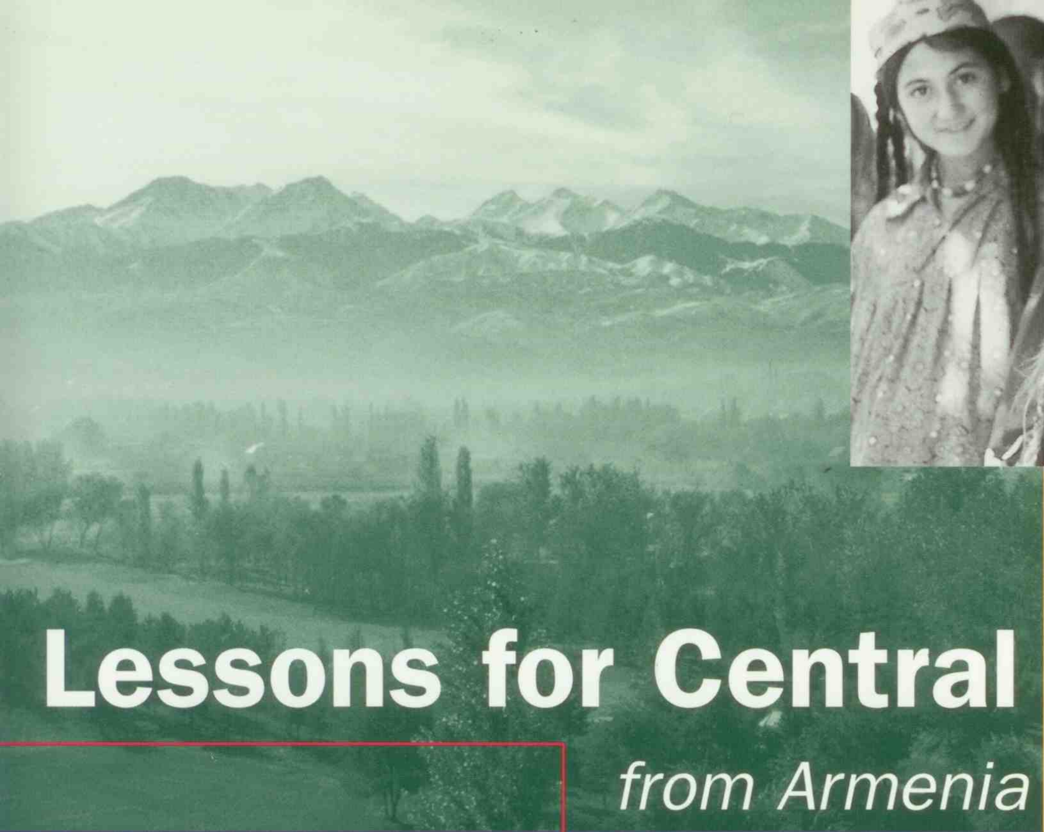
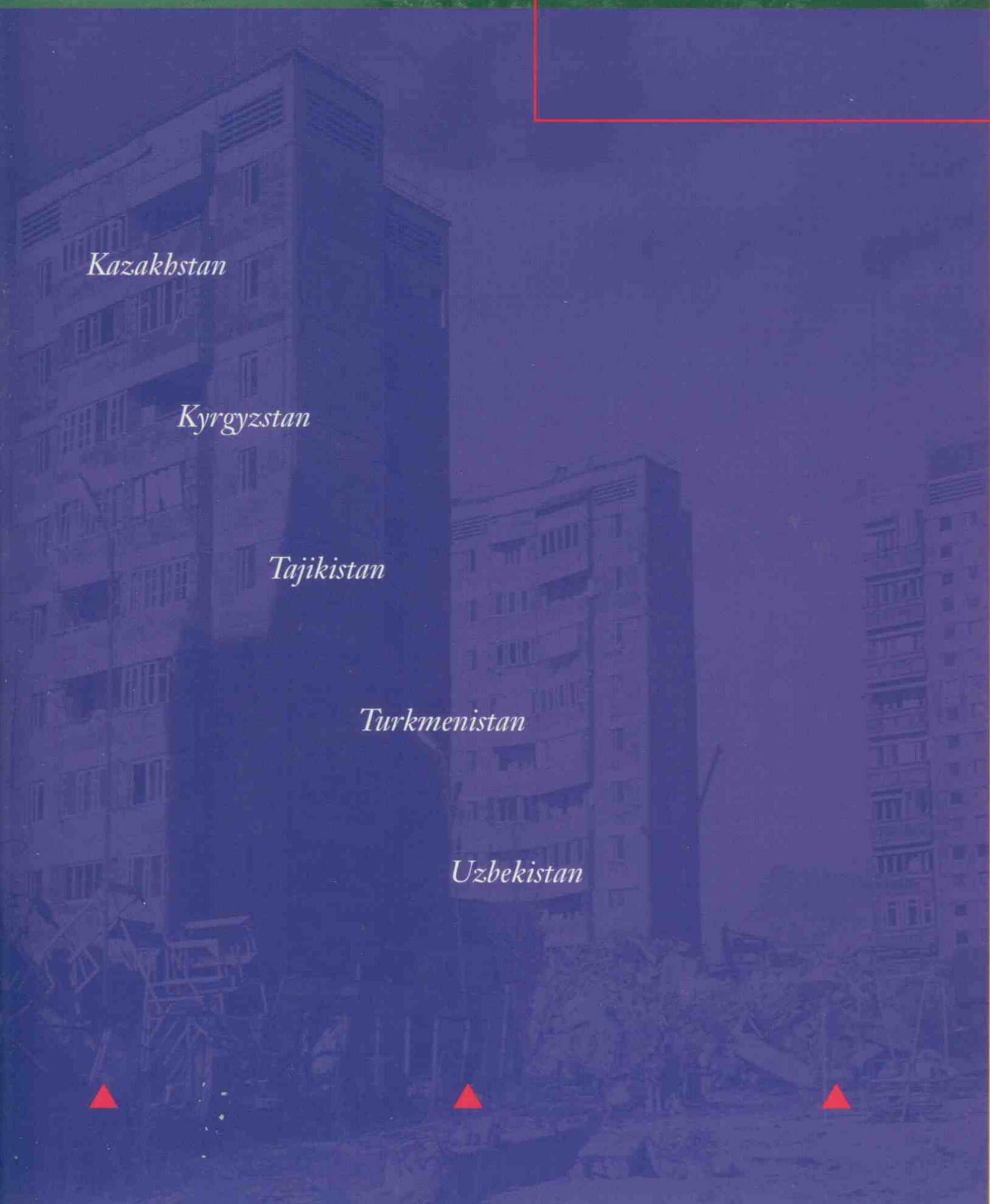


Lessons for Central Asia

from Armenia and Sakhalin



Strategies for Urban Earthquake Risk Management for the Central Asian Republics

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Other supporting organizations (in alphabetical order)

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International Association of Seismology and Physics of the Earth's Interior
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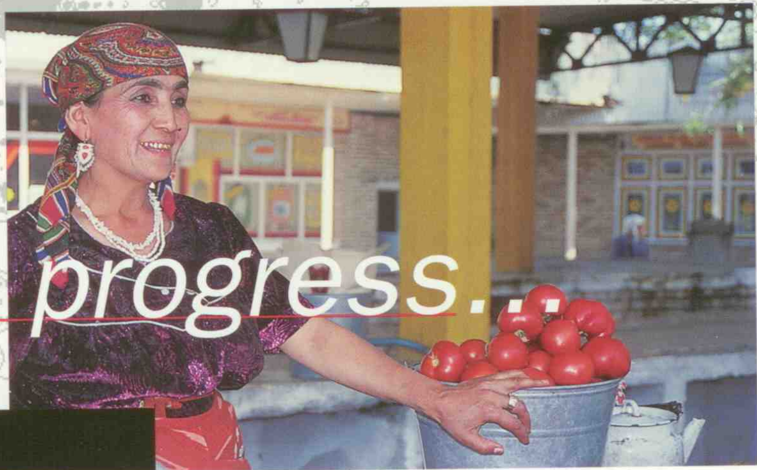
US National Center for Earthquake Engineering
World Seismic Safety Initiative

Central Asia's *rapid progress...*

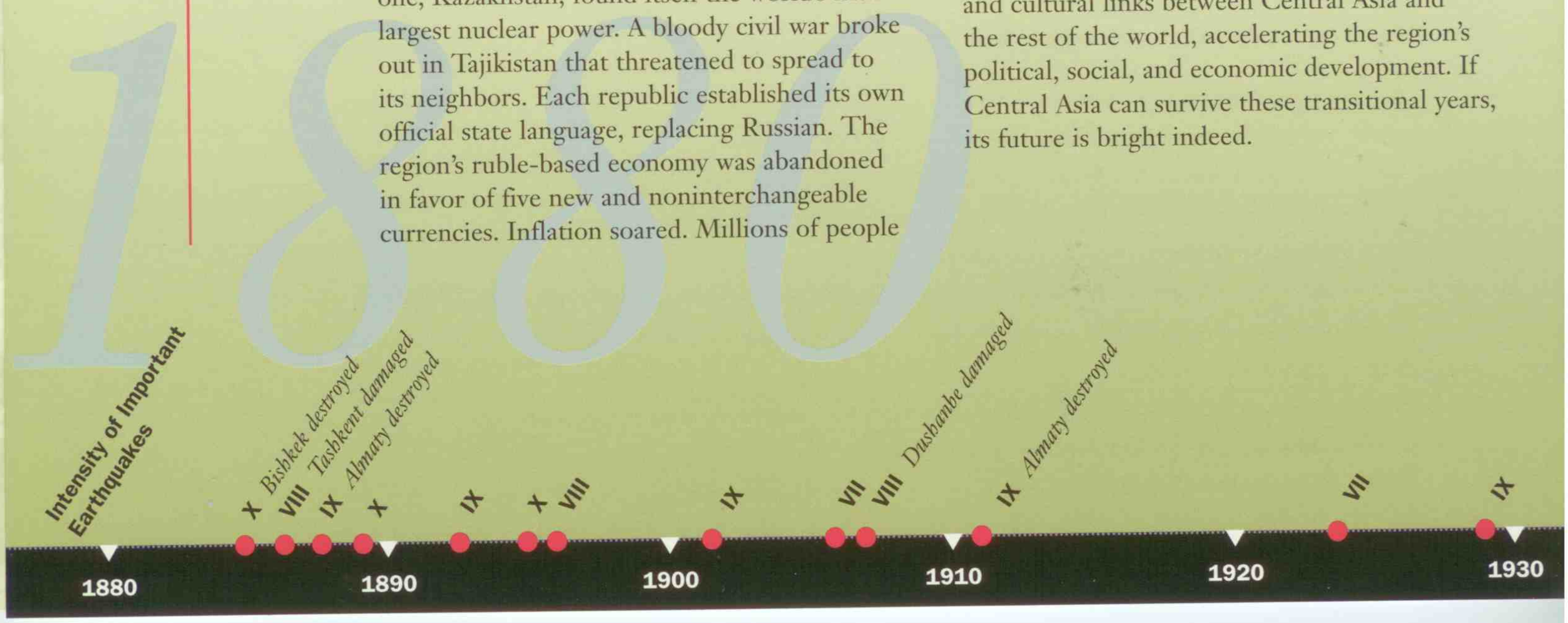


CENTRAL ASIAN DEMOGRAPHICS

REPUBLICS			CAPITAL CITIES	
Name	Population (Millions)	Area (Thousand sq. km)	Name	Population (Millions)
Kazakhstan	*17.0*	*2,720*	Almaty	*1.5*
Kyrgyzstan	*4.4*	*200*	Bishkek	*0.8*
Tajikistan	*5.8*	*140*	Dushanbe	*1.1*
Turkmenistan	*4.5*	*490*	Ashgabad	*0.5*
Uzbekistan	*22.7*	*450*	Tashkent	*2.2*
All republics	*54.4*	*4,000*	All capitals	*6.1*
United States (contiguous)	*260.0*	*7,884*		

The dissolution of the Soviet Union in 1991 triggered a renaissance bordering on chaos in the five Central Asian republics of Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan. After 70 years of technical, political, and economic dependence on Moscow, these republics were, instantaneously and against their wishes, on their own. Each had to form a new system of government. None could guarantee its territorial security, even though one, Kazakhstan, found itself the world's fifth-largest nuclear power. A bloody civil war broke out in Tajikistan that threatened to spread to its neighbors. Each republic established its own official state language, replacing Russian. The region's ruble-based economy was abandoned in favor of five new and noninterchangeable currencies. Inflation soared. Millions of people of non-Central Asian heritage emigrated. Religion burst onto the scene: In 1989, each capital city averaged 10 mosques; two years later, this number had grown to 1,000. In place of security and stability came vulnerability and volatility, and most importantly, opportunity.

Given the enormity of the challenges they faced, these republics have made and continue to make remarkable progress. They have held elections and developed foreign policies. The civil war in Tajikistan has not spread and shows signs of ending. Inflation has abated. Investors have been attracted to the region's natural resources, which include some of the largest deposits of minerals, oil, and natural gas in the world. Billions of dollars in foreign currency are being spent on oil and gas exploration, automobile factories, telecommunication networks, international airports, and hotels. Pipelines are planned to stretch to the China Sea, the Indian Ocean, and the Mediterranean. A trans-Asian railroad and highway are under construction, and will connect the republics to each other and their immediate neighbors. These enterprises are forging new commercial and cultural links between Central Asia and the rest of the world, accelerating the region's political, social, and economic development. If Central Asia can survive these transitional years, its future is bright indeed.



...is jeopardized by *earthquakes*

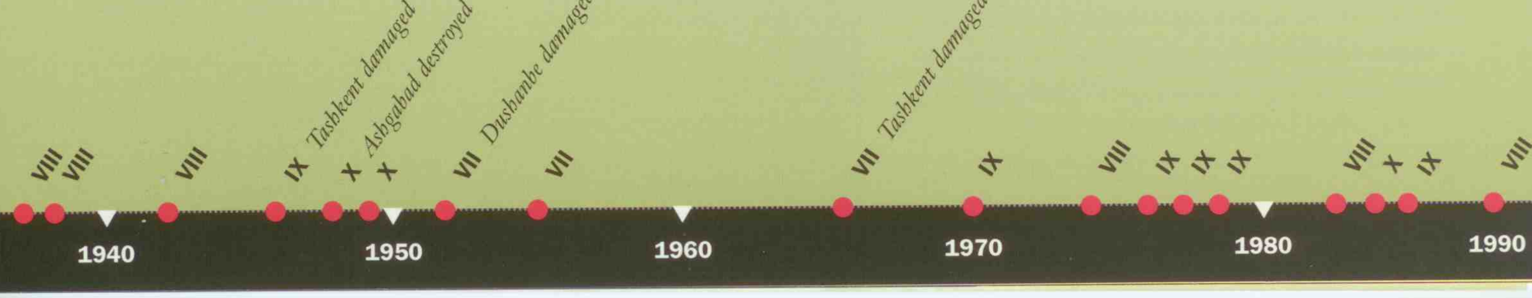
Central Asia's earthquake activity has long been recognized as one of the highest in the world, but the extreme vulnerability of its Soviet-era residential buildings was realized only after two recent earthquakes outside the region. In 1988, an earthquake in Armenia caused the collapse of more than 95% of one type of residential building and 75% of another type in the city of Leninakan; other types of buildings in that city remained standing but were damaged. In 1995, another earthquake near Sakhalin, an island in the northwest Pacific Ocean, caused all of yet another type of residential building to collapse in the city of Neftegorsk; again, other building types survived. These experiences in Armenia and Sakhalin suggest that the thousands of residential buildings with similar design and construction found throughout Central Asia are highly vulnerable to earthquakes.

Just as Central Asia's large urban earthquake risk was being recognized, the ability to manage it was drastically decreasing. Since the Soviet Union's disintegration, responsibility for earthquake preparedness and response has been turned over to local officials, who are often inexperienced and usually more than occupied with present-day emergencies. None of the five republics has a standing army capable of managing the consequences of a natural catastrophe. Among the millions of people who recently emigrated were about half of Central Asia's most experienced civil engineers and earth scientists. Those who remain are isolated from their colleagues in other republics and have difficulty attracting students to their professions. Funding for research and development has virtually ceased. For all of these reasons, it is understandable that the lessons of Armenia and Sakhalin have gone unheeded. But continuing to ignore them is unacceptable for both Central Asians, who live there, and the world community, which is poised to pour additional investments into the region.

Recognizing the urgency of addressing Central Asia's urban earthquake risk, GeoHazards International, a nonprofit organization dedicated to improving earthquake safety worldwide, mobilized resources to assess the vulnerability of the region's Soviet-era residential buildings and develop a strategy for reducing it. Support was obtained from a wide variety of organizations. The government of Kazakhstan agreed to act as host. The resulting workshop was held in Almaty, Kazakhstan, from October 22 – 25, 1996, and involved more than 50 experts from the fields of seismology, earthquake-resistant design, and emergency response from across Central Asia and around the world. This report summarizes their findings and recommendations.

1990

The quality of building construction in Central Asia today is similar to that found throughout the former Soviet Union, including the Russian city of Neftegorsk, pictured in this photo hours after an earthquake in 1995. The remains of these five-story residential structures, shown here as they fell, lie among damaged but still standing structures of different types.



Central Asia's *Earthquake Hazard*

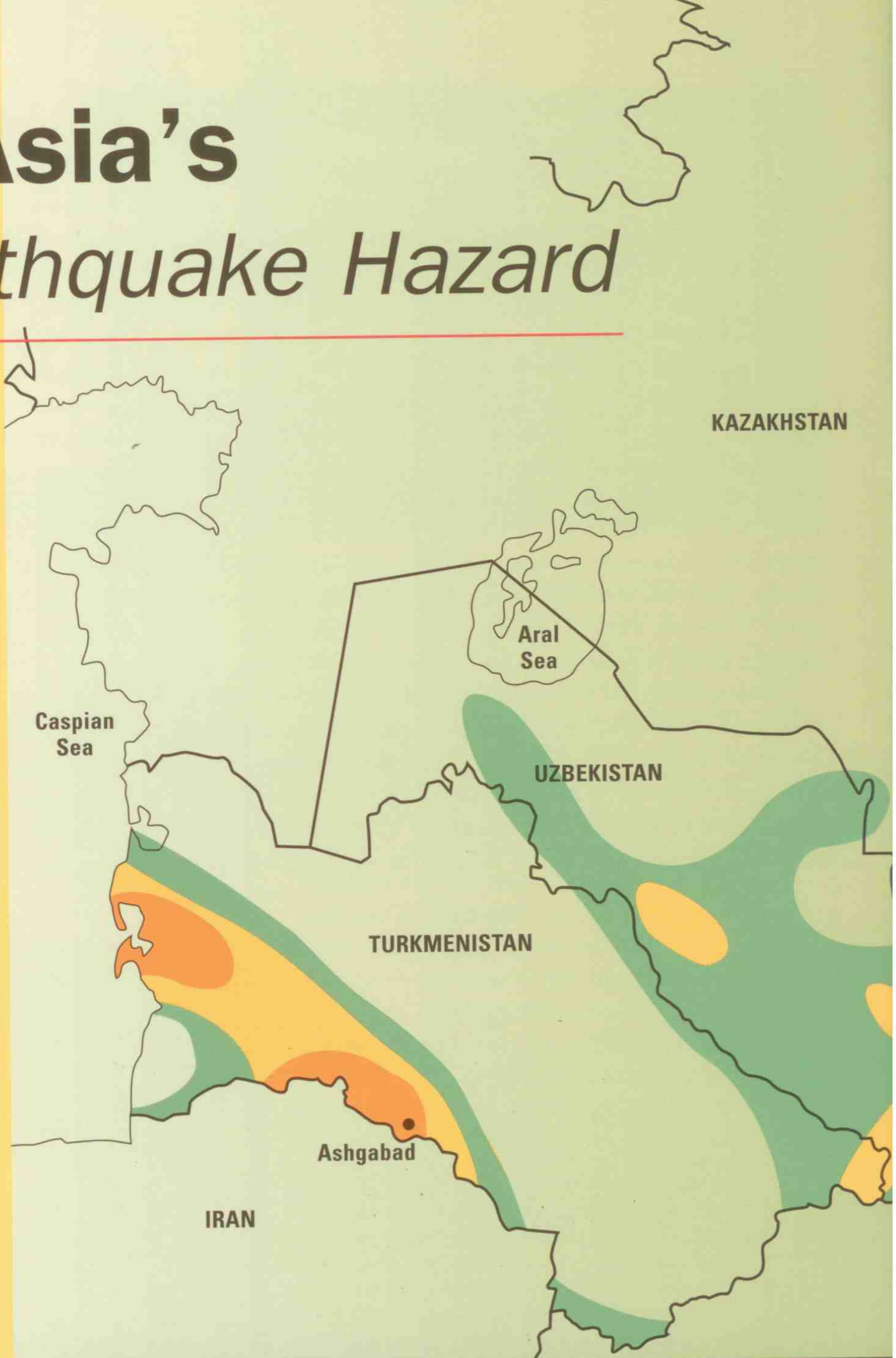
The earthquake hazard—that is, the maximum ground shaking expected at a given location over a specified period of time—of the most populated portion of Central Asia is approximately equal to that of California. Central Asia's earthquakes and two-thirds of its population are concentrated in the region's southern quarter, which has about twice California's area and about twice its annual number of earthquakes.

Earthquake hazard is often expressed in terms of seismic intensity, which is a qualitative description of the consequences of earthquake shaking on people and structures. In the former Soviet Union, seismic intensity is measured on a 12-step scale, called the Medvedev-Sponheuer-Kárník (MSK) scale. This is similar to the Modified Mercalli Intensity scale used in the United States and Europe.

Maps of seismic hazard in Central Asia have been derived primarily from descriptions of the consequences of past earthquakes. These records show that, over the last century alone, all of the region's capitals were heavily damaged by earthquakes and many were totally destroyed; for example, Ashgabad in 1948, and Almaty in 1887 and again in 1910.

The simplified version of the official seismic hazard map for the former Soviet Union that is shown here indicates that all of the Central Asian capitals, with the exception of Tashkent, can expect an MSK IX level of shaking. Tashkent can expect MSK VIII. (The period of time over which this level of shaking is expected varies from location to location in a manner that cannot be rigorously explained in the space available.)

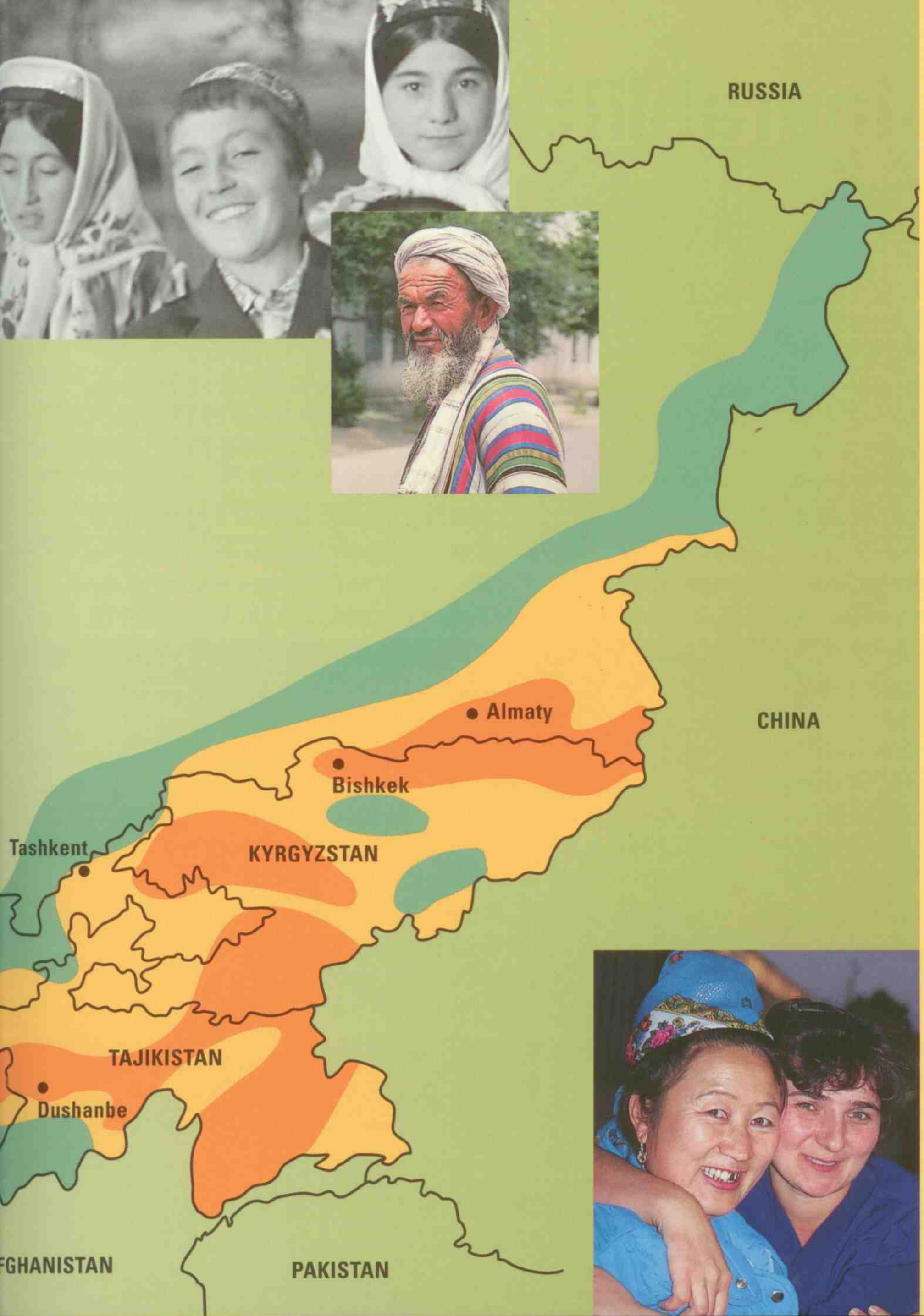
There are two reasons to believe that this map significantly underestimates the region's hazard. First, it does not take into account the amplification effect of the soft-soil conditions common in large areas of the capitals, which is important because soft soils can produce intensities one or more MSK units greater



MAP UNDERESTIMATES INTENSITIES

Comparison of maximum intensity expected from the 1978 Soviet Seismic Hazard Map and maximum intensity observed for destructive earthquakes since 1988. Map significantly underestimates observed intensities.

Earthquake (Date, Place)	Maximum Intensity Expected (MSK)	Maximum Intensity Observed (MSK)
1988, Leninakan (Armenia)	VIII	IX
1990, Zaysan (Kazakhstan)	VI–VII	VIII
1991, Racha (Georgia)	VII–VIII	IX
1991, Yakutia (Russia)	V	VIII–IX
1992, Soosamir (Kyrgyzstan)	VII–VIII	IX
1995, Neftegorsk (Russia)	VII	IX



This map, a simplified version of the 1978 official Soviet seismic hazard map, plots the maximum expected seismic intensity (in MSK units) for Central Asia. Recent studies indicate that this map significantly underestimates the region's seismic hazard.

than on nearby stiff soils. Second, all of the recent destructive earthquakes in the former Soviet Union have been significantly larger than would be expected from examining the map (even allowing for soft-soil conditions). This underestimation of seismic hazard is partially (but only partially) responsible for the widespread collapse of buildings in Armenia and Sakhalin, because those structures were designed to withstand smaller ground motions than actually occurred. This map is being revised in Moscow.

At the Almaty workshop, seismologists analyzed the above information and the reports prepared specially for the workshop about the seismic hazard of each of the five republics; they concluded that:

There is a high (about 40%) probability that an earthquake will occur near one of the Central Asian republics' capitals within the next 20 years. Such an earthquake will produce maximum ground shaking in that city equal to the maximum ground shaking experienced in Armenia and Sakhalin, that is, MSK IX.

PARTIAL DEFINITION OF MSK INTENSITY SCALE

MSK INTENSITY	CONSEQUENCES
VII	**People:** Frightened **Buildings:** Poor-quality structures considerably damaged; ordinary structures slightly damaged
VIII	**People:** General fright, some panic, difficulty standing **Buildings:** Poor-quality structures collapsed; ordinary structures considerably damaged; and well-built structures slightly damaged
IX	**People:** General panic **Buildings:** Many ordinary structures destroyed; well-built structures heavily damaged
X	**People:** Thrown to ground, strong disorientation **Buildings:** Most buildings destroyed, including some well-built structures

Seismic Vulnerability

of Residential Buildings

Because design and construction practices were centralized in the former Soviet Union, four-fifths of all Central Asian residential buildings can be placed into one of only six structural types. The seismic vulnerability of these types is variable and depends on such factors as design, detailing, materials, construction methods, and maintenance. The six Central Asian structural types, their occupancy total in all five capital cities, and the average level of damage expected for different levels of earthquake shaking are described briefly in the table below.

The seismic vulnerability of most of the six Central Asian structural types is high. Only one (Type 6) is considered satisfactory; its good performance during earthquakes is due to its seismic-resistant design and its relative insensitivity to construction quality. One-half of all the residents of the Central Asian capitals—about three million people—live in buildings (Types 1-5) that are highly vulnerable to earthquakes.

The economic cost of building damage can be estimated using the table below by knowing that buildings suffering slight or moderate damage *can* be repaired, buildings suffering heavy damage *might* be repaired, and buildings that partially or completely collapse *cannot* be repaired.

Building damage also has a human cost. Based on worldwide experience, it is estimated that the fatality rate in urban centers of developing countries will be 0.5% for MSK VIII and 5% to 7% for MSK IX. Similarly, it is estimated that the rate of serious injuries (i.e., those requiring hospitalization) will be 2% for MSK VIII and 20% for MSK IX. The expected number of deaths and injuries for the Central Asian capitals can be estimated assuming MSK IX intensity in Almaty, Ashgabad, Bishkek, and Dushanbe; and assuming MSK VIII intensity in the 60% of Tashkent's area that has stiff soil conditions and MSK IX intensity in the 40% with soft-soil conditions.

CENTRAL ASIAN STRUCTURAL TYPES, THEIR OCCUPANCY TOTAL IN ALL FIVE CAPITAL CITIES, AND THE EXPECTED DAMAGE LEVELS

STRUCTURAL TYPE	OCCUPANCY		DAMAGE LEVEL		
	Thousands	% 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, one to two stories, pre-1955	*1,400*	*23%*	*Moderate to heavy damage*	*Partial collapse*	*Total collapse*
3. Brick bearing-wall systems with precast reinforced concrete (RC) floors, three to five stories, pre-1957			*Slight to moderate damage*	*Heavy damage to partial collapse*	*Partial collapse*
4. Brick bearing-wall systems with precast 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, four to nine 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%*			

At the Almaty workshop, structural engineers analyzed this information and the reports specially prepared for the workshop about each of the five capitals' building stock; they concluded that:

It should be expected that an MSK IX level of ground shaking in a Central Asian capital will cause tens of thousands of fatalities, and at least a hundred thousand serious injuries. As many as half of the city's residential buildings will collapse or be damaged beyond repair.

ESTIMATED DEATHS AND INJURIES IN CENTRAL ASIAN CAPITALS

CITY, REPUBLIC	SERIOUS INJURIES (Thousands)	DEATHS (Thousands)
Almaty, Kazakhstan	300	75
Ashgabad, Turkmenistan	100	25
Bishkek, Kyrgyzstan	160	40
Dushanbe, Tajikistan	220	55
Tashkent, Uzbekistan	180	45

Warning from Armenia

This photograph of damage in the city of Leninakan, Armenia, caused by the 1988 earthquake presages what could occur in Central Asia. In the background is an essentially undamaged precast-large-panel structure (similar to Type 6 in the table on page 6). Of the 16 such structures in Leninakan, none had significant damage. In the foreground is a collapsed precast-frame structure (similar to Type 5). Of the 138 such structures in Leninakan, 132 collapsed or were damaged beyond repair. Comparable design and construction exist today throughout Central Asia.

Soviet-era Construction

The vast majority of all Central Asian residential buildings fall into one of only six structural types. One (Type 6 in the table on page 6, pictured on the far right) has good seismic resistance. The other five (including Type 3, pictured on the immediate right) do not, and house among them three million people.

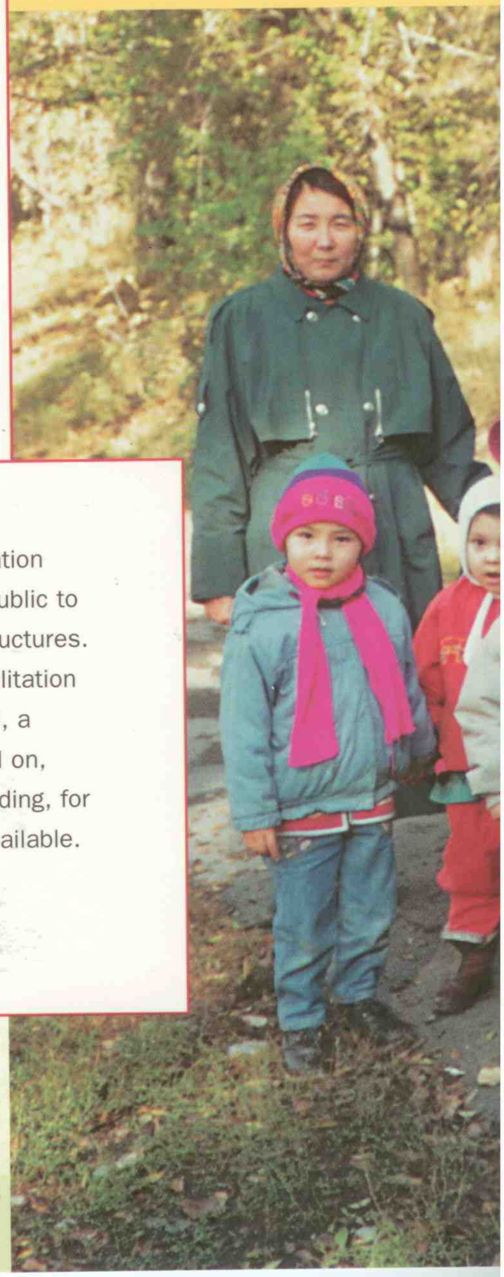
A Call to Action

Central Asia's urban earthquake risk is unusually easy to evaluate. Its buildings vary little in design and method of construction because the vast majority of them were built over a short period, when design and construction were controlled by one central authority. Further, how some of these building types perform in earthquakes has been tested and found to be poor, first in Armenia and again in Sakhalin.

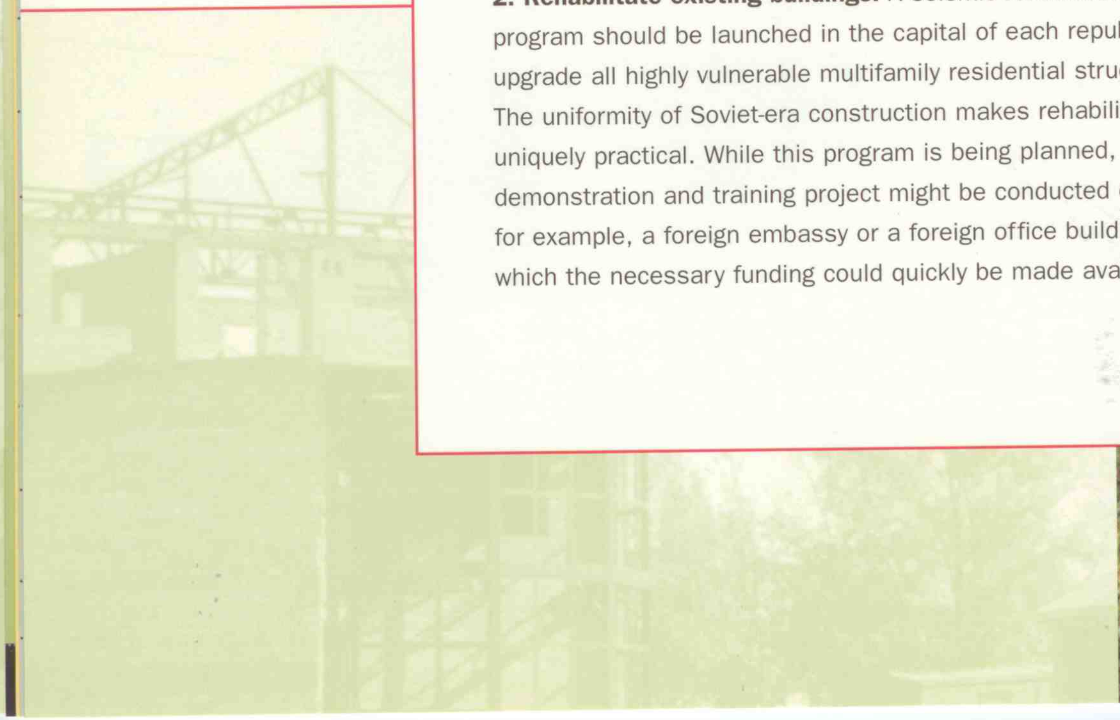
Consequently, the earthquake specialists who gathered from across Central Asia and around the world at the Almaty workshop could agree that there is a high probability that, during the next several decades, a large earthquake near one of the Central Asian capitals will cause human and economic loss even greater than that already experienced in Armenia and Sakhalin . . . unless corrective action is taken soon.

In order to confront this crisis, projects must immediately be initiated that allow for Central Asia's current social, political, and economic conditions, and address the following five broad needs.

1. Inform the people most at risk. Responsible officials in each republic must first notify the occupants of Soviet-era residential buildings of the high vulnerability of some of these buildings, and next undertake a detailed inventory and ranking of vulnerable buildings in their respective capitals. It is a basic human right to know if one is exposing oneself and one's family to great risk. Informing those who are at great risk would be not only a responsible but also an effective first step, because projects to improve seismic safety in Central Asia are possible today only with the strong support of the public.



2. Rehabilitate existing buildings. A seismic rehabilitation program should be launched in the capital of each republic to upgrade all highly vulnerable multifamily residential structures. The uniformity of Soviet-era construction makes rehabilitation uniquely practical. While this program is being planned, a demonstration and training project might be conducted on, for example, a foreign embassy or a foreign office building, for which the necessary funding could quickly be made available.



3. Regulate new construction. New seismic design codes should be written taking into account currently available material and construction methods. Designs that minimize sensitivity to construction quality, such as that of structural Type 6, are desirable. Liability for illegal construction must be established. Sharing the experience of other nations in drafting, enforcing, and updating seismic safety laws would be fruitful. New construction must be continuously inspected by trained and independent public officials, who can be held accountable. Lethal construction must cease.

4. Unite and support local experts. Central Asia's too few, underfunded, and isolated earthquake engineers and seismologists must reestablish contact with each other and create new links with international colleagues, including recent émigrés. Exchange of information will help the republics to train new professionals, establish laws and standards, and advocate earthquake safety. Collaboration should be increased with Internet connections, attendance at international conferences, subscriptions to foreign professional journals, and cooperative research projects.

5. Continue and extend risk assessment. Estimates of earthquake risk based on seismic intensity records are not adequate to guide public policy. A network of strong-motion accelerometers across each capital city and in standard buildings would determine local ground response and building performance. Maps of soil conditions would also be useful. Finally, while the Almaty workshop focused on residential buildings, it also revealed that the earthquake resistance of other structures is highly suspect. Consequently, an assessment of the seismic vulnerability of critical structures such as schools, hospitals, government buildings, and lifelines should immediately be undertaken.

The participants of the Almaty workshop assessed the earthquake risk of Central Asia's Soviet-era residential buildings and recommended means to manage it. Now is the time for others to act who understand the risk faced by their families and their communities. Only a group of concerned, determined Central Asian citizens—from the very highest government officials to civil servants, parents, and teachers—can take the actions required to avert tragedy.

Other GeoHazards International Publications:

Investing in Quito's Future: The Quito, Ecuador, School Earthquake Safety Project
Issues in Urban Earthquake Risk
The Quito, Ecuador, Earthquake Risk Management Project: An Overview
Uses of Earthquake Damage Scenarios
GeoHazards International

GeoHazards International, *Lessons for Central Asia from Armenia and Sakhalin* (Stanford, GeoHazards International, 1997)

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