. A recent outburst flood in 2008, from a lake that developed in the space of a few months near the Zindan glacier in Kyrgyzstan, released 459,000 m^3 of water and massive amount of debris upon the areas below.

Most sources of glacial lake outbursts are located in Kyrgyzstan, Tajikistan, and Kazakhstan. They are briefly characterized below:

- About 70 GLOFs occurred in Kyrgyzstan between 1952 until 2007, resulting in several hundred deaths, as well as tremendous damage to settlements, roads, power lines, pipe lines, agricultural lands and pastures. A significant portion of these breaches are owing to the Mertsbaher Lake, as its dam is breeched almost every year. Based on the catalogue of lakes from the year 1999, a total of 287 lakes in the country are susceptible to failure. Of these, 63 could fail during the next few years. Each year, there are twenty lakes that are in acute danger of failure. Approximately 300 settlements are exposed to potential GLOFs.[36]
- The southwestern Pamir mountain range in Tajikistan contains around 335 lakes with GLOF potential. According to the most recent investigation, out of 428 glacial lakes in the Pamir mountain range, six were determined to be extremely hazardous and 16 hazardous. The most highly exposed areas are as follows: Rivakkul/Rivakdara and Varshezdara in the Gunt Valley; Zardivkul/Sezhdara and Durumkul/Durumdara in the upper Shahdara; Khidorjevdara, Sharfdara and Dashtdara (where in 2002 a GLOF event occurred) in the lower Shahdara. Although this hazard is growing, the recurrence rate of large GLOF events is low.[37]
- In Kazakhstan, GLOF hazards are greatest in the Ili-Alatau mountain range, where the number of glacial lakes grew from 41 in the 1980s to 61 in the 1990s. GLOFs from these threaten the former capital city of Almaty and its environs.[38]

Owing to the large volume of water released by GLOFs, they present a significant transboundary hazard. According to the Uzbekistan hydromet, the country is threatened with 271 potential GLOFs, most of

[36] "Natural Hazards in Kyrgyzstan," (accessed 2011), http://www.geomin.cz/index.php?menu=21&jazyk=en. Sergey Erohin and Michal Cerny, 2009, "Monitoring of Outbursting Lakes of Kyrgyzstan," http://www.geomin.cz/conference/menu/Erohin_Cerny_paper_eng.pdf; State Agency on Environment Protection and Forestry under the Government of the Kyrgyz Republic, 2009, *The Second National Communication*, pp. 144-45.

[37] Jean F. Schneider and Martin Mergili, 2011, "A Procedure for Analyzing Lake Outburst Hazard and its Application to the South-Western Pamir, Tajikistan," *Geophysical Research Abstracts*, Vol. 13, EGU2011-8251.

[38] Ministry of Environment Protection, 2009, *Kazakhstan's Second National Communication*, pp. 94-95, 116-18.

which are located outside its borders (as shown in Figure A7).[39] For example in 1998 a GLOF from the Alaudyn glacier lake in the Alay range discharged over 50,000 m3 from a thermokarst lake on a debris-covered dead ice zone and killed over 100 residents from Uzbekistan's Shahimardan village. The largest transboundary GLOF hazard, Lake Sarez, was created by a seismic-triggered landslide in 1911. The resulting Usoy dam (670 m in height) holds in around 16 km3 of water (maximum volume). If the dam were to collapse the wave would engulf a significant area of southern Tajikistan, as well as lower lying areas of the Amu Darya River basin.[40]

Most experts predict that climate change will dramatically reduce glacier areas and volumes (e.g. projected reduction of glacier area in Kyrgyzstan from 64-95% by 2100), which would significantly increase the number and volume of glacial lakes and dramatically heighten the GLOF hazard. Although there is a general consensus concerning the likelihood of this, the modeling and predicting of GLOFs (and also the outburst of landslide-dammed lakes) remains a challenge, owing to lack of data concerning glaciers and the process of GLOF formation, (bathymetry of the lakes, subsurface water, properties of dams, type of dam breach, understanding of process chains and interactions) and lack of suitable modeling tools.[41]

Drought

Drought is classified variously in different parts of the world. It is most common in the West (based largely upon the work of the National Drought Mitigation Center in the US) to classify droughts as "meteorological" (high air temperature and low precipitation and humidity), "hydrological" (sever water scarcity, which usually follows prolonged meteorological drought), and "agricultural" (conditions leading to production losses in this sector). In ECIS, two classifications are have been traditionally utilized: "atmospheric" (roughly corresponding to meteorological drought) and "soil" (deficit in soil moisture, which is a precondition for agricultural drought related to crop losses). The ensuing analysis covers meteorological and hydrological drought.

The arid continental climate of Central Asia frequent exposes large areas of Central Asia to meteorological drought conditions. Drought strikes in one or more areas almost every year (at varying scales). Severe and widespread meteorological drought (50% or greater precipitation deficit) occurs in foothill areas around three times per century, while moderate drought (a 20-25% deficit in seasonal precipitation) happens in three to four-year intervals. In the desert and semi-desert lowland areas, drought is more frequent (50% or greater precipitation deficit every 10 years; 20% deficit every five

[39] Hydrometeorological Service under the Cabinet of Ministers of the Republic of Uzbekistan, 2009, *Second National Communication*, pp. 100-01.

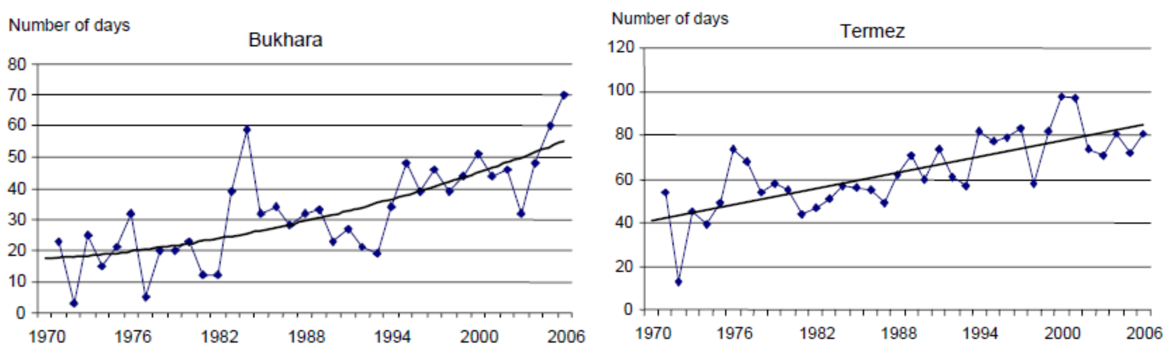
[40] There are conflicting views of the stability of the Usoy dam. See: A.R. Ishchuk, 2006, "Usoy Dam: Problem of Security," *Italian Journal of Engineering Geology and Environment, Special Issue 1*; H. Raetzo, 2006, "Hazard Assessment of Lake Sarz Rockslides and Usoy Dam (Tadjikistan), *Italian Journal of Engineering Geology and Environment, Special Issue 1*.

[41] Martin Mergili, Demian Schneider, Norina Andres, Raphael Worni, Fabian Gruber, and Jean F. Schneider, 2010, "Challenges in Understanding, Modelling, and Mitigating Lake Outburst Flood Hazard: Experiences from Central Asia," *Geophysical Research Abstracts*, Vol. 12, EGU2010-4946.

years).[42] The most severe meteorological drought in recent memory hit Central Asia in 2000-01, when a precipitation deficit of 30-70% was observed in most countries, coupled with above-average temperatures. The areas affected by widespread meteorological drought cut across national boundaries, i.e. it is a regional hazard.

Meteorological drought has become more frequent in Central Asia. Aridity has risen (as shown for Tajikistan in Figure6), together with the number of days with meteorological drought conditions (as shown below for Uzbekistan in Figure 9). Above-average temperatures and below-normal precipitation have become increasingly prevalent in the summer and fall seasons. The change is most noticeable near the Aral Sea, due to its desiccation.

Figure 9: Occurrence of Meteorological Drought in Bukhara and Termez, Uzbekistan, 1970-2006



Source: Hydrometeorological Service under the Cabinet of Ministers of the Republic of Uzbekistan, 2009, *Second National Communication*, p. 104.

The occurrence of hydrological drought in Central Asia depends upon the availability of water in the upper catchments of the river basins and, owing to the high degree of flow regulation, the management of reservoirs and other water infrastructure. Hydrological drought has become more prevalent in the last few decades. As shown in Figure 7 above, during the period 1991-2007 the Amu Darya River basin (which accounts for the majority of water resources in the region) has experienced more frequent hydrological drought (by a factor of 1.3), while for the Syr Darya River basin the rate of occurrence has remained largely constant. One the Amu Darya the "depth" of extremely low-water years (i.e. deviation of the mean flow in low-water years from the average) increased 1.5 times.[43]

[42] World Bank, 2006 *Drought Management and Mitigation Assessment for Central Asia and the Caucasus: Regional and Country Profiles and Strategies*.

[43] UNECE, 2007, *Our Waters: Joining Hands across Borders - First Assessment of Transboundary Rivers, Lakes and Groundwaters*; V.A. Dukhovny, A.G. Sorokin, G.V. Stulina, 2008, *Should We Think about Adaptation to Climate Change in Central Asia?* Here low water is defined as 75% probablility of exceedance of the average and extremely low water as 90%.

Hydrological drought is heavily influenced by water management at the regional, national, and sub-national levels. For example, in 2000 hydrometeorological services predicted flows for the Amu Darya and Syr Darya Rivers 30% and 17% above the actual level, respectively.[44] This inaccuracy skewed O&M planning (both regionally and nationally). To make matters worse, during this and the next year, upstream provinces on the Uzbekistan section of the Amu Darya River (Surkhandarya and Kashkadarya) often exceeded water withdrawal limits, which left downstream provinces (Khorezm and Karakalpakistan) with a fraction of the required amounts of water (as shown in Table 3 below).[45] Lack of agreement among countries concerning the timing of releases from upstream reservoirs for hydropower also makes downstream areas highly susceptible to hydrological drought in summer. [46]

Table 3: Water Distribution on the Amu Darya River During Various Seasons of 2000 and 2001

	2000 Vegetative	2001 Vegetative	2002 Non-Vegetative
Limit (km^3)	38.1	31.4	12.0
Actual (km^3)	26.3	24.3	11.3
Percent of Limit Received			
Total	69.0	77.3	94.1
Upstream	84.2	97.3	90.9
Midstream	82.8	91.8	116.2
Downstream	48.4	49.5	53.6
Karakalpakistan	30.7	27.5	16.2

Source: ICWC, cited in *Tsentral'naia Aziia: problemy opustynivaniia*, No. 40, June 2002

Climate change is expected to heighten exposure to meteorological and hydrological drought, particularly during summer months. Although average annual precipitation is expected to increase (as shown in Table 2), its variability will rise, meaning monger periods between precipitation events, particularly during the summer growing season. Although models of average annual runoff indicate little or no change by 2030, runoff during the critical spring and summer ("vegetative") period will decline. Figure 10 indicates that all of the main river basins of Central Asia will be affected by 2030, with the situation becoming even worse by 2050. Small watercourses (such as those of the Chirchik/Ahangaran and Chaktal region) will experience the greatest reduction and variability in runoff. Among major river basins, the Amu Darya is predicted to be hit the hardest.[47] (It must be emphasized

[44] The hydromet predicted flow of 86% and 93% for the Amu Darya and Syr Draya, respectively. UNECE, February 2002, *Diagnosticheskii doklad dlia podgotovki pegional'noi strategii patsional'nogo i effektivnogo ispol'zovaniia vodnykh resursov tsentral'noi Azii*, pp. 19-21.

[45] World Bank, 2006 *Drought Management and Mitigation Assessment for Central Asia and the Caucasus: Regional and Country Profiles and Strategies*.

[46] Upstream countries release the water in winter for hydropower egenration, while downstream countries want the water in summer for irrigation.

[47] Source: Hydrometeorological Service under the Cabinet of Ministers of the Republic of Uzbekistan, 2009,

that, as for floods, the present state of modeling and analysis does not permit precision in predicting the impacts.

Gaps in Data and Analysis

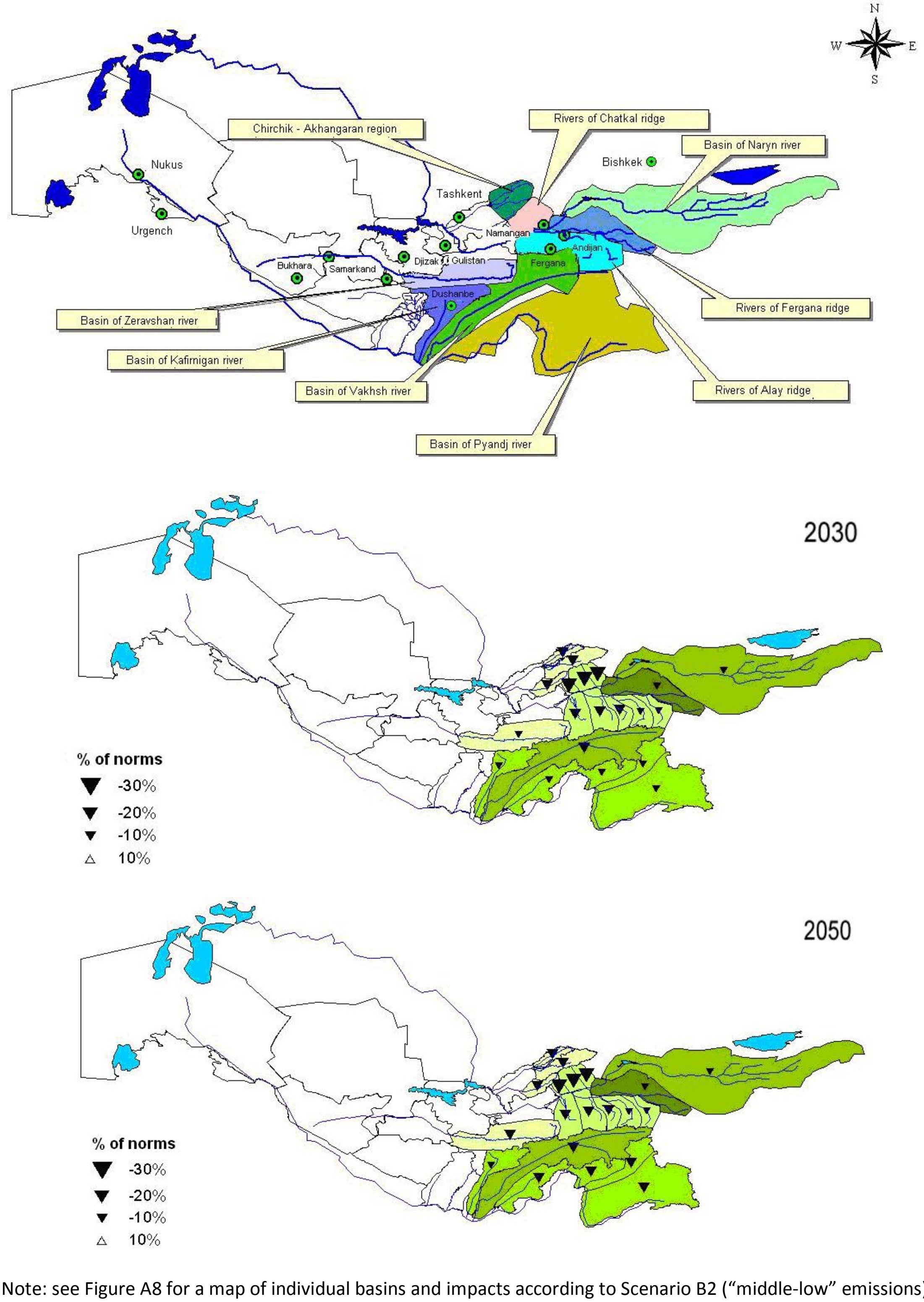
It must be emphasized that there is significant degree of uncertainty in analysis for meteorological hazards, owing to several factors. First and foremost, the availability and accuracy of data has diminished, as the monitoring network has deteriorated. As presented in Table A1 andA2), during the 1990s the number of meteorological stations in the Aral Sea basin declined by 20%, that of hydrological posts by almost 30%. Snowpack surveys and glacier monitoring in the mountain areas were virtually halted. Although attempts are ongoing to refurbish these networks, and remote sensing can compensate in some measure, significant gaps in data and analysis remain.

Second, since the collapse of the USSR the exchange of data among countries has fallen off. Despite an agreement signed in 1998, data sharing remains constrained in part by lack of an adequate infrastructure for this and in part due to political circumstances. It is hopes that the recent signing by hydromets in the region of a protocol on data sharing will remedy the situation.

Another challenge for the assessment of meteorological hazards is climate change, which is altering exposure. Although modeling of the impacts of global warming upon temperature and precipitation patterns has improved in the last decade, the spatial and temporal resolution of most models is still too broad. Most relevant for hazard analysis, a high degree of uncertainty remains concerning the impact of temperature increases upon the hydrological cycle and, consequently, precipitation patterns and runoff.

Second National Communication, p. 87. Uzbekistan's modeling outputs are utilized here, as the hydromet for this country regularly performs the regional prognosis for itself and other countries and possesses the highest capacity for regional hydrological modeling.

Figure 10: Impact of Climate Change on Runoff in Vegetative Period for Main Basins of Central Asia under the Climate Change Scenario A2 ("middle-high" emissions)



Note: see Figure A8 for a map of individual basins and impacts according to Scenario B2 ("middle-low" emissions).
Source: Hydrometeorological Service under the Cabinet of Ministers of the Republic of Uzbekistan, 2009, *Second National Communication*, p. 76.

Compound Hazards

Aside from the more regular interactions among hazards noted above, periodically hazards can combine to produce unexpected impacts. Most prominent among these are the combination of hydrological drought and extreme cold and technogenic hazards triggered by floods and landslides.

Hydrological Drought and Extreme Cold

In 2007-08 hydrological drought and extreme cold in Tajikistan and Kyrgyzstan combined with vulnerabilities in energy transmission, rising food prices, macroeconomic uncertainties, and lower access to remittances to create an unexpected "compound crisis," in which food security and heating became problematic for a significant number of households and critical public facilities in these countries. Damages amounted to around $250 million in Tajikistan alone. Hydrological drought was caused by abnormally low precipitation (25-75% of the norm for various seasons), as well as excessive drawdown of reservoirs in the preceding years for the purpose of hydropower generation. As noted above, these conditions are characteristic of regular hydrological droughts in the region. However, temperatures were highly anomalous, being the coldest in several decades.[48]

As noted above, hydrological drought is expected to become more acute by 2050, owing to global warming. By contrast, temperatures are expected to increase more during the winter months than any other season. Although the possibility of another anomalous year such as 2007-08 cannot be excluded, over the long term this will reduce probability of such a combination of hazards occurring.[49]

Technogenic Hazards

Technogenic hazards in Central Asia are mainly connected with the unsafe storage of toxic substances in earthquake, landslide, and flood hazard zones. Kyrgyzstan, particularly the portion of the country that lies in the Ferghana Valley, is most affected. As of 1999 there were 36 uranium tailings sites and 25 uranium mining dump sites on the territory of Kyrgyzstan. Most of the sites are associated with the Mayli-Suu uranium processing facility in Jalalabad Province, which contains around 2.3 million tons of uranium tailings. The site is located near several active landslides, within the impact area of the Talas-Ferghana fault, and in close proximity to three transboundary rivers (Naryn, Mayli Suu, Sumsar) in the upper portion of the Syr Darya River basin. Although the largest tailings deposits have been covered with gravel and clay, these could be mobilized by a significant landslide, earthquake, or mudflow, which could potentially contaminate the Syr Darya River.[50]

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[48] UNDP, 2009, *Central Asia Regional Risk Assessment: Responding to Water, Energy, and Food Insecurity.*

[49] It also should be noted that projections for temperature changes owing to climate changes are generally more accurate and reliable than for precipitation.

[50] Other radioactive waste sites include the Kara-Balta Ore Mining Combine, Kadzhi-Say, Khaidarkan, Min Kush, Samsar River, Shekaftar, and Terek-Say

Disaster Incidence and Impacts

According to a recent analysis funded by Global Facility for Disaster Reduction and Recovery[51], in Central Asia between 1988 and 2007 floods and earthquakes are the most frequent major natural disasters, followed by landslides, avalanches, and drought (shown Table 4 below). Among Central Asia countries, natural disasters reported to global databases are most common in Tajikistan, followed by Kyrgyzstan, Kazakhstan, Uzbekistan, and Turkmenistan. It is likely that the incidence is more frequent for all countries than indicated in the table, due to reasons given below.

Table 4: Average Annual Incidence of Disaster in Central Asia (1988-2007)

Disaster Type	Kazakhstan	Kyrgyzstan	Tajikistan	Turkmenistan	Uzbekistan
Earthquake	0.20	0.20	0.70	0.05	0.05
Flood	0.20	0.10	0.95	0.05	0.05
Landslide	0.05	0.30	0.50		0.15
Ex. Temp.	0.05	0.05	0.05		0.05
Epidemic	0.15	0.10	0.25		0.05
Transportation	0.10	0.05	0.20	0.05	0.05
Miscellaneous	0.25	0.20	0.15		0.15
Industrial	0.10	0.10	0.05		0.10
TOTAL	1.1	1.1	2.85	0.15	0.65
Of which, Natural Disasters	0.5	0.65	2.2	0.1	0.3

Source: UN ISDR, 2009, *Central Asia and Caucasus Disaster Risk Management Initiative (CAC DRMI): Risk Assessment for Central Asia and the Caucasus, Desk Review.*

Impacts are significant. Among natural hazards, earthquakes caused the largest number of deaths (6,683), followed by floods (1,512) and landslides (700). Droughts affected the largest number of people (70% of the total affected population in the region), followed by floods (19%) and earthquakes (six percent). Earthquakes inflict the highest overall economic losses (an annual average of $186 million), followed by floods ($52 million), landslides ($18 million), and droughts ($6 million). It should be noted that the analysis underestimates drought losses during this period by almost a factor of three.[52] Among individual events, severe earthquakes and droughts cause the greatest economic losses.

Among the Central Asian countries, fatalities resulting from natural and technogenic disasters are highest in Tajikistan and Kyrgyzstan (as presented in Table 5 below). Average annual fatalities per million are also considerably higher in these two countries than for others. According to the, the dataset

[51] Source: UN ISDR, 2009, *Central Asia and Caucasus Disaster Risk Management Initiative (CAC DRMI):Risk Assessment for Central Asia and the Caucasus, Desk Review.*

[52] The data base lists losses at $107 million dollars, while in fact damages only to the agricultural sector resulting from the drought of 2000-01 reached almost $300 million. See: World Bank, 2006 *Drought Management and Mitigation Assessment for Central Asia and the Caucasus: Regional and Country Profiles and Strategies.*

utilized in this analysis, economic losses are in the range of $60-90 million for all countries except Kyrgyzstan (according to this analysis). The distribution among countries for economic losses is likely skewed, as it is clear that disaster incidence and fatalities are higher in Tajikistan and Kyrgyzstan than in other countries. According to a recent analysis of meteorological hazards by World Bank in these two countries average annual losses from these comprise $29.8 million and $27.3 million, respectively.[53] The Ministry of Emergency Situations of Kyrgyzstan has calculated average annual losses from natural disasters of least $35 million.

Table 5: Average Annual Fatalities and Economic Losses Resulting from Natural and Technogenic Disasters in Central Asia (1988-2007)

Country	Average Annual Fatalities	Average Annual Fatalities Per Million	Average Annual Economic Losses ($ Million)
Kazakhstan	14	0.9	63
Kyrgyzstan	22	4.2	11
Tajikistan	443	65.7	79
Turkmenistan	2	0.4	79
Uzbekistan	16	0.6	92
Central Asia	498	8.4	264

Source: UN ISDR, 2009, *Central Asia and Caucasus Disaster Risk Management Initiative (CAC DRMI): Risk Assessment for Central Asia and the Caucasus, Desk Review.*

There are several reasons why global datasets present an inaccurate picture of disaster impacts. First they are maintained at global observation level and national resolution level, which often ignores minor disasters and/or (in the case of those utilized to support insurance) focus more upon countries with (at least prospective) insurance coverage.[54] As noted above, In Central Asia, the frequency of minor flood, landslide, earthquake, and drought events is quite high, and often these are not captured. Moreover, among global databases, values for economic losses are frequently missing, and entries for the number of people affected, dead and injured are often incomplete.[55] Finally, even if primary data from national disaster management agencies were to be included, economic losses would be lower than actual, as entries for individual events frequently present losses in physical terms (e.g. number of houses and structures destroyed or damaged and area of agricultural land affected, etc.), with no corresponding economic value provided.

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[53] Supporting country studies for World Bank, 2008, *Weather and Climate Services in Europe and Central Asia: A Regional Review, World Bank Working Paper No. 151.*

[54] The EM-DAT database can be accessed at www.emdat.be. For inclusion in this database one of the following criteria must be met: 10 or more people reported killed, 100 or more people reported affected, declaration of a state of emergency, and call for international assistance.

[55] Provention Consortium, 2002, *The Quality and Accuracy of Disaster Data: A Comparative Analyses of Three Global Datasets.*

Although economic loss data concerning disaster impacts is highly generalized, data on different types of losses available in national databases, as well as the available assessments of individual disasters, permit the identification of the main sectors affected.[56] These are as described below, utilizing examples from more significant disaster events.

Earthquakes. The majority of economic losses from earthquakes such as earthquakes and landslides are structural in nature, affecting buildings (particularly houses, schools, and hospitals), and transportation and utility infrastructure (particularly roads and gas and electricity networks). Major urban areas are disproportionately affected. During the past century earthquakes in Almaty (1911), Ashgabat (1948), and Tashkent (1966) leveled significant portions of the city and resulted in tens of thousands of fatalities (an estimated 56,000 in Ashgabat) and people affected (reportedly 100,000 in Tashkent). Less obvious (and not captured in datasets), but equally significant, are indirect economic impacts, particularly lost manufacturing capacity, crippled distribution channels, diminished revenues, unemployment, and lack of spending in urban areas. Sectors concentrated in major cities of the region include services, industry, trade, and finance. The Ashgabat earthquake of 1948 put 200 industrial enterprises out of commission. Total economic damages were estimated at five to six billion dollars.[57] Earthquake-prone cities also contain the seats of government of all countries except Kazakhstan. As noted above, secondary effects of earthquakes (landslides, mudflows, GLOFs) are significant in rural mountain areas of Tajikistan and Kyrgyzstan.

Landslides. Landslides destroy the houses and infrastructure of settlements located nearby, particularly in rural areas. Economic losses from individual events in the last two decades have been as high as $150 million. Landslides cause displacement of the population. For example, In Kyrgyzstan, the number of households moved from landslide zones since 1992 has reached the amount of 7,873, i.e. 656 houses annually.[58] Additionally, landslides ruin agricultural land. Landslides in remote areas pose the threat of blocking riverbeds and flows, which can result in mudflows and GLOFs.

Floods. River and flash floods, mudflows, and GLOFs affect houses in floodplains and infrastructure, particularly that for water control or diversion (embankments, channels, culverts, bridges, etc.). In extreme cases, such as the mudflows in Dasht (2002) and Shahimardan (1998), entire villages were destroyed (as shown in Figure 11 for Dasht.) Agricultural production is affected by the inundation of fields and pasture. Drinking water supplies commonly become contaminated, and sewage systems become flooded, creating an epidemiological threat. Although some cities such as Dushanbe and Kulyab face a significant threat from floods, impacts occur mainly in rural areas.

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[56] This analysis relies largely upon data available from the Committee of Emergency Situations of Tajikistan, as well as available studies and reports of individual disaster events.

[57] Cabinet of Ministers of Turkmenistan, Department for the Turkmenistan State Commission for Emergency Situations, 1994, *National Report*, pp. 9-10.

[58] State Agency on Environment Protection and Forestry under the Government of the Kyrgyz Republic, 2009, *The Second National Communication*, p. 144.

The impact of floods upon communities is evident from a survey carried out by the Asian Development Bank concerning flooding in the Kulyab, Vose, Farkhor and Hamadoni areas (Pyanj River basin). Ninety-six percent of respondents noted floods in 2005 had seriously or moderately damaged their houses, and 54% of their land had been flooded and inundated with debris. Seventy-one percent believed that their income had fallen below average as result of the disaster. Production of grain had fallen by 70%, vegetables by 83% and grapes by 95%. Furthermore, collectively, respondents had lost 38% of cattle stock and 58% of poultry.[59]

Figure 12: The Village of Dasht, Tajikistan Before and After the Mudflow of 2002

Drought results in significant loss of livelihoods, particularly in rural areas. [60] Agriculture is most profoundly affected. Meteorological drought has a significant impact upon rainfed crops and pasture. For example, the rainfed wheat crop in Tajikistan almost entirely failed as a result of a hundred-year drought in 2000. Cereal crops failed on 112,600 ha (causing $87.4 million of damage), and pastures dried up entirely on 199,000 ha ($22.5 million of damage). Food supply became insecure enough warrant relief aid for 3,011,786 persons (58% of the rural population).

Due to hydrological drought downstream in the same year, around 200,000 farms (1,000,000 people) lost crops in Uzbekistan (an estimated $50 million in damages). The next year crop losses amounted to $80 million in the Karakalpakistan and Khorezm areas alone. Already overgrazed pastures near villages were stripped entirely of vegetation, and fodder supplies dwindled by one-half to one-third of normal levels. Because there is little employment outside of agriculture in rural areas, some families in drought-impacted areas resorted to desperate measures to obtain income in 2000-01, even dismantling their homes and selling them as construction materials.

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[59] Asian Development Bank, 2007, *TA 4811-TAJ Khatlon Flood Management Project: Final Report*, p. 4.

[60] The examples below are taken from World Bank, 2006 *Drought Management and Mitigation Assessment for Central Asia and the Caucasus: Regional and Country Profiles and Strategies.*

Severe drought also creates social displacement, as occurred during 2000-01. Outmigration increased in downstream areas with no water. In some areas, at least two to three members of each family migrated elsewhere (most commonly to Kazakhstan from Karakalpakistan) in search of a better livelihood. It was estimated that by 2001 drought had left 79,000 farm households unemployed in Karakalpakistan, and 21,000 in Khorezm.

Hydrological drought also profoundly affects drinking water supplies (which occurred in terms of both quantity and quality in 2000-01) and hydropower generation (as exemplified by the "compound crisis" of 2007-08. Tensions concerning water allocation and distribution are often heightened between upstream and downstream areas during period of severe water scarcity. Finally, drought conditions also accelerate desertification processes.

Vulnerabilities

A significant portion of disaster impacts in Central Asia could have been avoided, if not for the presence of a high degree of vulnerability to natural hazards. The analysis below covers the vulnerability of the economies of the region, structural vulnerabilities, and socioeconomic vulnerabilities.

Economic Vulnerability

The economies of Central Asia are highly vulnerable to natural disasters. The most recent calculation of this dimension of vulnerability was conducted by UN ISDR and is shown in Table 4 below.[61] The absolute amount of potential economic losses is greatest for Uzbekistan, Turkmenistan, and Kazakhstan. Tajikistan has the greatest potential losses relative to GDP.

It should be noted that the calculation of loss potential is based upon the incomplete dataset presented above for the years 1988 to 2007. If fed into the upward curve of exceedance probabilities upon which Table 6 was calculated, a more accurate dataset would produce considerably higher values, particularly for Kyrgyzstan. Such a result was obtained in a World Bank calculation of economic vulnerability (presented below in Figure 13), which estimates potential losses for Tajikistan at over 70% of GDP (with an annual exceedance probability of 0.5%), followed by Kyrgyzstan (around 20%), Kazakhstan (around five percent), and Uzbekistan (less than five percent).[62]

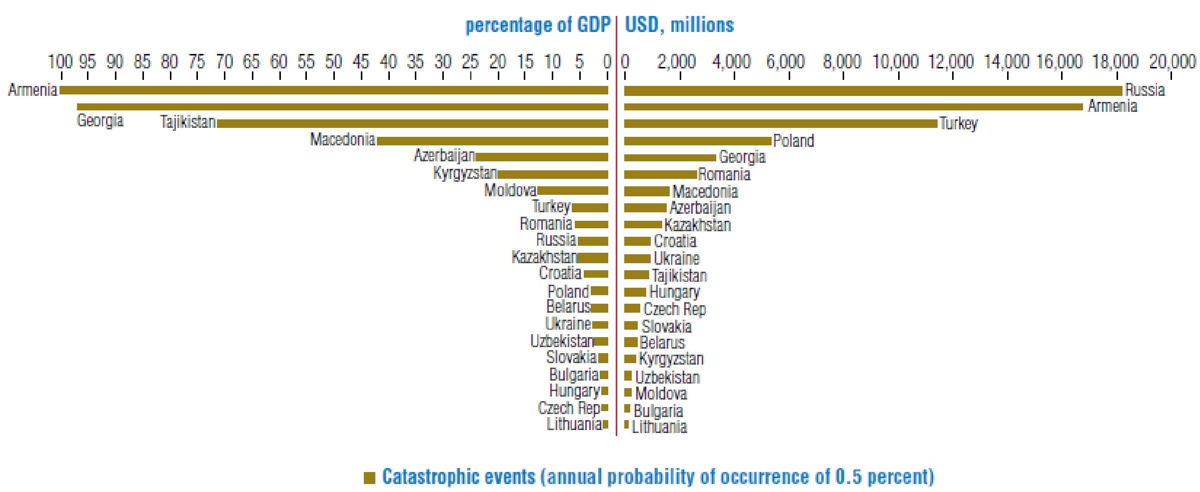
[61] UN ISDR, 2009, *Central Asia and Caucasus Disaster Risk Management Initiative (CAC DRMI): Risk Assessment for Central Asia and the Caucasus, Desk Review*.
[62] World Bank, 2004, *Preventable Losses: Saving Lives and Property through Hazard Risk Management, Working Papers Series No. 9*, p. 12.

Table 6: Economic Loss Potential Due To Disaster In Central Asia (UN ISDR calculation)

	Annual Exceedance Probability	Economic Loss (USD million)	Percentage of GDP (2007)
Kazakhstan	0.5%	1,136	1.09
	5.0%	348	0.34
	20.0%	100	0.10
Kyrgyzstan	0.5%	160	4.57
	5.0%	49	1.40
	20.0%	15	0.42
Tajikistan	0.5%	776	20.92
	5.0%	355	9.56
	20.0%	139	3.75
Turkmenistan	0.5%	1,564	12.10
	5.0%	433	3.35
	20.0%	115	0.89
Uzbekistan	0.5%	2,128	9.5
	5.0%	623	2.8
	20.0%	177	0.8

Source: UN ISDR, 2009, *Central Asia and Caucasus Disaster Risk Management Initiative (CAC DRMI): Risk Assessment for Central Asia and the Caucasus, Desk Review*.

Figure 13: Economic Loss Potential Due To Disaster In Central Asia (WB calculation)



**Note*: Armenia's all hazards damage is 708.5% of GDP

Source: World Bank, 2004, *Preventable Losses: Saving Lives and Property through Hazard Risk Management, Working Papers Series No. 9*, p. 12.

Several factors heighten the vulnerability of the economies of Central Asia to disasters. Most countries have the specialized, export-dependent economies that are vulnerable to external shocks. This attenuates financing gaps for disaster response that exist for many countries (most notably Tajikistan and Kyrgyzstan). Moreover, state planning and other controls upon economic sectors, as well as trade barriers, hamper the ability of the economy and society to manage risks in accordance with specific conditions and needs.

Economies of the region are particularly vulnerable to meteorological hazards posed by climate variability and change. A recent study by World Bank noted that weather-dependent sectors such as agriculture account for between 40% and 60% of GDP in the Central Asian republics. Agriculture, which is profoundly affected by meteorological hazards, comprises between 20% and 30% of GDP in most countries. Its importance is heightened by the fact 1) that the majority of the region's population is rural and, owing to the dearth of off-farm employment, remain highly dependent upon agricultural production for livelihoods and 2) a significant portion of industrial output is in secondary processing of agricultural products (cotton ginning, canning, etc.).

Table 7: Share of Weather-Dependent Sectors and Agriculture in GDP

Country	Share of Weather-Dependent Sectors, % of GDP	Share of Agriculture % of GDP
Kazakhstan	43	7
Kyrgyzstan	48	32
Turkmenistan	42	18
Tajikistan	61	20
Uzbekistan	n.a.	24

Source: Supporting country studies for World Bank, 2008, *Weather and Climate Services in Europe and Central Asia: A Regional Review, World Bank Working Paper No. 151.*

Structural Vulnerability

Structural vulnerabilities are primarily in housing and infrastructure. A strong earthquake would significantly damage housing. During a workshop conducted for the GeoHazards International study in 1996, local and international specialists explored potential impacts upon residential buildings. The structural type, occupancy total in major cities of the region, and average level of damage expected by seismic events of varying intensity on the MSK scale is presented in Table 8 below. If an intense earthquake (9 on the MSK scale) hit a major city in Central Asia, around half of the residential building stock would collapse or be damaged beyond repair. It should be noted that since 1996 the structural integrity of most buildings has declined, owing to depreciation of the building stock in the region. In all cities except Tashkent, around 20% of the population would sustain serious injuries and around five percent would be killed (as shown in Table 9).

Table 8: Central Asian Structural Types, Occupancy Total in Major Cities, and Expected Damage Levels in 1996

Structural Type	Occupancy		Damage Level		
	1,000 People	% Urban Population	MSK VII	MSK VIII	MSK IX
1. Unengineered structures, including small adobe and unreinforced masonry buildings	1,200	20%	Heavy damage	Partial to total collapse	Total collapse
2. Brick bearing-wall systems with wooden floors, 1-2 stores, pre-1955			Moderate to heavy damage	Partial collapse	Total collapse
3. Brick bearing-wall systems with pre-cast reinforced concrete (RC) floors, 3-5 stories, pre-1957	1,400	23%	Slight to moderate damage	Heavy damage to partial collapse	Partial collapse
4. Brick bearing-wall systems with pre-cast reinforced concrete (RC) floors, some seismic detailing, post-1957			No damage to slight damage	Moderate to heavy damage	Heavy damage to partial collapse
5. Precast RC frames with welded joints and brick infill walls, 4-9 stories	400	7%	Slight damage	Moderate to heavy damage	Heavy damage to partial collapse
6. Precast RC large-panel systems with dry or wet joints	1,800	30%	No damage to slight damage	Slight to moderate damage	Moderate damage
Other	1,300	20%	-	-	-
TOTAL	6,100	100%			

Source: GeoHazards International, 1996, *Lessons for Central Asia from Armenia and Sakhalin*, p. 6.

Table 9: Estimated Deaths and Injuries in Major Cities of Central Asia Resulting from a MSK IX Earthquake

City	Population	Serious Injuries	Deaths
Almaty	1,500	300,000	75,000
Ashgabat	500	100,000	25,000
Dushanbe	1,100	220,000	55,000
Bishkek	800	160,000	40,000
Tashkent	2,200	180,000	45,000

Source: GeoHazards International, 1996, *Lessons for Central Asia from Armenia and Sakhalin*, p. 7.

Infrastructure, particularly for diverting, distributing, and storing water, remains vulnerable. In all countries, flood embankments and other hydraulic structures constructed in the Soviet era have deteriorated significantly, as the governments have been able to afford only emergency repairs, and river channels have not been maintained. This has rendered significant areas (as well as irrigation intakes and canals, bridges, culverts, etc) more susceptible to damage by flooding.[63] Due to the scale of investment required, rehabilitation projects funded by international donors can only partially implement the necessary capital repairs.

Socioeconomic Vulnerability

Socioeconomic vulnerabilities have a variety of dimensions. Table 10 below summarizes human interventions that contribute to disaster vulnerability. The absence of systematic data makes it difficult to quantify the relative importance of various factors. The main vulnerabilities are described in brief below, using available analyses from the relevant sectors.

Persistent poverty and income disparities make communities and social groups less resilient to natural disasters. Poverty incidence remains high in Tajikistan (over 50% of the population), Kyrgyzstan (almost 40%), Uzbekistan (almost 30%), and Turkmenistan (over 20%). Rural poverty remains above the national average (including around 20% in Kazakhstan). Additionally, income disparities are high, particularly in urban areas. Poor households tend to rely heavily upon own consumption from agricultural production, which make the impact of meteorological disaster particularly acute. Inadequate and poorly targeted social safety nets, in addition to poverty, make it harder for families to recover from disasters.[64]

[63] UNECE, 2007, *Dam Safety in Central Asia: Capacity-Building and Regional Cooperation,* pp. 5-7.

[64] Various World Bank poverty assessments and living standards surveys.

Table 10: Key Socioeconomic Vulnerabilities to Natural Hazards in Central Asia

Vulnerabilities	Earthquake	Landslides	Floods	Drought
Socioeconomic status (poverty, income disparities and social status)	X	X	X	X
Poorly targeted social safety nets	X	X	X	X
Location in remote areas, especially mountains, and transportation access	X	X	X	X
Poor land use and/or land use planning	X	X	X	X
Haphazard urbanization and poor municipal planning	X	X	X	X
Inadequate operations and maintenance of infrastructure	X	X	X	X
Outdated building and safety codes and standards	X	X	X	X
Inadequate channel maintenance and bank reinforcement			X	
Destruction of slopes (mining and excavation)		X		
Off-farm employment and income diversification			X	X
Inefficient on-farm water use		X		X
Poor salinity management				X
Unsustainable agronomic practices			X	X
Low access to agricultural credit, inputs, and markets			X	X
Overgrazing		X	X	X
Desertification		X	X	X
Wind and soil erosion		X	X	X
Deforestation		X	X	X
Loss of wetlands			X	
Lack of buffers/illegal construction on riverbanks			X	
Unsafe storage of toxic substances			X	

Social status is a key determinant of vulnerability, and in this regard gender roles figure prominently. It is commonly accepted that women are more vulnerable the other social groups to disasters. However, owing to dearth of research on this issue in Central Asia, specific aspects of women's vulnerability must be deduced from general assessments of gender roles, poverty and sector studies, and global studies on gender and DRR.[65] Common areas of vulnerability are as follows:

[65] Asian Development Bank, 2006, *Republic of Tajikistan Country Gender Assessment*; Asian Development Bank, 2005, *Republic of Uzbekistan Country Gender Assessment*; UNDP, 2008, *UNDP Kazakhstan Gender Mainstreaming Strategy;* UNDP, 2008, *UNDP Kyrgyzstan Gender Mainstreaming Strategy*.

- Men are better positioned than women to anticipate disasters, as they are more likely to read information in newspapers and elsewhere, to participate in community meetings, and to have access to other information sources.
- Owing to the fact that men are more likely to migrate for labor, women are more likely to be present in communities when disaster strikes.
- Socio-cultural constraints on women's behavior towards men often contribute significantly to risk of death at the time of a disaster. For example, in Central Asia women are less likely to be able to swim, owing to cultural taboos, and thus less able to save themselves in event of a flood. The strong preference of men for women to remain at home and attend to domestic duties makes it much more likely that they will be victims of earthquakes.
- Women's reproductive functions also influence their vulnerability. Pregnant or lactating women, or those with small children, are physically less able to escape disasters, and tend to stay with their children, even if this means that they will perish.
- In terms of dealing with the psychological trauma of a disaster, men and women tend to react quite differently. Women often have to provide psychological support to others (particularly children), but they also tend to have a stronger awareness of social bonds and are able to support each other. Men, by contrast may experience strong feelings of frustration and alienation after disasters.
- Women are largely responsible for domestic duties, i.e. meeting needs for food, clean drinking water, energy supply (collecting fuel), health care, etc. During slow-onset disasters and in the aftermath of all types of disasters, when supplies become scarce and/or access is significantly curtailed, women must work even harder to meet basic household needs.
- In recovering from disasters, men often have better access to information, funds and credit, and natural and physical assets, which places women (especially female heads of households) at a disadvantage.
- Households headed by women are more likely to fall under the income poverty line, and wages of women are typically lower than for men, which reduces their resilience to disasters.

Poor land use and municipal planning heightens vulnerability to all types of disasters. This is particularly evident in urban areas, which contain an increasing concentration of the population and economy. Municipal plans are outdated, with the result that housing and infrastructure are placed in hazard-prone areas. Land use planning is geared toward optimization and does not account for exposure to hazards. Uncontrolled settlement places communities and economic endeavors in the way of hazards such as earthquakes, landslides, and floods, while unregulated land use contributes to the formation of landslides and mudflows. Delivery of social services is usually not planned in a manner that accounts for disaster contingencies, which makes it susceptible to interruption during these events.

Inadequate management of infrastructure increases the vulnerability of the population. Since 1992 the availability of funds for the maintenance of infrastructure has significantly diminished, with the result that much of it has deteriorated. The result is that protection structures are less effective against floods and landslides, and dams are more susceptible to potential breaches and outburst floods. For example, in Kazakhstan around 40% of major hydraulic structures are in need of capital repairs, and the average rate of depreciation is around 60%. Some small-scale structures have been abandoned entirely.[66] Channel maintenance has fallen off in many areas, which reduces the flood carrying capacity of rivers. Municipal drainage systems are increasingly unable to remove water, which heightens urban flood risks. Irrigation systems and municipal water systems have depreciated in some countries as much as 50%. Because they cannot deliver water without significant losses, hydrological drought impacts are amplified. Decrepit agricultural drainage systems often result in land salinization, which consequently heightens water demand and vulnerability to drought.

Inefficient planning and operations of water infrastructure is a major component of flood and drought risks. Within the main transboundary river basins of the region, operations are hampered by disputes over allocations for agriculture and energy, which, as noted above, has heightened exposure to floods and hydrological drought.[67] At the national level and below, the nascent state of integration among various sectors in water resource management and weak user participation hinders the ability of water users in all sectors to effectively respond to hydrological extremes and reduces financial sustainability (thereby making even less money available for maintenance).[68]

Outdated building and safety codes and standards make structures vulnerable to natural hazards. For example, seismic building codes in the region were developed and updated in 1957, 1968, 1978, and most recently the mid-1990s. There is need to rework the codes in accordance with the most recent analysis of seismic hazards (for the region, from 1997), also taking into account the currently available materials and construction methods. Moreover, the enforcement of codes and standards is lax. Addressing this issue will require adequate funding and improved governance for inspection, as well as accountability for violators.[69]

Within rural development and agriculture, several vulnerabilities contribute to the risk posed by drought and flood hazards. First and foremost, in many countries of the region off-farm employment is lacking and/or farm production is not diverse enough to provide backup income options in the event of natural disasters. This is particularly true of the small farms that are predominant in many countries, which also do not permit adequate soil fertility maintenance through proper crop rotation and complicate water distribution. Second, the rural financial system constrains credit access and is inadequate for the introduction of financial risk management instruments. Input and market access is also limited, often owing to state control. Moreover, on-farm water management, salinity management, and agronomic practices are inappropriate for drought management in many areas, and the collapse of agricultural

[66] Asian Development Bank, 2007, *TA 4811-TAJ Khatlon Flood Management Project*; Asian Development Bank, 2003, *Project Completion Report on the Flood Emergency Rehabilitation Project*.
[67] See, for example: Asian Development Bank, 2002, *The Study on Water and Energy Nexus in Central Asia.*
[68] World Bank, 2005, *Drought Management and Mitigation Assessment for Central Asia and the Caucasus*.
[69] GeoHazards International, 1996, *Lessons for Central Asia from Armenia and Sakhalin: Strategies for Urban Earthquake Risk Management for the Central Asian Republics*; UNDP, 2004, *Lessons from the Lugovskoy Earthquake of 23 May 2003 for Kazakhstan*; UNDP, 2005, *Local Risk Management in Earthquake Zones of Kazakhstan*.

advisory services (formerly provided by collective farms) hampers dissemination of good practices. Unsustainable agricultural practices on rainfed cropland in mountain areas also make it more likely that erosion processes will contribute to mudflows. Finally, overgrazing near villages and wells is widespread, which induces wind erosion and desertification processes in rangeland, thereby rendering it more vulnerable to drought.[70]

Environmental degradation also heightens drought vulnerability in several ways. Desertification, wind and soil erosion, and deforestation reduce the resilience of ecosystems and agricultural land to meteorological drought, floods, and shallow landslides. Loss of wetlands and vegetative buffers make it difficult and in many instances impossible for riverine areas to absorb floods. Finally, unsafe storage of toxic substances in flood hazard zones makes it possible for their mobilization into downstream areas (the most egregious example being the Mayli Suu uranium tailings described above).

For the foregoing analysis it is clear that significant loss of life and economic damages could be avoided through reducing vulnerability. Economic, structural, and socioeconomic vulnerabilities are the product of flawed development that does not adequately integrate disaster risk reduction. For some actions and target locales, the general direction of action and target sectors required to achieve this are obvious. However, the lack of in-depth studies of vulnerability in Central Asia makes it difficult to more precisely target interventions and geographic locales within specific sectors.

Several actions are needed to improve targeting for disaster mitigation and prevention, beginning with the collection and management of disaster data. The following are the main issues to be resolved in this regard:

- Harmonization of disaster definitions and classification, as well as entry criteria, and thresholds for inclusion.
- Cross-checking multiple sources of information and establishing procedures for validation.
- Strengthening primary data collection procedures, i.e. post-disaster disaster needs assessment.
- Improving accessibility of data and developing analytical capabilities.

In the realm of vulnerability analysis, there is a need to build capacity in DRR agencies through provision of tools and methodologies. The chief weakness in this regard is economic analysis. Owing to the multitude of sectors and variety of technical expertise required, coordination and collaboration among agencies in vulnerability analysis is also critical for the task.

Conclusion

Despite the limited amount of data and analysis available concerning the vulnerability components of disaster risk in Central Asia, a number of general conclusions can be drawn concerning it. These are provided below for the major types of hazards.

[70] World Bank, 2006 *Drought Management and Mitigation Assessment for Central Asia and the Caucasus: Regional and Country Profiles and Strategies*.

Earthquakes are the predominant risk for urban areas of Central Asia. All of the major cities in Central Asia are exposed to significant seismic hazards. These contain growing populations and the seats of government of all countries except Kazakhstan. Housing, services, finance, industry, and trade sectors are most affected by earthquakes, and these are concentrated in urban centers. Due to the presence of significant vulnerabilities (such as deterioration of housing infrastructure, haphazard urbanization and land use planning, and outdated and poorly enforced building codes and standards), all major cities in the region must be considered at high risk of a major earthquake event.

Secondary effects of seismic events (triggering landslides, mudflows, GLOFs, and mobilization of toxic substances) are significant and mostly affect rural mountain and foothill areas. Most of them (particularly GLOFs) have profound transboundary implications. However, additional research is required to properly understand the interactions between geophysical and other hazards.

In contrast to earthquakes, landslides mainly affect housing and infrastructure in rural areas. They have significant transboundary implications for the potential release of toxic substances in Ferghana Valley, as well as in the formation and triggering of GLOFs through Central Asia. Due to the role played by hydrometerological factors in the mobilization of landslides, they will probably become more frequent and intense owing to climate change. Uncontrolled land and water use reduces slope stability and contributes to their formation.

Floods are the most frequently occurring disaster in Central Asia, and climate change is expected to significantly amplify exposure to river floods, mudflows, and GLOFs. Owing to deteriorated protection infrastructure and vulnerabilities in several sectors, floods cause considerable damage to housing, infrastructure, and agriculture, mainly in the countryside. Although it is clear that river flood hazard has risen in the last few decades, a significant component of it at the transboundary level is the lack of consensus among Central Asian countries concerning the distribution of the resources of the Syr Darya and Amu Darya Rivers. Mudflows affect all countries and have transboundary implications primarily in the Ferghana Valley. Due to the accelerating melting of glaciers in the region, outburst floods present an increasing threat.

Meteorological and hydrological drought occurs most frequently at the local level, but at five to ten year intervals encompasses wide areas including several countries and river basins. Climate change will continue to increase the frequency and severity of both meteorological and hydrological drought in the region. The management of water infrastructure heavily influences the occurrence of hydrological extremes such as drought and floods. More than for any other hazard, drought impacts are felt in rural areas and are concentrated in, but not limited to, the agriculture sector. Similarly, socioeconomic vulnerabilities to drought are primarily in the rural development, agriculture, and water management sectors. Greater numbers of people are affected and impacts upon food security are more profound than for any other type of disaster. Environmental impacts are also considerable.

Because all disaster risks have transboundary dimensions there is need for regional cooperation in addressing them. First and foremost is restoring regional cooperation in hazard monitoring and analysis, as well as early warning. Some vulnerabilities, particularly in water management, are aggravated by the lack of cooperation at the regional level. Reconciling differences in the water and energy sectors has proven especially difficult. However, conducting in-depth risk assessment and engaging gin evidenced-based advocacy concerning the common good in addressing hydrological extremes may be an entry point to bring the various parties together in agreement. In the realm of preparedness and response, there is considerable scope for cross-border coordination of actions, if impediments to the movement of goods and personnel can be overcome.

Much work remains to improve risk assessment in the region. For hazards, there is a need for strengthened monitoring, particularly with regard to meteorological hazards, and bringing together experts to reconcile differences in the analysis of transboundary hazards. This will require significant investment to replace deteriorated (or missing) equipment. To enable a more precise targeting of interventions for reducing vulnerability, there is a need to improve datasets on disaster impacts and conduct specific analyses for various dimensions of vulnerability, particularly the economic and socioeconomic. Given the impacts expected from climate change, there is an urgent need to heighten the precision of projections of exposure to flood and drought hazards, as well as conduct in-depth analysis of present and potential vulnerabilities in agriculture and water management.