Chapter 7
Natural Hazards in the North-East Region of India

Abstract North-East India is afflicted by three main natural hazards: floods, earthquakes and landslides. Of these, the earthquakes are most unpredictable. Earthquakes are generally grouped under four categories depending on their severity, measured on the Richter scale. In common parlance, these are known as 'slight', 'moderate', 'great' and 'very great' earthquakes. These categories, on the Richter scale, measure as <4.9, 5–6.9, 7–7.9 and >8, respectively. The frequency of these earthquakes varies with the intensity of the earthquakes, slight earthquakes occurring more frequently than the great or very great ones. The low-intensity tremors occur quite frequently in the contact zone of plate boundaries or along the lines of structural weakness, like the Main Boundary Fault (MBF) or the Main Central Thrust in the Himalayan region or along a chain of thrusts extending from Lohit district (with Mishmi fault) in the north to Manipur and further south. From the mid-nineteenth century till date, there have been seven earthquakes with an intensity of >7.0 on the Richter scale, of which the two occurring in 1897 and in 1950 were very severe, the first one measuring 8.7 and the second one 8.5 on the Richter scale. The earthquake of 1950 not only caused tremendous loss of property and life, but even changed the course of many rivers including the morphology, especially depth profile of Brahmaputra.

Floods are a recurring annual feature of Assam when Brahmaputra and its tributaries, with very large catchments, are flooded exceeding the limit of bankful discharge and submerge a substantial part of Brahmaputra plain. In very severe floods, three to four million hectares of land are affected. These floods occur between May and September, the period of summer monsoon. The floods affect the crops, cause erosion, breach embankments, wash away cattle, destroy houses, uproot trees and even affect the wildlife sanctuaries.

Natural hazards are caused by a loss of equilibrium in the crust of the earth, or its atmosphere, unleashing a chain of events that manifest themselves in natural hazards. An earthquake, a volcanic eruption and a tsunami owe their origin to an

K.R. Dikshit and J.K. Dikshit, *North-East India: Land, People and Economy*, Advances in Asian Human-Environmental Research, DOI 10.1007/978-94-007-7055-3_7,

accumulation of stress and its release, or some loss of equilibrium, in the crust of the earth. Similarly, atmospheric disturbances produce disastrous cyclonic storms that cause tremendous damage to society. Cyclones and floods are the frequently occurring and most commonly recognised natural hazards that have their origin in the atmosphere. A snow avalanche, a landslide, a rock fall or even a simple slope failure always results from some disturbance somewhere. All these natural hazards, regardless of their origin and depending on their intensity, cause huge loss of life and property and occasionally change the appearance of the land they visit.

Natural hazards are the balancing acts of nature and existed even before the humans arrived on the scene. Since many of these balancing acts of nature affected humanity adversely, we labelled them as natural hazards or natural disasters.

Natural hazards are episodic and their occurrence cannot be predicted much in advance. While incidents like earthquakes occur suddenly without any prior indication, those related to atmosphere, like cyclones and floods, involving the process of their development and movement, offer enough indication of their visitation, a day or two in advance. This helps in taking mitigating measures to avert or lessen the impact of such natural hazards.

In the context of the North-East region, the most common natural hazards are:

1. Floods and droughts
2. Earthquakes
3. Landslides

Each one of these could be variously destructive depending on the severity of the event.

7.1 Floods

The two principal rivers of the region, Brahmaputra and Barak, have an annual flood regime. There is no monsoon period, when the mighty Brahmaputra does not experience floods. The only variant is the severity and destructiveness of the flood. Sometimes, a flood is accompanied by another hazard, as it happened on the 15 August 1950, when a flooded Brahmaputra experienced the most severe earthquake of the century, causing unprecedented damage to the profile of the river and the regional landscape as much as to the people and their property.

7.1.1 Causes of Floods in Brahmaputra

The floods in Brahmaputra, as in any other river, occur when the discharge at any point on the long profile of the river exceeds the bankful discharge of the river. In deeply incised channels, there is hardly any chance of flood: an increase in discharge remains confined in the deep gorge like channels of the rivers. But, in open channels, dovetailed with their flood plains, a very high discharge, when it exceeds the bankful discharge capacity of the channel, spills onto the flood plain, causing floods.

The three factors that can be directly related to floods in the Brahmaputra are as follows: (1) intensity of rainfall, (2) gradient of the longitudinal profile of the river in the region and (3) basin ratio, i.e. the area of the catchment, divided by the length of the river, at a specific point on the river. This would be determined largely by the shape of the basin. There could be exceptions, as in the case of deeply incised river channels.

7.1.1.1 Amount and Intensity of Rain

It need not be emphasised that Brahmaputra catchment, in India, receives a relatively heavy rainfall. The mean annual rainfall for the entire catchment, in India, is 2,678 mm with a coefficient of variation of 8.2 % (IMD 1981). Hourly intensity of rainfall being an unavailable, daily intensity of data for the rainiest month is obtained by dividing the rainfall of the month by the number of rainy days in the month. Leaving aside a few places, like Lumding in the rain shadow of Barail range, most places in Brahmaputra valley receive an average daily rainfall of 20–35 mm, during the rainy months. The heavy episodic rainfall associated with depressions lingering in the catchment of the river, is what gives the river a sudden high discharge, progressively increasing downstream. The most recent case of high-intensity rainfall in Assam was in June 2012, when Assam received nearly 510 mm of rainfall between 1 June and 27 June, 31 % in excess of normal rainfall of 388 mm. The result was the most devastating flood of the decade.

7.1.1.2 Longitudinal Gradient

The distance between Dibrugarh (111 m ASL), an easternmost town of Assam on Brahmaputra, and Dhubri (45 m ASL), a westernmost town of Assam, beyond which the river enters Bangladesh is roughly 650 km. The difference in the height of these two towns on Brahmaputra is 66 m. This gives a descent of roughly 1 m from east to west, for every 10 km length of the river. Even, this gradient is variable as the slope declines westward. This very low gradient is partly responsible for the floods in Brahmaputra.

7.1.1.3 Basin Ratio

The catchment of Brahmaputra at Dhubri, including the area of Bhutan, is roughly 220,000 sq km. Taking the length of Brahmaputra in India to be around 850 km, the basin ratio will come to 260 km^2 of catchment, per km length of the river at Dhubri. This ratio will change from point to point depending on the shape of the basin. But, this ratio is quite substantial to cause floods in an area having an annual mean rainfall of over 2,500 mm and a river gradient of 1 m for every 10 km length of the river.

7.1.2 Discharge Characteristics and Floods in Brahmaputra

The floods in Brahmaputra, as well as in Barak, occur during the period of summer monsoons, more commonly between July and August when the rivers have the maximum discharge. Brahmaputra has an average annual discharge of about 19,200 cumecs (678,000 cusecs) which is nearly twice that of Ganges (Parua 2003), though for a period of 35 years Sarma (2005) has given a mean annual discharge at Pandu to be 16,682 cumecs. The maximum discharge of Brahmaputra as computed for the purpose of designing a bridge on Brahmaputra at Pandu (Guwahati) was measured as 19.5 lakh (1.9 million) cusecs, and the corresponding discharge at Dhubri was reckoned to be about 22 lakh (2.2 million) cusecs (Hazarika 1990). The highest ever recorded flood discharge in Brahmaputra at Pandu (Guwahati) was 72,148 m^3/s in 1962 (Goswami 1998, 2007). The maximum discharge of Barak flowing through Cachar is 181,000 cusecs (5,122 m^3/s).

Brahmaputra has a catchment of 178,213 km^2 in the North-Eastern states of India, of which about 47 % is in Arunachal Pradesh, over 40 % in Assam and 6 % each in Nagaland and Meghalaya. With an average rainfall of 2,678 mm, the basin receives 485 billion cubic metre of water, all discharged finally through the principal river Brahmaputra, much of it during the four monsoon months from June to September. The valley is 70–75 km wide, bordered by rising mountains on both sides of the valley, north and south. The channel, about 5 km in width and lying in the centre, is highly braided, with a series of streams criss-crossing a number of sandbars and islands which occur all through the length of the river, in Assam, a distance of 750 km, from Pasighat, where the river leaves the mountains of Arunachal Pradesh, to Dhubri where the river turns southward to enter in Bangladesh. Besides the normal discharge, it has to transport a heavy sediment load brought by the tributary streams, over a very gentle gradient of 10–12 cm/km.

7.1.2.1 The Area Affected by Floods

With the exception of Karbi-Anglong and North Cachar hills, all the districts of Assam are affected by floods. The districts which receive maximum impact are Dibrugarh, Dhemaji, North Lakhimpur, Sonitpur, Bongaigaon and Dhubri. Usually, the districts on the northern side of Brahmaputra are more susceptible to flood, because of important tributaries of Brahmaputra, like Subansiri and Kameng, joining the Brahmaputra on the northern bank. These tributaries with their large catchment contribute not only a large discharge but even a disproportionately large sediment load that adds to the impact of the floods. The excess load beyond the capacity of the main river is dumped on its flood plain, damaging at least temporarily the field and the crops.

Table 7.1 Severe flood years in Assam

These years were marked by floods submerging the northern bank of the river	1897,1910, 1911, 1915, 1916, 1931
Flood years in Assam	1950, 1954, 1962, 1966, 1972, 1974, 1977, 1978, 1984, 1986–2000 (each year)

Source: Revenue Department, Government of Assam:1

The area affected by Brahmaputra floods varies from one to three million hectares, but in years of unprecedented floods, as it happened in 1988, almost half the area of Assam (i.e. four million hectares) is affected, and over a million hectares of crops are damaged. In 1987–1988, over 100,000 cattle were lost, and the loss of human lives amounted to over 200. The floods are virtually an annual feature, only some years like 1978 are flood-free. Sometimes, these floods occur in successive waves depending on the prolonged duration of the depressions over the valley bringing heavy rainfall.

Besides the main reasons for the floods, explained earlier, that lead to a very high discharge, much above the bankful discharge of the river, there is an additional reason. All through the history of Assam, successive ruling dynasties have built embankments on both sides of the river, largely to protect the land and the villages from high floods, but equally to use these embankments as perennial land routes. Today, Assam has 4,465 km of embankments along its rivers. A breach or two in these embankments, during the floods, exposes the area behind these embankments to flood fury, not only inundating villages and croplands, but sometimes even washing away people.

The severe flood years in Assam are recorded in Table 7.1:

The floods in Brahmaputra occur any time between May and September, though July and August show the highest frequency of floods. The number of years that witness flood in Brahmaputra is far greater than the number of flood-free years. Besides the visible impact like destruction of cropland, submergence of villages and loss of life and property, there are also changes in the course, profile, depth and level of sedimentation in the course of the river. Almost the entire course of Brahmaputra in Assam is braided and the nature of braiding changes after every flood. Silting of the river channel is also affected every year. It is estimated that the river has over 6 m thick sand deposit in its course. In some parts of flood-affected areas, soil erosion also occurs.

The most severe flood years were 1987 and 1988. The impact of floods on Assam's land and people from 1973 to 2000, as reported by Revenue Department of Government of Assam, is noted below.

7.1.2.2 Impact of the Floods

The floods in the river not only mean exceptional discharge above the bankfull discharge level; it also implies bank erosion in some areas and deposition of sediments in others. Other changes include breach in embankments, destruction

Photo 7.1 Brahmaputra in flood (Photo Dasrath Deka)

of crops, houses and damage to other properties. Cattle are washed away, trees are uprooted and wildlife is threatened and often perishes in the process of emergency migration (Photo 7.1). Many plants and animals suffer huge and sometimes irreparable damage. Some of the wildlife sanctuaries like Kaziranga suffer greatly, as animals trying to escape meet death in road accidents. Others are caught by unsocial elements.

The impact of the flood is usually assessed by the damage caused to the people, their life and property and to the economy of the region in general. Besides, there are also damages to public property like roads and bridges, public buildings and means of transport and communication. It takes time to recover from the ravages of the floods, and some time the impact lasts for several years. The landscape of the areas and the economy are also affected in different ways, as the work of rehabilitation of the affected people and the repairs of infrastructures slows down the economy. The concrete way in which damages are assessed is by the area affected, loss of human life and cattle, population affected, cropped area damaged and damages to house property, crops and public utilities and other infrastructures. Some of the details of the losses caused by floods in Assam are given in Table 7.2, through a summary of flood damages in Assam, for a period of four decades (1953–1995).

The severity of the floods in Brahmaputra varies from year to year. But the most severe flood in the river occurred in 1988, the year of maximum damage to life and property in the state. The 1988 flood in Brahmaputra was by far the most devastating known in the history of Assam. Roughly 38,000 km^2 of land, almost half the area of the state, was affected during floods in 1988, damaging 12,000 km^2 of cropped land and half a million houses in the state. If the hilly areas of Karbi-Anglong and North Cachar hills were to be excluded, about three-fourths of the area of Assam went

Table 7.2 Summary of flood damages in Assam (1953–1995)

Ȋtem	Total	Maximum
Area affected	41,600 km^2	38,200 km^2 (1988)
Population affected (in millions)	98.10	10.47 (1987)
Damage in crops		
(A) Area	50,800 km^2	11,300 km^2 (1988)
(B) Cost (Rs. crores)	3288.31	334.10 (1988)
Damage to houses		
(A) In numbers	33,27,189	4,99,835 (1988)
(B) Cost (in Rs. crores)	296.80	103.92 (1988)
Number of cattle lost	431,537	108,913 (1987)
Number of human lives lost	1,724	226
Damage to public utility in Rs. crores	832.42	255.82 (1988)

Source: Revenue Department, Government of Assam:2

Table 7.3 Damages caused by Floods in Assam

Nature of damage	1973	1978	1983	1988	1992	1998	1999
Area affected/lakh (100,000) hectares	10.262	3.06	7.36	38.2	2.31	9.66	2.23
Cropped area affected/lakh hectares	2.94	1.18	NA	1.13	0.042	2.89	NA
No. of villages affected	NA	NA	NA	NA	NA	5,298	1,503
Population affected (in lakhs)	22.09	9.17	22.57	84.1	9.71	NA	8.9
No. of houses damaged	29,596	NA	NA	618,272	15,117	29,791	NA
Human lives lost	19	02	23	232	12	102	03

Source: Revenue Department, Government of Assam:5–8

under water in 1988. The severity of soil erosion is the highest in North Lakhimpur district followed by Darrang and other districts. The 1990s were the years of severe floods in Assam (Table 7.3)

It must be noted that the area submerged and the areas with maximum damage to crops don't always coincide and depend on the timing of the flood. Very early floods, like the one in May, do not cause much damage to the crops.

It is generally believed that the frequency and severity of floods in Assam have increased during the recent decades. The increased frequency is attributed to a number of factors like deforestation in the catchment, increase in the area of cultivated land and building up of a large number of cultural features, particularly the railroads and bridges that have the effect of constricting the channel flow and forcing it to rise. The hills of Karbi-Anglong as well as those of Kamrup district restrict the floods from spreading much to the south, though rising floodwaters of Brahmaputra block the free flow of its tributaries like Kopili and Dhansiri, in their confluence zone, which, in a condition of choked flow, rise in floods. There is no cyclic occurrence of floods, though there are casual observations that a severe flood is a triennial phenomenon. Besides Brahmaputra, the river Barak, in the southern part of the state, draining the districts of Cachar, Karimganj and Hailakandi, is periodically in spate, but the floods are not as severe as in Brahmaputra (Table 7.4).

Table 7.4 Group of districts in Assam shown according to severity of floods

Districts almost immune to floods	Districts with light to moderate floods	Districts with severe floods	Districts with very severe floods
N. Cachar, Karbi-Anglong, Kokrajhar, Bongaigaon, Tinsukia	Dibrugarh, Cachar, Darrang	Goalpara, Kamrup, Sibsagar	Lakhimpur, Dhemaji, Golaghat, Jorhat, Barpeta

In a severe flood, roughly 5,000 villages, i.e. about 20 % of the total rural settlements, are affected and 10,000 km^2 of land, i.e. about 12–13 % of the area of the state, is submerged. It was only in the exceptional flood of 1988 that over half the area of the State was affected. It is estimated that 'Assam has lost 429,000 ha (4,290 km^2) of land, roughly 5.5 % of the area of the state to river bank erosion, with 130,000 families left landless' (Kashyap 2012).

7.1.2.3 A Brief Description of Assam Flood of 2012

A brief account of Assam flood, as it occurred in July 2012, is provided here to give a glimpse of the floods in Assam. The last severe flood in Brahmaputra before 2012 occurred in 2004, after which several measures were taken by the State as well Central Governments. The flood of 2012, despite the safety measures undertaken by the State Government and the National Disaster Management Authority, proved quite disastrous. The floods have washed away 20 bridges and culverts and damaged 191 bridges, besides washing away approaches to 575 bridges and 230 culverts. The river has breached embankments in Tinsukia, Dhemaji and Sonitpur districts and on the river island of Majuli. At least 77 people have lost their lives. Around two million people are affected and nearly half a million are temporarily accommodated in relief camps (Kashyap 2012). Many of the villagers remain stranded in knee-deep water in their houses, for fear of losing their belongings.

7.1.2.4 Floods in Arunachal Pradesh

The lower regions of Arunachal Pradesh, bordering Assam, are susceptible to minor floods. The floods occur in lower regions of Subansiri, Ranga and Dirang valleys. The district of Pasighat, where Siang (later known as Brahmaputra) debouches from the mountainous region, also experiences floods in some years. The northern tributaries of Brahmaputra, still in a phase of incision, collect not only the rainfall of their catchment but also a large sediment load derived from the stripping of the weathered mantle, perched on the divides and the valley side slopes. Flowing on a steep gradient, the two principal northern tributaries, Subansiri and Kameng, rising at around 3,000 m in the Himalayas, join the sluggishly flowing Brahmaputra, at around 100 m ASL. During high waters, Brahmaputra, the principal river, chokes the flow of water from these tributary streams, causing flood in their lower reaches and forcing them to dump their sediments transported from upstream, in the confluence region, giving rise to a river delta. It may be noted that Subansiri has turned southwest wards, avoiding the river island of Majuli, which is like a river delta, formed by Subansiri at its earlier confluence with Brahmaputra.

7.1.3 Flood Control Measures

The most common practice to protect the land from the fury of the flood is the building of embankments. This kind of device has existed in Assam from the medieval periods. The Ahoms and the Koches were the patron builders of such embankments, which, while saving the territory in the immediate hinterland, constrict the flow of floodwater raising the flood level and causing occasional breaches in the embankments. In years of severe flood, the risk of submergence of land behind the embankments, following sudden breaches in them, is real. Dredging, as a measure to limit the flood level, has never been seriously undertaken. Some dredging operations were undertaken in the past to facilitate river navigation, but it has never been a serious enterprise, as it is generally believed that in a river with a width of 5–7 km, it is not a practical solution. It may be mentioned that there is no dearth of funds, but these are utilised for relief and rehabilitation. Flood control in Brahmaputra is still a far cry.

7.1.3.1 A Suggested Measure to Moderate Floods

Adaptation to any situation is inherent in nature. Excessive braiding, sometimes resulting in additional lateral channels, is an adaptation to excessive sediment load. The lateral stream, Kalang, taking off from Brahmaputra on its left bank at Jakhalabandha, swinging southward in a broad arc and joining Brahmaputra downstream, at a point 25 km east of Guwahati, is a facilitating device of nature to ameliorate the flow condition of Brahmaputra by partially sharing the work of the latter. Similar is the case of Kherkutia river, a channel branching off from Brahmaputra, on its right bank opposite Sibsagar, and joining Subansiri about 35–40 km further down. These loops of Brahmaputra, branching off and then rejoining, can serve as examples to be emulated in designing the flood control structures along the river.

These natural loops can be replicated by transforming Brahmaputra into an organised multi-channel stream, in which the subsidiary lateral channels, flowing parallel to Brahmaputra, like canals, would join Brahmaputra further down. A lattice of several such streams on alternate bank could perhaps ameliorate the flood situation and could also be used as irrigation canals during dry season. As for flood warnings, the mechanism has seen improvement during the last few decades, with more rain gauges in the catchment and stage and discharge monitoring stations set up on Brahmaputra and its tributaries.

7.2 Earthquakes

Though not as common and widespread as the floods, earthquakes form the second most damaging natural hazard in the North-East. In India, the Himalayan region is seismically the most active region with a high frequency of earthquakes. The North-East is an extension of the Himalayan zone of convergence of the Indian and Central Asian plate on the one hand and Indian and the Burmese plate on the other and experiences frequent tremors and earthquakes, sometimes with unprecedented severity.

The intensity of earthquakes is measured on a Richter scale, which ranges from 0 to 10. On the basis of this scale, the earthquakes are grouped into four descriptive classes:

Class of earthquake	Magnitude on Richter scale
1. Slight	<4.9
2. Moderate	5–6.9
3. Great	7–7.9
4. Very great	>8

India is divided into five zones, on the basis of the frequency and intensity of earthquakes. In this scheme the zone I is least susceptible and the zone V is the most susceptible region of the county. The North-East (all the seven states) is included in the seismic zone V. The other areas in the seismic zone V are Kutch, Andamans and a few isolated pockets in the Himalayan region. The entire Himalayan belt is in zone IV, which though seismically active has not experienced earthquakes, as severe as the North-East.

7.2.1 Earthquakes in the North-Eastern Region

The earthquakes in the region, as elsewhere, occur in the contact zone of plate boundaries or along the lines of structural weakness, like the Main Boundary Fault (MBF) or the Main Central Thrust (MCT) in the Himalayan region or along a chain of thrusts extending from Lohit district (with Mishmi fault) in the north to Manipur and further south. The plate boundaries are the most active sites of earthquakes. The most important reason for the earthquakes in the region is the collision of Indian and Tibetan plates on the north and the Indian and the Burmese plates on the eastern boundary of the region. Additional evidence comes from the focal mechanism studies. Gupta (1974) observes that: *Between Hindukush and Burma the earthquakes are scattered widely and are restricted to shallow focal depths. The focal mechanism studies indicate predominance of thrusting. In Burma the focal zone dips towards east. Under thrusting of the lithospheric block in the same direction has been indicated by the focal mechanism studies*. In the North-East, the Lohit valley with Mishmi fault is the scene of frequent tremors. Small earthquakes, not very consequential,

Table 7.5 Some of the major earthquakes that occurred in the North-East

Date	Place and region	Severity on Richter scale	Other earthquakes in the last 500 years	
10-01-1869	Cachar (Assam)	8.0	1. 1548	8. 1759
12-06-1897	Shillong plateau	8.7	2. 1598	9. 1770
08-07-1918	Assam	7.6	3. 1601	10. 1838
02-07-1930	Dhubri (Assam)	7.1	4. 1642	11. 1842
23-10-1943	Assam	7.2	5. 1660	12. 1875
15-08-1950	Assam	8.5	6. 1696	
06-08-1988	Indo-Burma border	7.2	7. 1732	

Source: Indian Meteorological Department (2001), Gazetteer of Assam State, Kamrup (1990)

are frequent in the region. 'Between 1970 and 1973, 2,500 earthquakes were recorded within a radial distance of 450 km from Shillong' (Mallick 1984). The Dhubri fault, west of Meghalaya, and the Dauki fault in its south are also the active zones of earthquakes (Table 7.5)

Besides the earthquakes mentioned above, there must have been earthquakes in earlier centuries as well of which we don't have a record. One of the very severe earthquakes of which no elaborate account is available is that of the year 1663, 'which took place during Mir Jumlah's retreat from Garhgaon, and is said to have lasted for half an hour. Another, occurring in Rudra Singh's reign did serious damage to a number of temples' (Gait reprint 2005:331).

The two most severe earthquakes, during the last hundred years, were those of 1897 and 1950. The latter one is still fresh in the memory of elderly people.

7.2.2 The Indelible Impact of 1897 Earthquake

The 1897 earthquake of Shillong surpassed in intensity all the previously recorded earthquakes. The epicentre of the earthquake was near Shillong. It had an intensity of 8.7 on the Richter scale and occurred at 05:15 P.M. on 12 June 1897 and lasted for 3 min 30 s. The aftershocks continued for several days, and on 19 June again, there was a severe shock (Chief Commissioner Assam 1897). The drainage lines were disturbed. At Guwahati, Brahmaputra rose more than 7 ft. '*The earthquake was felt over an area of 1.75 million square miles (4.53 million km^2) from Rangoon on the southeast to Kangra in the northwest, from the Himalaya to Massulipatam, and serious damage done to masonry building over an area of 145,000 sq. miles*[1]' (Allen 1905).

'The shock occurred in Guwahati a little after 5 P.M. on 12 June 1897 and was so violent that every masonry building in the town was wrecked. All the public offices

[1]Memoirs of the Geological Survey of India vol. XXIX, p 52, quoted from B C Allen (1905) Assam District Gazetteer, vol. IV, Kamrup, p 14.

Table 7.6 Shillong earthquake 1897

District	Number of deaths
Khasi, Jaintia hills	916
Sylhet	545
Kamrup	29
Garo Hills	27
Darrang	12
Goalpara	5
Nowgong	3
Cachar	3
Sibsagar	2
Total	1,542

collapsed with the exception of the post and telegraph office, the training school and the Dak bungalow…. In many parts of the district (Kamrup), fields were covered with water or deposits of sand. Ordinary drainage channels were choked, the beds of rivers were raised and the town of Barpeta, which was built on comparatively low ground, was at once submerged' (Chief Commissioner, Assam 1897).

The total loss of life, in the nine districts, was 1,542, with the largest number of casualties in Khasi and Jaintia hills. Table 7.6 presents the district wise break-up of deaths.

Another earthquake, though of far lesser intensity, had occurred in the area on 10 January 1869, causing considerable damage in Manipur, Cachar and eastern part of Barak valley.

7.2.3 The 1950 Earthquake

The earthquake occurred on 15 August 1950, during the rainy season when rivers were flooded and witnessed far greater damage by way of landslides, raising of the river beds, change of river courses, emergence of river islands and a great loss of life and property.

While the 1897 earthquake had most devastating effect in Sylhet, Cachar and Meghalaya plateau and Western Assam, the 1950 earthquake had its epicentre at Rima, beyond the headwaters of Lohit, in Tibet. The impact of the earthquake was disastrous in Eastern Assam and parts of Arunachal Pradesh. This was the greatest recorded earthquake in the history of Eastern Assam and Arunachal Pradesh. The tremors continued for a number of days.

> Hills were shaken and millions of tons of rocks rolled down the hill with explosions and agonising and deafening sound. A large cloud of dust developed over a vast area. The faces of hills pealed off not leaving a shred of vegetation and hardly any tree was visible where there were thick forests. Many parts of the land were made desolate. (Choudhury 1978:12)

Several small rivers were blocked by landslides and choked by debris as large amount of mud was thrown into rivers. When the breach of these blockages occurred severe floods took place. There were changes in the course of the rivers. Sadya was completely destroyed and washed away by the floodwaters of Lohit. The river Brahmaputra was badly affected, especially in the upper course; a number of shoals appeared; and the river navigation came to a grinding halt. Even today, Brahmaputra is not an effective waterway as it used to be before 1950.

7.3 Landslides

Landslides are a phenomenon of the rainy mountainous areas of the world. Structure, no doubt, plays a part. A concurrence of the dip slope with the general topographic slope is the most facilitating factor. In areas of asymmetrical valleys, the gentler valley sides coinciding with the dip slopes are more vulnerable to landslides. The lithologic character of rocks is equally important. Rocks, like shale with parallel bedding planes, are far more susceptible to sliding. The structure is helped by rainfall and its infiltration creating lubricating surfaces that accelerate landslides. In case of thick overlying weathered mantle or loose earth material perched on slopes, the angle of repose is critical, beyond which the weathered mantle cannot remain perched and slides down. This depends on the composition and texture of the weathered material. The role of vegetation is important as the roots of vegetation work as a binding agent to prevent the weathered rocks from sliding. All these factors are helped by external as well internal agents. Excessive rain in a terrain with high infiltration capacity promotes landslides. But the most potent factor is 'seismic tremor'. The frequent seismic tremors in the North-East provide the trigger effect. With the tremors, the delicately balanced rock or weathered material comes down as landslides.

Anthropogenic factors are a cause for increased frequency of landslides. Human interference works in multiple ways, deforestation, conversion of sloping land into agricultural fields and cutting of hillsides for road building or other constructional purposes.

North-East is notorious for occurrence of frequent landslides, large and small. Since the area is seismically active, frequent tremors bring down the weathered mantle, perched on the slopes. Most of the landslides occur in the rainy season when the interface between the weathered mantle and the bedrocks provides the sliding surface. More often, slope failures result from cutting the hillsides for roads. Deforestation, construction of roads, coupled with incessant rains subjected to seismic tremors result in landslides.

The states most affected by landslides are Mizoram, Manipur and Arunachal Pradesh. Tiwari and his associates (1996:96) have studied a series of landslides in Mizoram, of which the two most severe are those of Bawngkawn (23°45′30″N and 92°44′E) and South Hlimen (23°41′ N and 92°43′ E), which are very significant. The Bawngkawn landslide located on the northern outskirt of Aizawl, occurring on 17 September 1994, caused disruption of traffic on Aizawl–Lunglei road for 3 days, as the entire area was covered with the debris and other clastic material sliding down from the upper segments of slope. Two factors that seem to have caused this landslide are as follows: (1) the instability of a fault in the vicinity and (2) the high

Photo 7.2 The Rengtekawn landslide, Mizoram (Photo Dr. R P Tiwari)

dipping anticlinal folds in argillaceous and arenaceous rocks of Neogene period. The tectonic instability coupled with steeply dipping fold facilitated a slide down of weathered and partially weathered rocks (Photo 7.2).

The second landslide occurred in a 300-m-long quarry having a depth of 250 m., at a village called South Hlimen (23°41′ N and 92°43′ E), about 6 km south of Aizawl, the capital of Mizoram. The landslide occurred on 9 Aug 1992. This was the most disastrous landslide that the North-East had ever witnessed, causing the death of reportedly 100 persons. The E-W-trending vertical joints intersected with E-W-trending vertical joint planes had resolved the area into huge blocks. 'With the continuous removal of toe material, the natural support for the uphill blocks was losing and thus the stability got disturbed and ultimately these were subjected to free fall along the bedding planes' (Tiwari and Kumar 1997). In this case the intersection of the bedding and joint planes had loosened the material considerably to stand any undercutting and leading to ultimate collapse. Similarly, a landslide in 1995 devastated the town of Saiha and Lawngtlai causing the death of 34 people (Awasthy 2003). In Nagaland, on the other hand, Awasthi has attributed 'high saturation of slope-forming material, with water through surface and sub-surface induction and the shaking of the ground, triggered by the 6 August 1988 earthquake, as the major causative factors' for the landslide in Mon district, near Tuli Paper Mill.

In Manipur, Okendro and Kushwaha (2008) have studied the incidence of landslides along National Highway No. 53, in a linear stretch of about 10 km, and identified

Photo 7.3 Landslide on NH-52A near Pahalwan Mod, Arunachal Pradesh (Photo Dr. (Ms.) Tage Rupa)

16 landslides, a majority of them attributed to anthropogenic causes. The underlying fact, in most cases, is the assumption that since the area lies in the Indo-Myanmar unstable zone, because of its being on the plate boundaries, a slight disturbance causes landslides on precariously balanced slopes. Most of these slides occurring along the road section are mainly due to anthropogenic activities, except a few, which are natural. 'Out of the total landslides about 44 % are anthropogenic, 31 % natural, and the remaining 25 % are compound in nature. The Churachandpur-Mao thrust, the regional fault believed to be the western boundary of the Indo-Myanmar subduction zone, is, as suggested by seismological evidences, tectonically active due to strike slip movement' (Kumar and Singh 2008). This active north–south-trending thrust, dividing Manipur in two halves, western and eastern, should be the most active zone of landslides in the state. Trilochan Singh (2003) in his traverse of Arunachal on Tezpur–Bomdila–Tawang route discovered a large number of landslides. This is the mobile zone of the North-East, with steep slopes and heavy rain, where a little tremor causes immediate landslides.

Most studies of the landslides, in the North-East region, show a roadside location. In such a situation, slope failure is the obvious triggering point for landslides. This concentration of landslides on the roadsides raises the question – whether the landslides occur more frequently on the roadsides or that this reflects the choice of investigators who prefer traversing largely along the roads for reasons of easy movement (Photo 7.3). Whatever the reason, landslides are a menace for the region and preventive measures need to be taken. The task of addressing this problem is undertaken by the Geological Survey of India (GSI) who is fully committed to introduce preventive measures, wherever necessary.

7.3.1 Protection Against Natural Hazards

In case of floods, advance warning is an effective way. To effect this, a number of rain gauges in different areas and gauge and discharge stations have been increased in the Brahmaputra basin to enable the administration to have advance warning about the impending danger of flood.

As for the earthquakes, they cannot be predicted, yet to understand where and how frequent are the tremors, more seismographs have been of late installed. In the 1980s, five more were operated by IMD at Shillong, Tura, Agartala, Imphal and Lekhapani (in Mishmi Hills). Now more seismographs have been installed in Arunachal Pradesh and Nagaland. This should, if at all, help understand the possibility of earthquakes in certain areas better. And for landslides, the cooperation of people is necessary to avoid unhealthy practices of land use.

References

Allen BC (1905) Assam district gazetteer, vol IV, p 14 quoted from Oldham RD (1898) Report on the great earthquake of 12th June 1897. Memoirs GSI 29:52

Awasthy AK (2003) A brief review of the investigations of landslides in North-East India. In: Husain Z (ed) Environmental issues in North-East India. Regency Publications, New Delhi, pp 3–10, published for NECSSR. Shillong

Chief Commissioner of Assam (1897) Report on the earthquake of June 12, 1897. Submitted to the Secretary, Government of India, 14 Aug 1897, p 4

Choudhury DS (1978) Gazetteer of India, Arunachal Pradesh, Lohit district, p 12

Gait EA (1905-reprint-2005) A history of Assam. LBS Publications, Guwahati, p 331

Goswami DC (1998) Fluvial regime and flood hydrology of the Brahmaputra river, Assam. In: Kale VS (ed) Flood studies in India, vol 41. GSI Memoir, Bangalore, pp 53–75

Goswami DC (2007) Flood forecasting in the Brahmaputra River, India, a case study. Documents. http://www.southasianfloods.org/document/ftb/index.html. Accessed 9 June 2007

Government of Assam (1990) Gazetteer of Assam State. Government of Assam, Kamrup, p 32

Gupta KK (1974) Some seismological observations and tectonics from Hindukush to Burma region. Himal Geol 4(pt.1):465–480

Hazarika BB (1990) Gazetteer of India, Assam State, Kamrup district. Government of Assam, Guwahati

India Meteorological Department (IMD) (1981) A study in trends and periodicities of rainfall, over Brahmaputra catchment. Basin Hydrometry. Monograph no. 9:14

India Meteorological Department (IMD) (2001) Earthquakes and safety measures, p 5 (a pamphlet)

Kashyap, SG (2012) Flood of struggles. Indian Express, Guwahati, July 1, 2012

Kumar A, Singh B (2008) Measurements of active deformation by installation of 3D fault deformeter in Manipur. Indian Landslides 1(1):37–39

Mallick LK (1984) Seismological set-up of Northeast India. In: Tripathi RS (ed) Resource potential of Northeast India, vol II. Meghalaya Science Society, Shillong, pp 7–21

Okendro M, Kushwaha RAS (2008) Landslide incidences along part of NH 53, between Noney and Nungba, Manipur. Indian Landslides 1(1):41–44, National Institute of Infotech Management (NIIM), Shillong

Parua PK (2003) Flood management in Ganga-Brahmaputra-Meghna basin: some aspects of regional co-operation. Civil Engineering Today 2003:68–75, ASCE-IS, Calcutta

Revenue Department, Government of Assam. http://www.dhemaji.nic.in/flood/flood_history.htm. pp 1–2

Sarma JN (2005) Fluvial process and morphology of the Brahmaputra River in Assam, India. Geomorphology 70:226–256

Singh T (2003) Geo-environmental hazards vis-à-vis restless Arunachal Pradesh. In: Husain Z (ed) Environmental issues of North-East India. Regency Publications, New Delhi, pp 11–20, published for NECSSR, Shillong

Tiwari RP, Kumar S (1997) South Hlimen landslide in Mizoram – a pointer. ENVIS Bull Himal Ecol Dev 5(2):12–13

Tiwari RP, Sharma BL, Singh B (1996) Geotechnical appraisal of Bawngkawn Landslide, Aizawl, Mizoram. In: Proceedings of the international conference on disaster and mitigation, Madras, pp 125–131