Chapter 2
Natural Hazards in Pakistan

Pakistan is a country with diversity not only of people, cultures, and traditions but also of physiography. A phrase from the Pakistan Handbook (Mannheim and Winter 1996) states that it has "an almost unbelievable range of landscapes and environments; mighty rivers and huge deserts; and fertile plains, thick forests, and towering mountains." From another perspective, this landscape is a perfect recipe for disasters caused by natural hazards.

Much of the northern areas of Pakistan are covered by the mountains of the Himalayas, Karakoram, and Hindu Kush, and the inhabitants face winter snow storms and blizzards, which often result in snow avalanches. At the same time, much of the southern and western areas of Pakistan suffer acute drought; and his seems to have been the case frequently in the last ten years. The extremely dry, hot climate in early summer causes catastrophic snow melting, often resulting in floods; and, once in every ten years, monsoon rains play havoc with life and property by causing flash floods and exceptional rises in water levels in the country's major rivers. The result of this is flooding throughout large tracts of the country all the way to Karachi on the shores of the Indian Ocean.

Slope stability is a major issue in the mountainous areas of Pakistan, especially early in the spring season when Pakistan receives rainfall from the westerlies and in the summer during the monsoon rains. None of these hazards, however, has caused greater loss of life and property than earthquakes. In the past 75 years, Pakistan has been hit by three earthquakes exceeding magnitude 7.5 (Quetta 1935; Makran 1945; and Kashmir 2005) with total loss of life exceeding 120,000. According to Bilham et al. (2001), the next major earthquake in the Himalayas (including Pakistan, India, and Nepal) might kill more than a million people, which will not be surprising considering the active geodynamic setting of the Himalayas and the rapid rate of population growth and growing urbanisation.

This report concentrates on only three of the natural hazards mentioned above: floods, landslides, and earthquakes. Snow blizzards and avalanches in the high mountains in north Pakistan and drought hazards in the Punjab, Sindh, and Baluchistan provinces are quite devastating also, but they are beyond the remit of this report.

Floods

Over the years, major floods have occurred in almost all the countries of South Asia, causing huge loss of life and property. Despite huge investments in river control in the region, the frequency of major flood disasters has actually increased over the past three decades. There is a growing consensus that the impacts of climate change may well lead to an increase in both the frequency and magnitude of floods (Kennedy 2004).

Like elsewhere in the world, floods in Pakistan are of two types: riverine and flash floods. Whereas the former is a substantially greater hazard in terms of extent of area and population affected, flash floods are deadlier because of their unpredictable nature.

Riverine floods

A riverine flood is caused by flooding of the river outside its regular boundaries. This can be accompanied by a breach of dykes or abutments next to the river. Such floods can be due to dense precipitation (not necessarily in the flooded area) or other causes such as melting snow or blockage in the river flow. In general, extreme river discharges can be predicted some time in advance (Jonkman 2005).

Much of Pakistan is drained by the Indus Basin that spans four countries of South-Central Asia (Afghanistan, China, India, and Pakistan), covering an area of one million sq. km. About 56% of the Indus Basin lies in Pakistan, covers 70% of the area (IUCN 2005), and is inhabited by 150 million people (UNESCO 2001). The Indus is the principal river in the region with the Chennab, Jhelum, Kabul, Ravi, and Sutlej rivers being the major tributaries. The major component of the annual flow of these rivers is derived from snowmelt, originating in the Hindu Kush-Himalayan region. Many of the catchment sources are in India but, because of its location downstream, the flood impact is greater in Pakistan than in the other three countries (Afghanistan, China, and India).

A combination of one or more of four major factors causes river floods in Pakistan.

- Monsoon torrential rains in the months of July and August
- Westerlies from the Arabian and Mediterranean seas in winter
- Excessive melting of snow in spring and early summer
- Natural damming and subsequent outbursts because of landslides, debris flows, or glacier advances (glacial lake outbursts can be an additional cause of floods in Pakistan.)

Usually, the late spring and early summer months (April-June) are dry in the Himalayas and associated with extremely high temperatures which result in catastrophic melting of the snows. This situation has been aggravated in recent years because of regional climate changes. The 2005-2006 floods in the North West Frontier Province (NWFP) were a result of this phenomenon. The heavy monsoons last from July to August, but recently they have begun to last into the month of September. Both these mechanisms are more effective in the catchments than in the Indus River Basin itself. The monsoon low or depression that causes intense rain develops in either the Arabian Sea or in the Bay of Bengal. Heavy flooding is associated with the depression from the Bay of Bengal moving across India in a west/north-westerly direction and then turning north at the border with Pakistan.

The Indus Basin is prone to flooding also because of collapse of temporary natural dams formed by glacial movements and landslides (including earthquake-triggered) and glacial lake outburst floods (GLOF). A recent study (ICIMOD 2005) found that of the 2,420 glacial lakes in the Indus Basin, 52 lakes are potentially dangerous and can result in GLOFs with consequent damage to life and property.

During flooding, the major rivers inundate areas along their banks, damage irrigation and communication facilities across or adjacent to the rivers, and cause erosion of land along the river banks. In the upper reaches of the Indus Basin, flood waters spilling over the river banks generally return to the river. However, in the lower reaches of the Indus River, which is flowing for the most part at a higher elevation than adjoining lands, overflows do not return to the river. This extends the period of inundation, resulting in extensive damage. Although embankments have been built for flood protection along almost the entire length of the river in Sindh Province and in many locations in the upper reaches, embankment breaches still occur. Such breaches often cause greater damage than would have been the case had there been no embankments, because of the intensification of land use following the provision of flood protection.

The existing discharge capacity of some of the infrastructure (barrages and rail or road bridges) on the Indus, Chenab, and Ravi is inadequate. During exceptionally high floods this results in afflux on the upstream side, which sometimes results in breaches in flood embankments. At times, the flood embankments have to be deliberately breached at pre-selected locations to save the main barrages and other vital settlements and installations.

Table 1 gives an idea of losses caused by flooding and the economic costs over the last fifty-eight years. Damage to agricultural and communication infrastructure alone by the ten largest floods cost Rs 225 billion (US$ 4 billion).

Table 1: Historical flood damage in Pakistan				
Year	Value of Property Damaged (million Rs)		Lives Lost	Villages Affected
	Unadjusted	Adjusted		
1950	200	11,282	2,190	10,000
1956	156	7,356	160	11,609
1957	152	6,958	83	4,498
1973	5,137	118,684	474	9,719
1976	5,880	80,504	425	18,390
1978	4,478	51,489	393	9,199
1988	6,879	25,630	508	1,000
1992	34,751	69,580	1,008	13,208
1995	6,125	8,698	591	6,852
2001	45	450	219	50
2003	5,175	5,175	484	4,376
2004	15	15	85	47
2005	Not Reported		59	1,931
Total	**64,208**	**380,631**	**6,051**	**84,525**

For the years from 1950 to 2001, the costs are adjusted to 2002 price levels.
Source: Federal Ministry of Water and Power

Flash floods

Whereas most large-scale floods are associated with overflow of rivers, flash floods are caused by intense rainfall in a limited area in a short span of time. Typically, flash floods occur when there is an abundance of atmospheric moisture, combined with absence of vertical wind shear. Flash flooding can be produced by large, slow-moving storms or as a result of 'train effect' storms (i.e., sequential mature storms that release precipitation over the same area). Train effect storms can be part of a multi-cell cluster or squall line storm systems. Flash floods can also result from an unanticipated break in or collapse of a flood protection embankment when stored water engulfs vast areas outside the natural flood plains with a sudden rise and speed. This precludes adequate warning and proper evacuation measures.

Flash floods move at incredible speeds, can roll boulders, tear out trees, destroy buildings and bridges, and scour out new channels. Murderous walls of water reach 10–20 ft in height. On small streams, especially near the headwaters of river basins, water levels may rise quickly in heavy rainstorms, and flash floods can begin before the rain stops falling. There is little time between detection and flood crest. Swift action is essential for the protection of life and property.

A large tract of mountainous country in both the north (Karakoram, Hindu Kush, and the Himalayas) and in the west (the Khyber-Kurram-Wiziristan-Suliaman-Kirtahar belt) is characterised by moderate to very steep slopes and, during the monsoons, they are susceptible to flash floods. Although the mountains in Pakistan experience the monsoons in the waning stages after they have swept through India and other areas of Pakistan, every few years or so the monsoons can be exceptionally intense and still moisture-laden when they strike the mountain fronts in Pakistan. Such incidences cause flash floods in parts of Kashmir, Hazara, Swat, and the Peshawar Plain. Less commonly, a similar phenomenon is observed in the western mountainous belt.

The steep, sediment-laden slopes in the hinterlands in the Himalayas, Karakoram, and Hindu Kush are prone to mass movements of rocks and sediment in the wake of flash floods. The region is, however, characterised by an arid climate with a very little annual rainfall, and this helps keep a delicate balance intact. Every ten to fifteen years, this exception is over-ruled when monsoons are so intense that they cross mountain barriers in the frontal region reaching as far inside as Baltistan, Hunza, Kohistan, and Chitral. When this happens, torrential rains of the least intensity can trigger severe flash floods giving rise to highly dangerous debris and mud flows. Almost the entire population in this region inhabits alluvial and debris fans located on river banks, leaving them highly susceptible to flash floods and associated debris flow hazards.

Almost every year one or more parts of the mountainous areas suffer from flash floods, although there are no systematic records of them. In 2006, however, records show that several mountain areas were subjected to flash floods: 1) Bolan-Sibi area in Baluchistan, 2) Charsada, Mardan, Mansehara, and Batagram districts in NWFP, and 3) Baltistan district in the Karakoram.

Earthquakes

Pakistan is bounded by active plate boundaries marked by the collision of India and Eurasia in the north and India and the Afghan Block in the west. Although the initial collision occurred at ~60 Ma (Beck et al. 1995), the compression is ongoing as shown by an up to 35 mm/year shortening across the Himalayas, reflected in recent data acquired using global positioning system technology (Bendick et al. 2007). Bilham et al. (2001) rightly pointed out that the Pakistan Himalayas, which had not had an earthquake in the recent past, was susceptible to an earthquake of a magnitude of ~8 in response to strain accumulation caused by ongoing compression in the region. The Kashmir earthquake of 2005 (7.6 M) is a product of that compression and killed over 80,000 people and made another 400,000 homeless. With the exception of this Kashmir earthquake of 2005, the Pakistan Himalayas, Karakoram, and Hindu Kush had not had an n earthquake of M>7 in a 100 years according to historical records, although there had been others through the centuries (Bilham 2004). This shows that the lack of earthquakes in the Pakistan Himalayas in the recent past was not because of lack of seismic activity in the region, but rather because of the long recurrence intervals associated with earthquakes in this part of the world. Seismic activity causing moderate to small earthquakes <7 M is frequent, suggesting that the region is seismically active. Table 2 presents several earthquakes in the recent past with magnitudes of from 5-7 M.

Table 2: Significant earthquakes in Pakistan and its immediate surroundings

Year	Epicentral Location	Magnitude	Fatalities	Source
Northern Pakistan				
2002-11-20	Astor	6.5	25	Hughes 2003
1981-09-12	Darel	6.0		Jackson & Yielding 1983
1972-09-03	Haraman	6.0		Jackson & Yielding 1983
2005-10-08	Kashmir-Hazara	7.6	80,361	ERRA 2006
1974-12-28	Pattan	6.0	994 killed, 1845 disabled	Ambraseys et al. 1975; 1981; Jackson & Yielding 1983
Western Pakistan				
1945-11-28	Makran coast.	8.3	4,000	Gates et al. 1997
1935-05-30	Quetta	7.5	30,000-60,000	
1992	Chaman		?	
1931	Machh	7.3	?	
Southeastern Pakistan				
1819-06-16	Allah Bund, Rann of Kuchch	7.7	?	Bilham 1998
2001-06-21	Bhuj (India)	Mw 7.7, Ms8	20,000	Rastogi 2001; Hough et al. 2002

Unlike the northern boundary, the western boundary of Pakistan defined by the Chaman strike-slip fault, Sulaiman-Kirtahar ranges, and the Makran subduction zone have had several major earthquakes in the last 100 years (Table 2). Of these the deadliest earthquake was that in Quetta in 1935 that killed over 30,000 people, although the Makran 1945 earthquake was largest in terms of magnitude (8.3).

A third region of significant seismic potential lies in the southeastern corner of Pakistan called the Kuchch Seismic Zone. In the past 200 years two major earthquakes have occurred at or close to Pakistan's border with Gujarat in India (Table 2). None of these two major earthquakes caused any damage to Karachi, although the Bhuj earthquake (2001) resulted in the deaths of 16 people in Hyderabad and its surrounding areas.

With a tectonic locale near the active plate boundaries with potential for great earthquakes (M >8), and a population growth rate >2%/year, Pakistan is extremely vulnerable to earthquakes, and none of the other natural hazards facing Pakistan has greater potential for loss of lives and livelihoods. Since there is no definite technique for predicting an earthquake, mitigation and preparedness revolves around realistic seismic hazard assessment. This helps to identify areas and regions vulnerable to earthquakes and the expected range of seismic shaking in terms of peak ground acceleration (PGA), development of building codes appropriate to PGA expected, and well-prepared planning and execution of search, rescue, evacuation, relief, and rehabilitation operations.

Landslides

Landslides are different from floods and earthquakes in that they are typically restricted to mountainous areas. Of the mountainous areas of the country, Hazara and Swat are particularly vulnerable because of steep unstable slopes, higher than average rainfall, and large populations (total population ~10 million). Chitral, Kohistan, Gilgit, and Baltistan further to the north are high mountain areas, with even steeper slopes than Hazara and Swat, but have relatively less annual rainfall and smaller populations. These regions have important regional as well as international routes (e.g., the Karakoram Highway linking Pakistan to China) which are constantly under threat from landslides.

Landslides in Pakistan are triggered by natural causes as well as by man-made activities. Activities like uncontrolled deforestation, excavation (for foundations, roads, and irrigation channels), and disturbing the natural drainage upset the critical slope-stability balance triggering landslides. A recent example of a landslide triggered by human activities was reported from Swat in 2006: several houses were carried away by a landslide killing 17 people. This was triggered by blockage of an irrigation channel on a steep slope.

Steep, unstable slopes trigger landslides because of natural causes like unusually heavy rains and earthquake tremors. Huge landslides bring heavy rock falls, some of the rocks weigh tons.

Areas that are extremely prone to landslides are located in the northern mountains. South-central Karakoram has a zone of active faulting and NW-directed thrusting in the Nanga Parbat-Haramosh region (Madin et al. 1989) characterised by a very high rate of denudation and river incision (as much as 8mm/yr since the last Pliocene) (Zeitler et al. 1989; Burbank et al. 1996). Geomorphic activity is extreme by global standards, especially the work of snow avalanches, glaciers, rock falls, rockslides, and debris flows (Hewitt 1968, 1993; Goudie et al. 1984). The earliest historical accounts of large mass movements are found in Conway (1894), de Filippi (1912), and Godwin-Austen (1864). First-hand accounts also testify to the great scale and devastation of landslides triggered by earthquakes (Mason1914; Cockerill 1902; Hewitt 1998a, b). A well- cited example is from1841 from the slopes of Nanga Parbat on the western side of the Indus River near Bunji. The landslide dammed the Indus for six months before it drained to cause the largest recorded flood on this river (Hewitt 1968; Shroder 1993).

The second largest flood also came from the outburst of a landslide dam that blocked the Hunza River for seven months in 1858 (Becher1859; Todd 1930). Rock avalanches have been widespread in the Karakoram and Himalayas. In the Karokaram, the slopes are often steeper than 45º and with elevation ranges of 500m that promote rockslide and rock fall events of great size.

Landslides may be the dominant erosive force in the Himalayas, but the construction of roads through a particular area increases the susceptibility of that region from 'normal' to 'high' (Dhakal et al. 1999). In an ICIMOD project (landslide hazard management and control in Pakistan) by Malik and Farooq (1996) landslide types, causes, analysis, and remedial measures have been studied along the important routes in Northern Pakistan.

Thousands of rock falls and landslides were triggered by the Kashmir earthquake in 2005. In the Balakot-Muzzaffarabad area alone, more than 70 landslides have been identified (only those of >7 sq m) and the total area covered by these landslides is 6.73 sq km, while the area covered by the reactivated landslides is 3.74 sq km.