LANDSLIDE INVENTORY AND LAND-USE MAPPING, DEM PREPARATION, PRECIPITATION THRESHOLD VALUE AND ESTABLISHMENT OFEARLY WARNING DEVICES

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Comprehensive Disaster Management Programme-II (CDMP-II)
Ministry of Food and Disaster Management (MoFDM)
Disaster Management and Relief Division (DMRD)
Government of the People's Republic of Bangladesh

Rainfall Triggered Landslide Hazard Zonation in Cox's Bazar & Teknaf Municipalities as well as Introducing Community-based Early Warning System for Landslide Hazard Management

Revised Report on Landslide Inventory and Land-use Mapping, DEM Preparation, Precipitation Threshold Value & Establishment of Early Warning Devices

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Landslide Inventory Mapping, Land-use Mapping and DEM Preparation

Executive Summery

In recent years many landslide events have been experienced in hilly districts of Bangladesh such as Chittagong, Cox's Bazaar, and Teknaf. It shows that a significant landslide hazard exists for such urban centers and many communities are vulnerable to this newly known type of hazard in Bangladesh, which may result in severe damages and severe socio-economic consequences in future in many other areas too. The urban centers which are threatened by the landslide events in the recent past are fast growing and with considerable influence in the economic developments of the country. It is therefore essential to have a realistic understanding of the nature, severity and consequences of likely damages and losses that possible future landslide events could cause on the vulnerable communities living near the landslide hazard prone areas and to develop a model for landslide risk management.

The key to success in future is the study of the events occurred in the past and takes appropriate proactive actions using the lessons learned. It is necessary to have a critical evaluation of the facts associated with past landslides and more importantly why there is a sudden increase in number of landslides and their magnitude in the two target cities. Also the findings of such study will serve as the basis for studies in other cities such as Chittagong where similar escalation of landslide events have taken place.

This report is prepared to summarize the findings of the activity for Inventorying the past landslide events in Cox's Bazaar and Teknaf Municipalities .The activity has been carried out under the Project on "Rainfall Triggered Landslide Hazard Zonation in Cox's Bazaar and Teknaf Municipalities for Introducing a Community-based Early Warning System for Landslide Hazard Management".

Any type of landslide risk evaluation aims to determine the "expected degree of loss due to a landslide" (specific risk) and the expected number of live lost, people injured, damage to property and disruption of economic activity (total risk) (Varnes et al., 1984). The activity for "Preparation of the Inventory of past landslide events in two target cities" namely Teknaf and Cox's Bazar, has been carried out with three specific purposes:

a. recording all facts connected to past landslide events in two cities to facilitate analysis of causative factors and corresponding impacts;
b. Identification of hotspots (or most vulnerable wards/urban settlements) of landslides;
c. Assess the degree of attributes of trigger of landslides in connection to all causative factors and modifying the weightings assigned to attributes selected as map units if necessary.

It is not the ideal situation to study the landslide events several months after the occurrence of the event. Many important factors may be lost with the passage of time and investigation team will have difficulties in postulating the scenarios at the time of the disaster. However during the execution of the activity, emphasis has been placed on postulating the event as it happened, and subsequently evaluating the post disaster scenario. In addition we have made an attempt to study the current status of the location and providing a description of the postulated scenario as well as the future threat, to succeed towards an evaluation of the exposure and a characterization of the future risk.

In the case of Teknaf and Cox's Bazaar following information related to past landslides has been collected through collection of past reports prepared by other agencies, field investigations, interviews with community members, discussions with local authorities etc in order to develop the inventory of landslides for last 25 years:

1. Location (coordinates –latitude and longitude- or at least name of nearest village/city).
2. Date (and if possible, time) of occurrence for postulating the scenario.
3. Rainfall data
4. Provide a description of the geological and geotechnical conditions of the site as we can witness now
5. Immediate consequences (quantification of casualties, injuries and damage) of the event.
6. Any other evidences to support definition of the future threat and to postulate the trigger mechanisms

In developing the inventory our team has gone through several steps and the report comprises the outcome of combined efforts. The first step was to study the old newspaper records and prepare the chronology of events as given in the media reports. The project team has visited archives of few national newspapers and collected the details which are given in the report. A team have had extensive efforts in order to collect information related to past at least 25 years from the field. In the same way Project team has studied the previous landslide reports prepared by District and Sub-district administration, respective LGED offices etc. The information provided by the institutions located in two cities such as the Department of Forest, Meteorological Department, armed force division etc also were very useful. The reports available with other agencies such as Geological Survey of Bangladesh, Disaster Management Bureau, and Dhaka university-Faculty of Geology, Chittagong University of Engineering technology (CUET) etc. also provided very useful information on past events.

The Project team wishes to acknowledge thankfully the assistance provided by all above mentioned institutions in preparing this report.

Based on the data collected from the combined methods explained above and thro' interviews of the community members, a Landslide Inventory for two target cities have been prepared. The accompanying map indicates the locations of all events that have been studied. The team also has carried out an assessment on the degree of attributes of trigger of landslides in connection to all causative factors and modifying the weightings assigned to attributes selected as map units if necessary.

This report has been accomplished as part of project on "Rainfall Triggered Landslide Hazard Zonation in Cox's Bazaar and Teknaf Municipalities for Introducing a Community-based Early Warning System for Landslide Hazard Management", CDMP has commissioned and allocated the responsibility for implementing the project to DatEx-ADPC Joint Venture. The Project is being implemented under Comprehensive Disaster management Programme (CDMP) of the Government of Bangladesh (GoB). CDMP is a program executed by the Ministry of Food and Disaster Management (MoFDM) which is supported by UNDP, DFID, Government of Norway, and the EC etc.

1. Landslide Inventory Mapping

1.1. Introduction

The incidents of landslides are becoming a very frequent disaster in many countries in Asia. Landslides usually do not bring significant negative impacts on the development initiatives like other major disaster events such as earthquakes and floods and the area affected is comparatively not very large. Therefore less attention has been given to landslide problems in many of the countries in Asia. However during past few years we have seen escalation in number and magnitude of landslide events in countries such as Bhutan, India, Indonesia, Nepal, Philippines, Sri Lanka and Thailand. The latest addition to this list may be Bangladesh. Usually Bangladesh is regarded as a flat country which gets affected often by flood and cyclone events. However in addition to such frequent hazards; landslides also continue to result in human sufferings, property losses during recent years especially in the southern hilly areas of Bangladesh. As population increases and societies become more complex, the economic and societal losses due to such events may continue to rise unless proper attention is given at early stages as increasing anthropogenic activities in the mountain areas can add to the existing vulnerability of communities further.

Bangladesh is highly vulnerable to several natural disasters and every year natural calamity upset human's lives and livelihood in some part of the country. Among major disasters concerned in the country, fatal landslides events in the recent years can be noted. Exposed soft sedimentary rocks in the vast tract of mountainous and hilly terrains (18% of the total area of the country) and interventions of human activities across the slopes caused fatal landslides triggered by the torrential monsoon rainfall. The hilly terrain in the southeastern part of the country has the long history of slope instability. The landslides hazard in Chittagong City area and its surroundings occurred on June 11, 2007 was a phenomenal one that took the life of 127 people and caused injury to hundreds of people and made many people homeless. The landslides were triggered by uncommon heavy downpour which was estimated 348 mm for a period of around 12 hours. Fatal landslides subsequently occurred in 2008 and 2009 at Chittagong city as well as Cox's Bazar and Teknaf (Golam Mahabub Sarwar 2008). In 2010, landslides again took place in Cox's Bazar and Teknaf and took the life of around 60 people. Considering the potential rainfall induced landslide hazard in Bangladesh and recent landslide events, attempt has been taken in CDMP-II to develop landslide hazard mapping of Cox's Bazar and Teknaf Municipal areas.

Objectives of this Report

This report is a submission as a part of the assignment being carried out jointly by datEx and ADPC. This report is prepared to summarize the findings of the activity for Inventorying the past landslide events in Cox's Bazaar and Teknaf Municipalities The report describes the landslide issues in Bangladesh in general and on Teknaf & Cox's Bazar Municipality in particular, geomorphology of Cox's Bazar and Teknaf, occurrences of landslides up to date in the study areas, detail list of observed landslide events within the administrative boundaries of two municipalities.

1.2. Statement of the Problem and Description of the Study Area

1.2.1. General Landslide History of Bangladesh

In the recent past, Landslide has become a major concern in the country and became common in the hilly areas of southeastern Bangladesh. These areas have a long history of instability. Although written records of landslide incidents are very rare, they have been a hazard to people ever since they have been living there. In fact, every year especially in the rainy season landslides take place in both natural and man-induced slopes. Although, Bangladesh is a densely populated country, the hilly region presents a sharp contrast with the overall demographic pattern. This is partly due to the landslide hazard potential which discourages many people to live there as well as to build infrastructures; however, inaccessibility, dense forest cover and the hilly topography are also discouraging factors.

Major processes that cause landslides in Bangladesh are 1) removal of lateral support: a) erosion by rivers, b) previous slope movements such as slumps that create new slopes, c) human modifications of slopes such as cuts, pits, and canals; 2) addition of weight to the slope: a) accumulation of rain water, b) increase in vegetation, c) construction on fill, d) weight of buildings and other structures, e) weight of water from leaking pipelines, sewers, canals, and reservoirs; 3) earthquakes; 4) 5) removal of underlying support: a) undercutting by rivers and waves; b) swelling of clays; 6) anthropogenic activities as jhum cultivation.

Table 1: Chronology of major landslides in Bangladesh.

Year	Event Description
1968	At Kaptai-Chandraghona road where the protective vegetation is removed, the soil gets exposed to the monsoon rains and eroded rapidly. This resulted in landslides, and the loose soil washed down the slopes and carried by rivers into the Kaptai Lake. As a result, the reservoir silted up and the authorities confirmed that in its 30 years existence it had lost about 25% of its volume due to siltation.
1970	Similar event along Ghagra-Rangamati road.
1990	Occurred on May 30, 1990. Affected the link road embankment at Jhagar beel area of Rangamati district.
1997	A major landslide occurred in July 1997 at Charaipada of Bandarban. The total area affected by it was about 90,000-sq m. If such a landslide occurred in Bandarban Town and any other urban or semi-urban centre, the devastation would be tremendous.
1999	Two big landslides one in Bandarban and the other one in Chittagong occurred on 11 and 13 August 1999 respectively claiming the life of 17 people. Out of 17 fatalities, 10 were in Chittagong and the rest in Bandarban district. Heavy and incessant rainfall at that time was one of the causes of sliding. This landslide affected Lama thana and the Aziz Nagar union of Bandarban district. Aziz Nagar is almost an inaccessible rugged hilly terrain. Landslide badly affected the villages of Chittaputti, Monargiri, Meounda, Muslimpara, Sonaisari, Bazapara, Kalargiri, Maishkata, Aungratali, Chionipara, Kariungpara. The 11 August landslide was followed again on 15 August at Chittaputti area. At least 50 houses were completely vanished under the solid earth and 300 houses were partly damaged. About 283.50 ha of cultivated land, 810 ha of household garden, and 50 km

Year	Event Description
	unmetalled road were crushed. Road communication between Bandarban headquarters and remote thanas became snapped. Especially, Aziznagar-Bazalia road had been closed for traffic due to falling of huge mass of earth over the road at 25 places. Chittagong landslide location was at Gopaipur under Chittagong Kotwali Thana. The slides crushed two thatched houses at the foot of the hill claimed the lives of the inmates of the houses who were asleep.
2000	At least 13 people were killed and 20 injured in landslide incidents on the Chittagong University campus and other parts of Chittagong City on Saturday, the 24 June 2000. The incident was caused due to the deluge of mud and water that swamped various part of the port city amid torrential rain. The landslides damaged property worth several lacs of taka in those places.
2003	6 members of a family were killed in a landslide at Lighthouse Para near Cox's Bazar town on 16th June. Two other people were also injured in the incident. 4 people were washed away by raging floodwaters in Fatikchhari upazila in Chittagong district on 28th June as the situation in southeastern and northwestern districts worsened because of torrential monsoon rains and onrush of hill waters. 6 people, including four sisters, were buried alive and nine others injured in two landslides on the outskirts of Cox's Bazar resort town on 29th July. The district administration and locals believed that torrential monsoon rains and multiple cracks caused to hillocks by previous day's earthquake triggered the mudslides at Kalatali and Purba Kalatali Adarsha Gram, two neighbouring villages.
2005	A landslide near the Garo hills at Baramari area of Nalitabari upazila of Sherpur killed a worker on 9th June 2005. Police and witnesses said Abdul Majid (35), son of late Janab Ali was digging for stones when the landslide took place. He died on his way to Nalitabari Upazila Health Complex. 2 construction workers were killed and 2 others injured in a landslide at OR Nizam Road Housing Society of the port city's Panchlaish area, police and witnesses said on 3rd August 2005. Sources said that the incident occurred when a big chunk of earth from nearby hill suddenly collapsed on a hut where four construction workers were staying, beside a under construction building at the Panchlaish area. A worker was killed and three others injured in a landslide at Akabpur village, bordering India's Tripura state area, under Kasba upazila of Brahmanbaria district on 12th October 2005. Three children, including two sisters, were killed and another was injured in a landslide at Shantinagar area adjacent to the Bangladesh Cooperative Housing Society in Bayezid Bostami thana in the port city on 31st October 2005.
2006	A mother and her daughter were buried in a landslide, and her another son is critically wounded. The landslide was triggered by incessant rainfall at Satkania upazila of the district early 7th July 2006. They died tragic deaths when a big chunk of the nearby hill suddenly fell on their thatched hut at village Mothuradanga under north Kanchona union of the upazila .
2007	At least 127 people were killed and hundreds more injured and missing as torrential rains sparked a series of devastating landslides in Chittagong on 11th June 2007 , plunging the country's second city into chaos, with power supplies snapped, the port and airport closed and residents seeking safety on their roofs. The heaviest rainfall in quarter of a century saturated the hillsides in and around the city giving residents no chance to escape when a tide of mud and water swept down on their homes in the early hours of yesterday morning, burying whole families under mud

Year	Event Description
	and debris while they slept. The powerful current simply washed others away.
2008	At least 10 people died in rain-induced landslides and wall collapse while two drowned in rainwater at Cox's Bazar 3rd July 2008. Torrential rain continued during the week in Teknaf triggering the landslides, sources claimed. Again on 6th July Landslide caused by torrential rains killed 4 members of a family at Kalyanpara in Teknaf upazila of Cox's Bazar. Meantime, another person was killed in a landslide at Mahajanpara in Cox's Bazar town, reported our Chittagong correspondent of the Daily Star. A rain-induced mudslide at Matijharna in Chittagong city on 18th August 2008 left 11 people, almost all of two families, dead and two injured. The mudslide destroyed 14 houses of a slum built on a hillside from which the government was relocating families apprehending the danger.
2009	A landslide claimed the lives of three labourers on the Chitra at Tero Kheda upazila in Khulna on March 28 2009. It also left two others injured. Sand and stone from an unprecedented landslide created a natural dam on the Shankha river at Bandarban, completely obstructing its flow for over 60 hours since 9th May 2009. Communication through the river has remained snapped because of the 20-foot long blockade across the 25-foot width of the river at Galenga in Ruma upazila of the district. This has affected the businesses in the area. Landslides triggered by heavy rains killed six people, five of them of a family, in two tea gardens in Srimangal upazila on 18th May 2009. Witnesses said a big chunk of mud collapsed on the hillside house. Incessant rain for the last four days triggered a massive mudslide at Harinmara of Lama in Bandarban on 31st July 2009 killing 10 people, including six of a family, and destroying 50 houses.
2010	2 people died in a landslide at Dhalirchara of Ramu upazila in Cox's Bazar at around 9am on 7th April 2010. The landslide occurred as the two were cutting a hill to build their house. At least 52 people were killed in a series of rain-triggered landslides in Cox's Bazar and Bandarban districts on 15th June 2010. Of them, 47 including five army personnel died in Cox's Bazar and the rest in Bandarban. Over 100 others were injured in the landslides. In Himchhari, bodies of the five army personnel were recovered while one man was still missing, said an ISPR press release. A woman was killed and two of her family members were injured critically in a landslide in on 16th December. Moyna along with her family members was digging into the hill at Nalapara in Ambagan area to expand their home, said Farid Ahmed Chowdhury, senior station officer of Agrabad fire station, quoting eyewitness.

**Source: Banglapedia, The Daily Star Online and BD News 24*

1.2.2. Landslide Problem in Cox's Bazar and Teknaf Municipality

Cox's Bazar is one of the attractive tourist places in Bangladesh due to its easy accessibility and presence of world's largest sea beach. Over the decades the district has developed at a good pace especially targeting the beach where a major part is located in the municipality area. As a result of the rapid development, there were lots of interventions on the natural settings of the municipality particularly on the hills. As a result of that, a number of landslides took place within the municipality which caused damage to property and life as well. Most of the landslides took place due to deforestation, hill cutting and heavy rainfall.

Field survey under this particular study has identified about 147 landslide events within Cox's Bazar Municipality. These events ranges from small scale mud flow to large scale slides where there were significant damage were on life and property.

The identified landslide events in Cox's Bazar Municipality dated back from 1995 to 2010. The trend of landslide events shows that the number increased with the years which indicate a positive correlation between new settlements and increase in number of landslides. About 85% of the landslides in the municipality took place during June 10th to 16th 2010 after heavy rainfall in the region. Following is the last of Landslides as identified through field survey under this project in Cox's Bazar and Teknaf Municipality respectively.

Table 2: List of Major Landslide Events in Cox's Bazar Municipality

ID	Name of the Locality	GPS Location		Date	Damage/ Casualty	Existing Situation of the Site		
		X	Y			Risk	House	Population
1	Mohajer Para	91.97772222	21.43755556	14 June,2010	1 Person Died	High	7	25
		91.97713889	21.43577778	June,2008	1 Person Died	High	10	70
2	South Ganar Ghona	92.0155	21.41661111	2008, 2010	1 House	Low	0	0
		92.01525	21.41727778	june, 2010	1 Betel leaf garden	Low	0	0
3	South Lar Para	92.00541667	21.41375	13,june, 2010	1 Betel leaf garden	Low	0	0
4	Adorsha Gram	91.98986111	21.41375	June 13,2010	1 House	Low	7	40
		91.99191667	21.41322222	june,2010	3 House	Medium	12	80
		91.99125	21.41511111	OLD LS and june,2010		Low	0	0
		91.99155556	21.41705556	June ,2010	1 House	Low	6	37
5	Kolatoli By Pass	91.99294444	21.42036111	June ,2010	1 House	Medium	0	0
		91.99419444	21.42177778	2008, 2010	1 House	Medium	2	17
6	West Lar Para	91.99638889	21.42661111	2003, 2010 (Repeat)	1 House	Medium	5	30
		92.00027778	21.42438889	June ,2010	1 House	Medium	2	13
7	Lar Para	92.00283333	21.42505556	2008, 2010	1 House	High	7	50
		92.00255556	21.42452778	June ,2010	1 House	Medium	4	27
8	South Dikkul	92.01044444	21.42252778	2009, 2010	1 House	High	3	17
9	South Haji Para	92.01111111	21.42405556	2006, 2010	2 House	High	7	42
		92.01075	21.42258333	2004, 2010	1 House	High	10	60
		92.01108333	21.42177778	2008,2010	1 House	High	5	28
10	Badshar Ghona	91.98061111	21.43344444	June ,2010	1 House	High	2	15
		91.98130556	21.43488889	June ,2010	1 House	Low	4	24
11	East Light House Para	91.98122222	21.42838889	June ,2010	1 House damaged and 1 person died	High	4	27
		91.98036111	21.42783333	2008, 2010	1 House	High	5	33

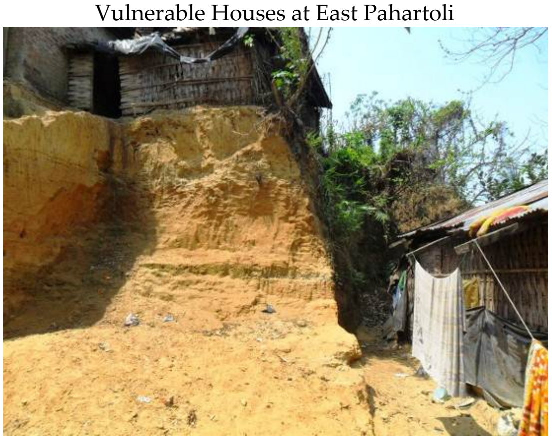
12	Pahartoli	91.98252778	21.43561111	June ,2010	1 House	High	6	25
		91.98375	21.43313889	2007, 2010	2 House	Medium	6	30
		91.98641667	21.43047222	June ,2010	1 House	Medium	3	17
13	Bahar Chara, South Kolatoli	91.99841667	21.39877778	June ,2010	1 House	Low	14	72
14	Bahar Chara	92.00222222	21.39555556	June ,2010	1 House	Low	0	0
		92.00055556	21.39630556	2008, 2009, 2010	1 House	High	1	7
15	Kolatoli	91.99330556	21.40588889	June ,2010	1 House	Medium	6	40
16	Baidder Ghona	91.98183333	21.43802778	2008, 2010	1 House damaged and 1 person died	High	15	76
		91.98111111	21.43855556	2006	1 House damaged and 1 person died	High	20	90

**Source: Field Survey, April-May, 2011*

Plate 1: Pictorial Illustrations of Frequent Landslide Locations in Cox's Bazar Municipality

Vulnerable Houses at East Pahartoli

Vulnerable Houses at West Lar Para



Vulnerable houses at Mohajer para

Ghonar para

Houses at Hillside of Kolatolii

Houses vulnerable to Landslide-Mohajer para

There were also several landslide incidents in Teknaf Municipality over few years. Most of these landslides took place due to hill cutting and after heavy rainfall. It is identified that since 2002, 18 landslides took place which killed 18 people and damaged about 10 houses in the municipality. Following is a list of landslide events in Tennaf.

Table 3: List of Major Landslide Events in Teknaf Municipality

ID	Name of the Locality	GPS Location		Date	Damage/ Casualty	Existing Situation of the Site		
		X	Y			Risk	House	Population
1	Urumchara, Puran Pallan Para	92.29227778	20.87102778	June,2010 and 2009	1 person died and 1house damaged	High	6	37
		92.29227778	20.87205556	June,2002	1 House Damaged	High	2	15
2	Puran Pallan Para	92.29111111	20.87227778	June,2010	1 person died and 1 house damaged	High	1	6
		92.29152778	20.87530556	June,2010	6 persons died & 1 house damaged	High	1	7
		92.29222222	20.87541667	June,2008	4 persons died & 1 house damaged	High	5	36
		92.29083333	20.87366667	June,2010	5 persons died & 1 house damaged	Nil	-	-

**Source: Field Survey April-May, 2011 and Compared with other media news*

Plate 2: Pictorial Illustrations of Frequent Landslide Locations in Teknaf Municipality

Houses near landslide site at Urumer Chara

Houses Located near the Landslide site at Puran Pallan Para

Landslide Sites at Puran Pallan Para

1.2.3. Regional Physiography

Physiography is a description of the physical nature (form, substance, arrangement, changes) of objects, especially of natural features.

Quaternary (began about 2 million years ago and extends to the present) sediments, deposited mainly by the Ganges, Brahmaputra (Jamuna) and Meghna rivers and their numerous distributaries, cover about three-quarters of Bangladesh. The physiography and the drainage pattern of the vast alluvial plains in the central, northern and western regions have gone under considerable alterations in recent times. The deposition of Quaternary sediments was influenced and controlled by structural activities. The eastward shift of the Ganges and tista as well as the significant westward shift of the Brahmaputra during the last 200 years gives evidence of epeirogenic movements even in recent days. Hillocks and hills are confined to a narrow strip along the southern spur of the Shillong Plateau, to the eastern and southern portions of the Sylhet district, and to the Chittagong Hill Tracts (CHT) in the southeast of the country bordering upon the Indian states of Tripura and Mizoram and Myanmar.

In the context of physiography, Bangladesh may be classified into three distinct regions (a) floodplains, (b) terraces, and (c) hills each having distinguishing characteristics of its own. The physiography of the country has been further divided into 24 sub-regions and 54 units (Rashid, 1991). Major sub-regions and units are as below:

i) Old Himalayan Piedmont Plain; ii) Tista Floodplain; iii) Old Brahmaputra Floodplain; iv) Jamuna (Young Brahmaputra) Floodplain; v) Haor Basin; vi) Surma-Kushiyara Floodplain; vii) Meghna Floodplain - a. Middle Meghna Floodplain, b. Lower Meghna Floodplain, c. Old Meghna Estuarine Floodplain, d. Young Meghna Estuarine Floodplain; viii) Ganges River Floodplain; ix) Ganges Tidal Floodplain; x) Sundarbans; xi) Lower Atrai Basin; xii) Arial Beel; xiii) Gopalganj-Khulna Peat Basin; xiv) Chittagong Coastal Plain; xv) Northern and Eastern Piedmont Plain; xvi) Pleistocene Uplands: a. Barind Tract, b. Madhupur Tract and c. Tippera Surface; xvii) Northern and Eastern Hills a. Low Hill Ranges (Dupi Tila and Dihing Formations), b. High Hill or Mountain Ranges (Surma and Tipam Formations) (Figure 1).
In the Chittagong region, this unit includes the Sitakunda and Mara Tong ranges and the complex of hills to the south and east of Ramgarh, including the eastern part of the Middle

Feni river valley. The Sitakunda range has 32-km long ridge in the middle, which reaches 352m at Sitakunda peak. To the north, the high peaks on this range are Rajbari Tila (274m) and Sajidhala (244m). To the south, there is an abrupt fall and Chittagong city heights are less than 92m. In the Mara Tong range a height of only 113m is reached. Further northeast the hills are higher. The topography is deeply eroded and rounded; the valleys are curved and almost isolated hillocks are common.

At the Sitakunda peak, there are several hot springs. There are five broken ranges of hills between Karnafuli river and the southern tip of Bangladesh. South of Bakkhali river the hills reach the sea at Cox's Bazar. Thereafter the main mass of hills goes down the Teknaf peninsula as the Teknaf range. There is a slight break in the west along the Rejukhal valley. In its northern part, the Teknaf range is comparatively low (61 to 91m). From Whykong a high ridge runs south; its main peaks are Baragong (119m), Taunganga (268m), and Nytong (168m). The southwestern end of this range ends at a village called Noakhali where there are a series of impressive cliffs, some 30m in height. The range ends at Teknaf Bazar. South of Gorjania (northeast of Teknaf peninsula) these hills continue into Myanmar. The Rejukhal valley is an important component of this broken-up landscape.

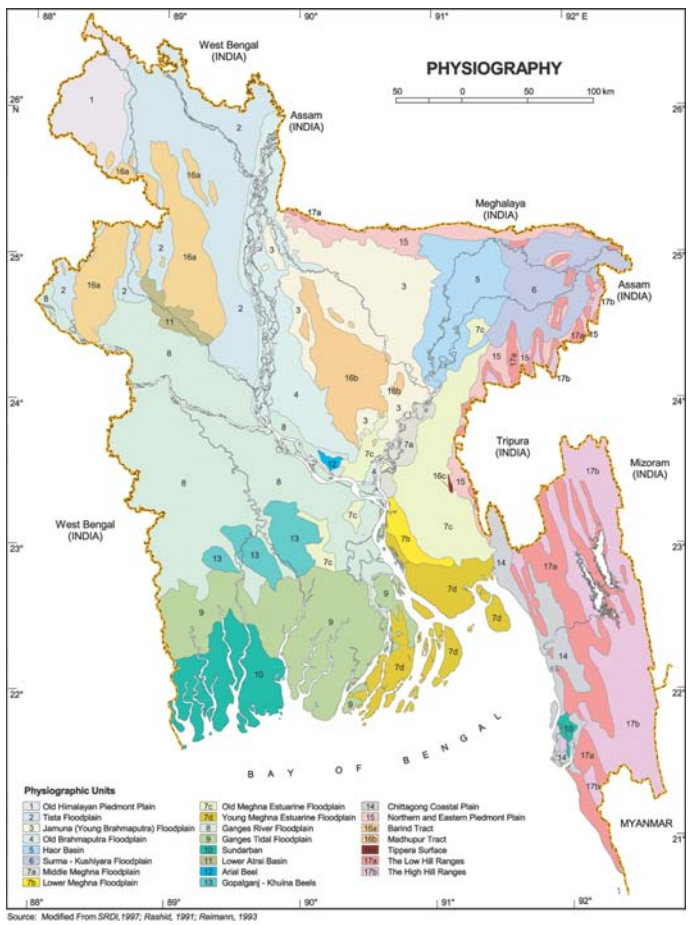


Figure 1: Physiographic map of Bangladesh (Banglapedia; Rashid, 1991; Reiman, 1993)

High hill or mountain ranges comprise an almost parallel ridge running approximately north-south and with summits reaching 300-1000 m. They have very steep slopes - generally >40%, often 100% and are subject to landslide erosion. They are mainly underlain by consolidated shales, siltstones and sandstones. This unit covers most of Chittagong Hill Tracts, some small parts of southern Habiganj, and the south and eastern borders of Maulvi Bazar. All the mountain ranges of the Hill Tracts are almost hogback ridges. They rise steeply, thus looking far more impressive than their height would imply, and extend in long narrow ridges, whose tops are barely 30m wide. Most of the ranges have scarps in the west, with cliffs and waterfalls.

These are different from the low rounded foothills to the west. There are extensive stretches of low hills and hillocks in between the ranges. Four ranges, with an elevation of over 300m, strike in N-S direction in the northern part of the region. The western-most, the Phoromani range, reaches 463m at Phoromani, 436m at Rampahar, and 417m at Bhangamura. The next range eastwards is the Dolajeri; its highest peak is Langtrai (429m). On the eastern side of this range are several high waterfalls: two of the highest have falls of 60 and 40m. Further east, across the Maini valley is the Bhuachari range, which rises to 611m at Changpai peak. The eastern-most, within Bangladesh, is the Chipui-Lungsir range (also known as the Barkal range). Its highest peaks, from north to south, are Khantlang (683m), Thangnang (735m), Lungtian (679m), Chipui (480m), Bara Toung (447m), and Barkal (572m).

South of the Karnafuli there are seven main mountain ranges within Bangladesh. The Muranja range rises out of the Chunoti hills 5 km east of Harbang, and strikes in a southeasterly direction. Its well-known peaks are Muranja (502m), Nashpo Taung (586m), and Basitaung (664m). East of the Muranja range and also roughly parallel to it are the Tyanbang, Batimain and Politali ranges. The Tyanbang or Chimbuk range rises south of Sangu river and continues into Myanmar. Its main peaks are Lulaing (720m), Thainkhiang (894m), Kro (868m), Rungrang (849m), and Tindu (898m). On a branch of the Lulaingkhal, near Lulaing peak, there is a waterfall of 107m height. The high peaks within Bangladesh are Waibung (808m), Mowdok Tlang (905m), Rang Tlang (958m), Mowdok Mual (1,004m) and Tajingdong, which is the highest peak of Bangladesh, officially called as *Bijoy* (1,280m).

1.2.4. Physiographic Features of Cox's Bazar Town and Surroundings

1.2.4.1. Land-use and Topography

The Cox's Bazar cliff runs from NNW to SSE direction along the shore of Bay of Bengal. The range lies on the eastern side of the Bay of Bengal. Beach runs approximately along S 35˚E. Eastern side of the cliff is accompanied by a series of hills. The highest ridge of the Cox's Bazar hill is about 82 m above the sea-level. Valleys are irregularly situated in this hill range. The height of the cliff along the beach varies within a narrow range from about 50m to 82m and these cliffs terminate abruptly against the beach presenting vertical sections.

Land Use Mapping

As per requirement of Landslide Hazard Zonation mapping, general land-uses were extracted from high resolution satellite images available with the consultant. Geographic information System (GIS) software such as ArcGIS 10 was used for extracting the land-uses by on-screen digitization method. Later on the land-use maps were verified and refined conducting GPS survey at field level. Land use features were identified and classified using the individual code and separated in different layers during data processing stage, from where the category wise land use map was drawn using the identification layers of each land uses features as presented in the table below and Map-1 & 2.

Land-use Category

Land-use Category	Rating Criteria	Description
A: Vary High	Land-uses with high impacts to land degradation	- Dense urban settlements on hills;
B: Medium	Land-uses with medium impacts to land degradation	- Cultivated area with poor drainage; - Dense urban settlement; - Scattered settlements; - Vacant hilly area with scattered bush and shrubs;
C: Very Low	Land-uses with minimum impacts to land degradation	- Forest area; - Area with good natural vegetation cover; - Area with good drainage. - Cultivable Land; - Uncovered Soil; - Airport area; - Beach Area; - Law land area with tidal influenced.

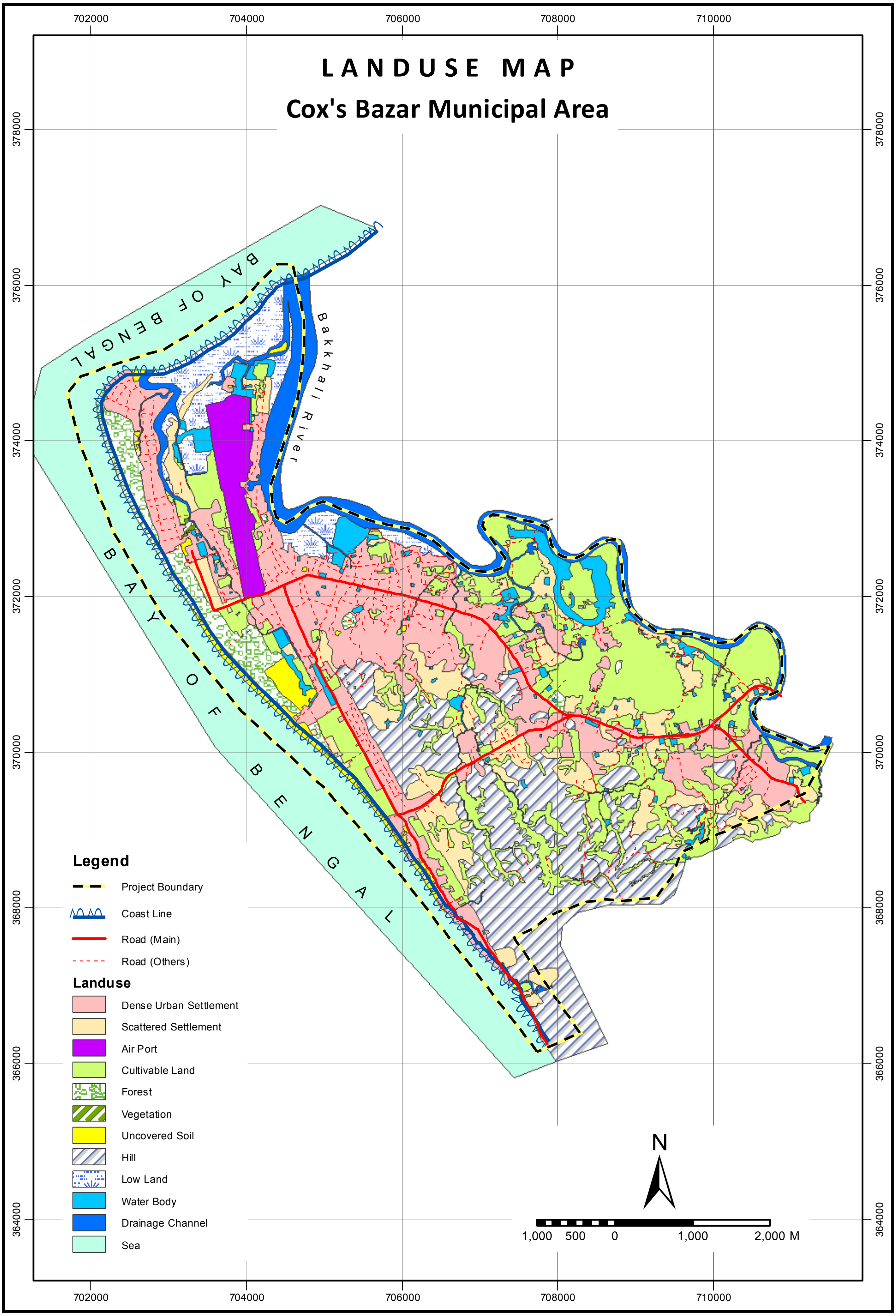
Contour Mapping & Digital Elevation Model (DEM)

The DEM of the study areas were prepared with a 2m Pixel size. DEM of Cox's Bazar and Teknaf municipalities were generated using the methods described below:

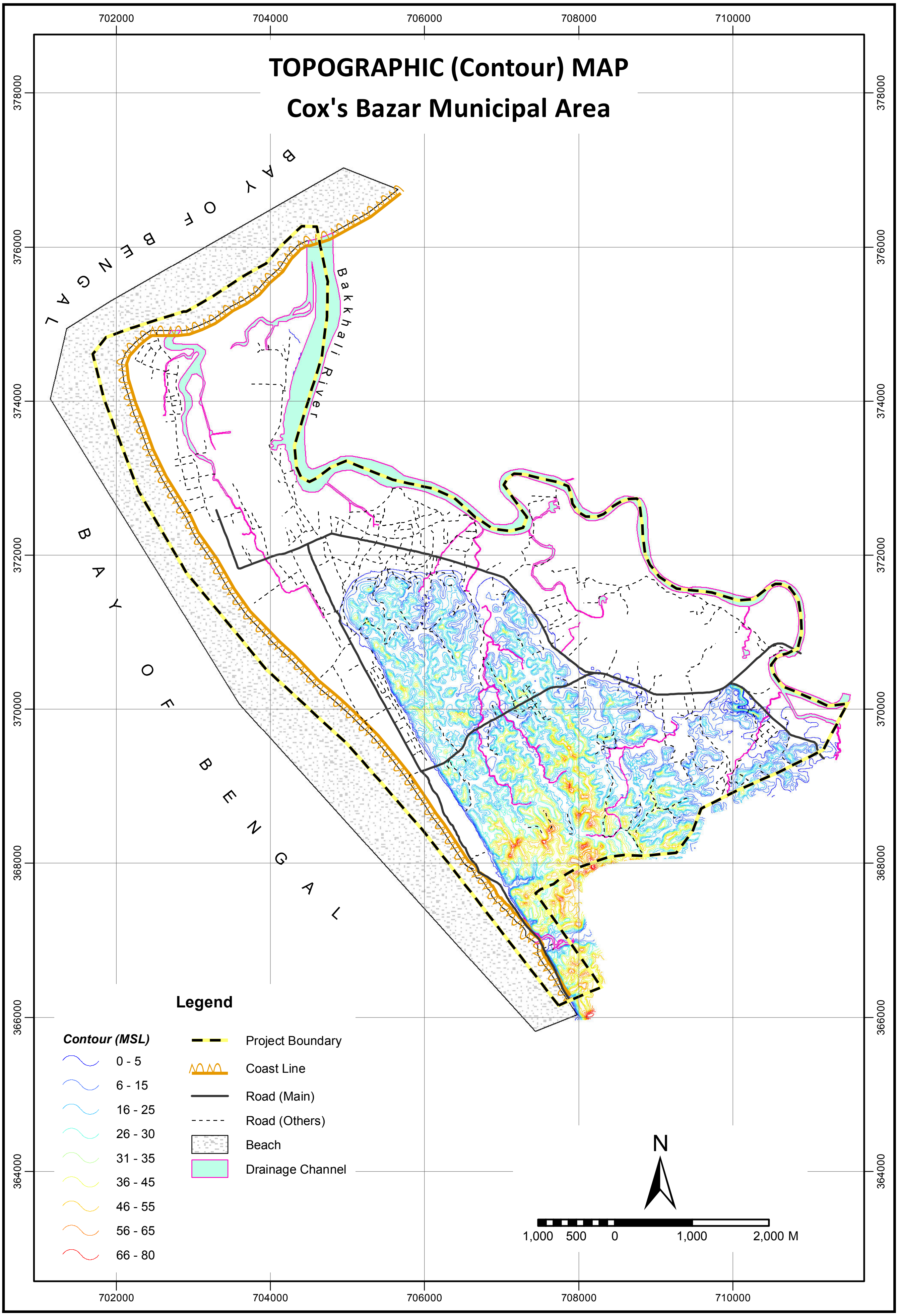
Spot/Land level data captured from existing topographical map of coastal area of Bangladesh prepared by FINMAP were used for generating DEM. After scanning & digitizing the spot levels/spot heights from existing topographic map prepared by FINMAP, random field level checking were done at various locations of the project area using GPS supported Total Station survey. Based on field checking survey necessary refinement and adjustment were done and the final spot heights were used as mass point for preparing 1.5m interval contours (Map-3 & 4) & DEM of 2m resolution (Map-5 & 6).

All spatial information or data were stored under a comprehensive GIS database component in BTM (Northing, Easting, MSL in meter) projection system. Geographic information System (GIS) software such as ArcGIS 10 was used for this purpose.

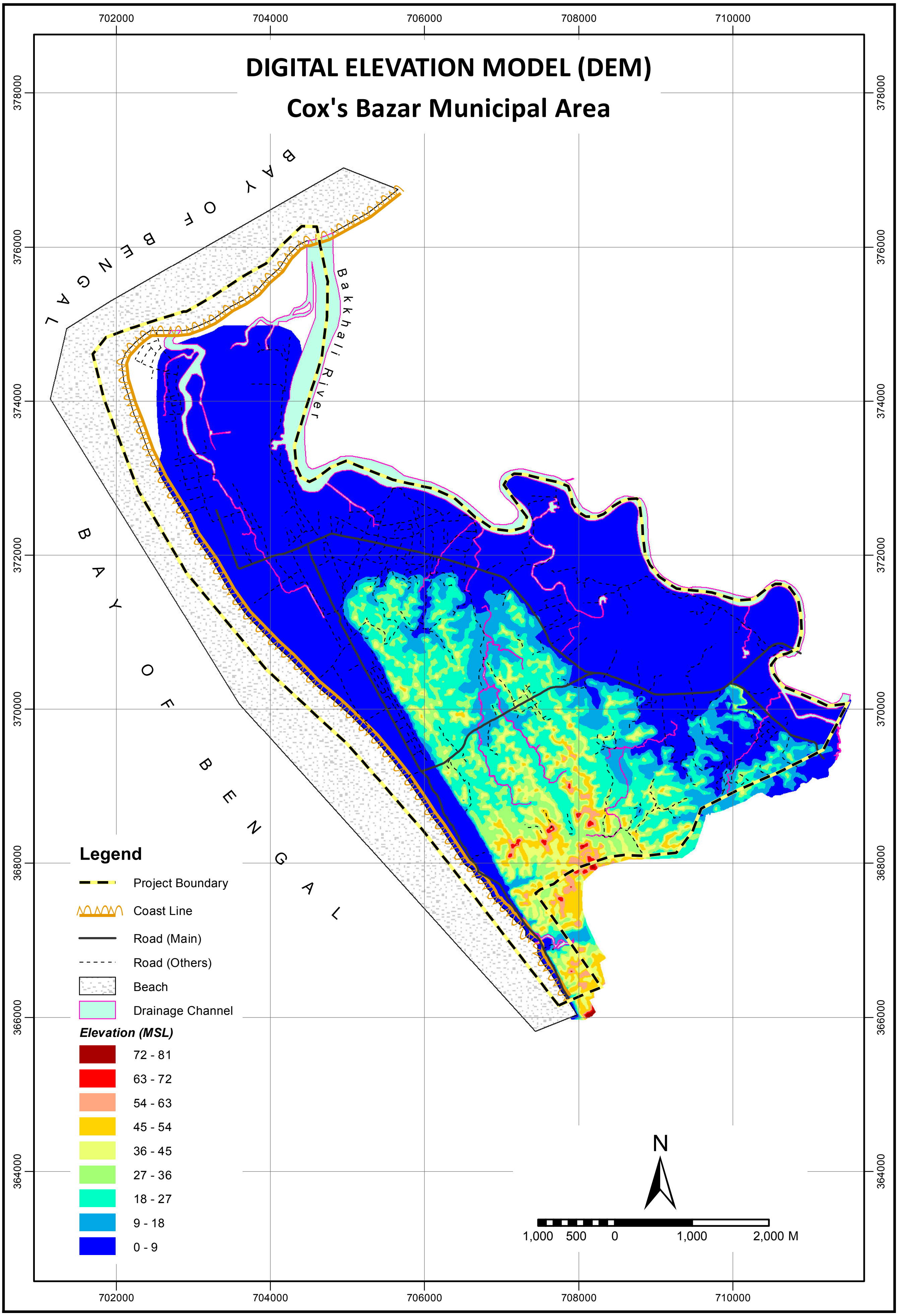
3D Analyst & Spatial Analyst modules of ArcGIS 10 was used for developing contour at 1.5m interval and DEM of 2m pixel size.



Map-1: Landuse Map of Cox's Bazar Municipal Area.



Map-3: Topographic (Contour, 5m) Map of Cox's Bazar Municipal Area.



Map-5: DEM of Cox's Bazar Municipal Area.

1.2.4.2. Drainage and Water Supply

There are several streams and streamlets in the area surveyed during the field work. Among them Rejukhal is the prominent stream of the area and the drainage is mainly effected by this stream. The Himcharichara, Amtalichara, Hatrachara and Kelatalichara are the other streams and streamlets of lesser significance. The streamlets are dried up in winter and become active in the rainy season. Rejukhal is the main source of water supply of this area and easily navigable throughout the whole season. The distance of Rejukhal from Cox's Bazar town is about 9.5 miles towards south.

1.2.4.3. Vegetation and Culture

Dense forest with tropical evergreen trees covers the area making it difficult to find exposure along the foot tracks on top of the hills. The forest shows a mixed vegetation character with jaw, Garjan, Shimul and Jarool trees. Bomboo and betelnut trees are also present in this area. The forest becomes more dense and green where the water supply is sufficient.

The soil of the valley is fertile, but the slope land of the hill is less fertile. Most of the areas are fit for cultivation throughout the year. The crops raised are paddy and other Robi crops. Soil and climate is not suitable for jute cultivation. 0n the slopes of the hill, cultivation of betel leaf gardens are carried out. Local people produce non-refined ordinary table salt in the coastal land by the local process.

1.2.5. Physiographic Features of Teknaf Town and Surroundings

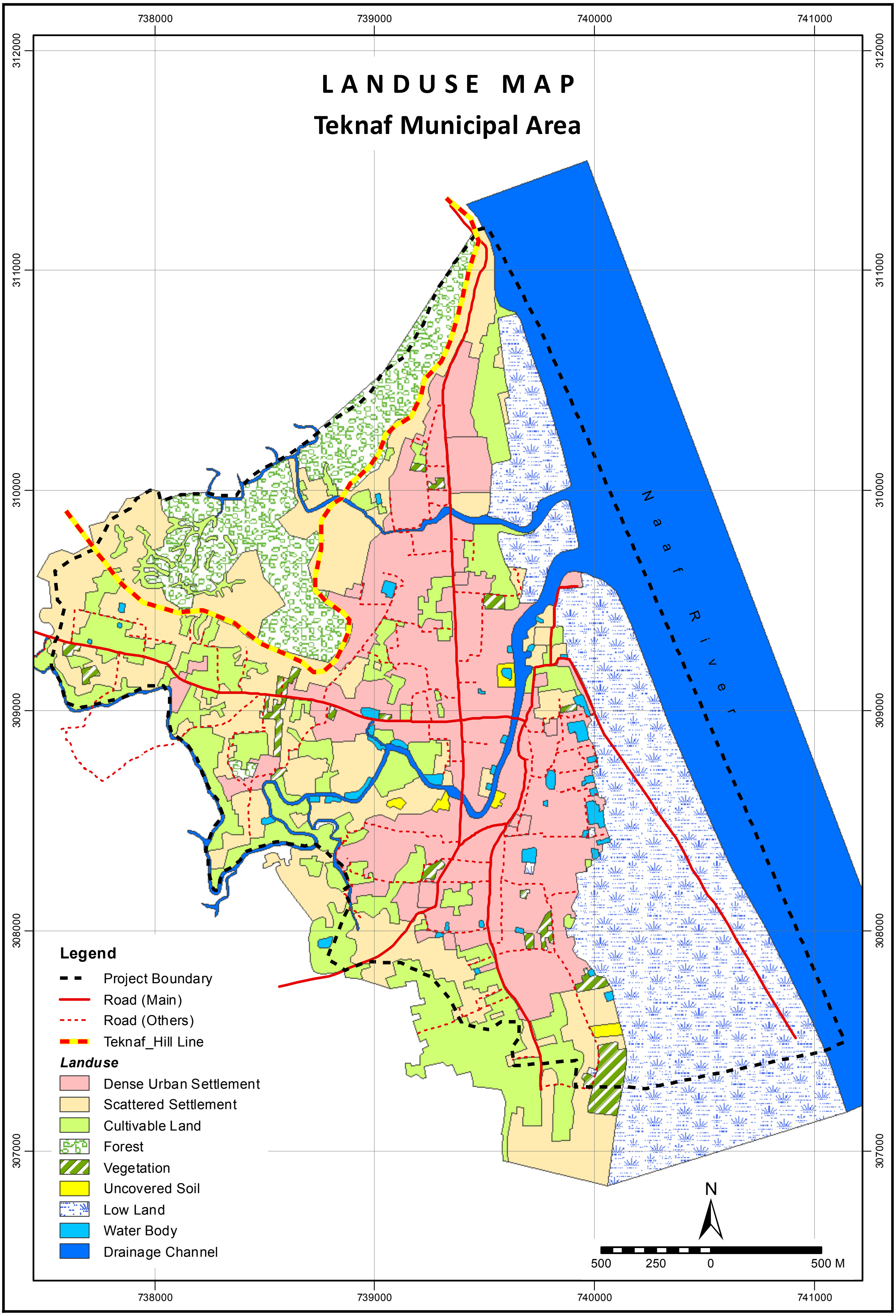
1.2.5.1. Land-use and Topography

The Teknaf town and its adjoining area can be divided into three distinctive physiographic units. The units are 1) Eastern Naf River and its adjacent flood plain; 2) Middle Dakhin Nhila Anticline and 3) Western Bay of Bengal. Among them the middle unit has been described because of its importance for the occurrence of landslide events.

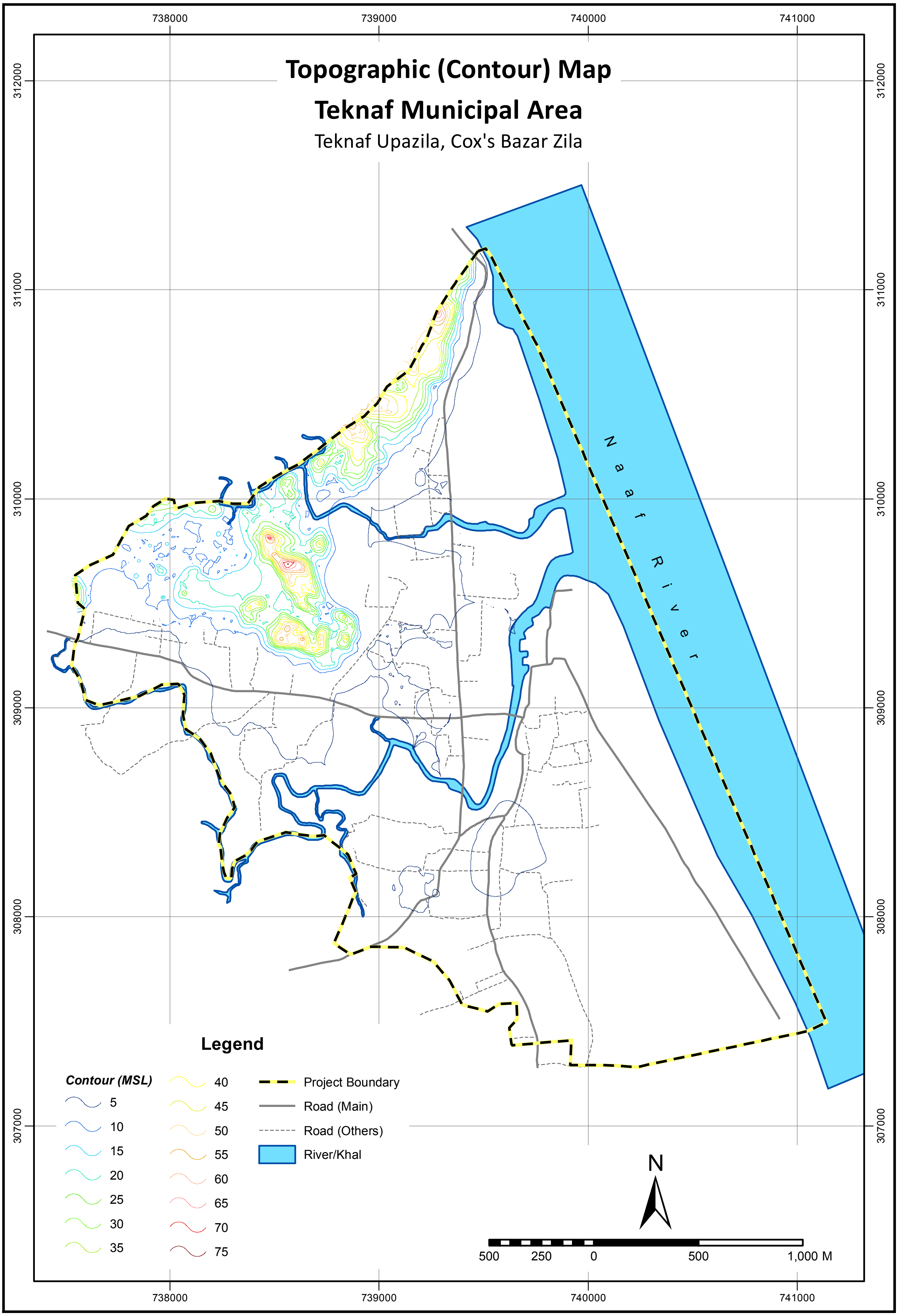
The topographic features such as hills cliffs, streams, escarpments etc. characterize the major portion of the central hill range. The distribution of various topographic features is mainly the result of subareal weathering and erosion process of streams. The whole hill range is characterized by isolated peaks and ridges. The sloping nature of the sides of the hill range is not same. The eastern flank of the Anticline is wide and gentle than the western flank.

The highest ridge of the hill inside the Teknaf pourashova area is about 76m above the sea-level. Valleys are irregularly situated in this hill range. The height of the cliffs of the hills varies within a narrow range from about 30m to 76m and these cliffs terminate abruptly against the beach presenting vertical sections.

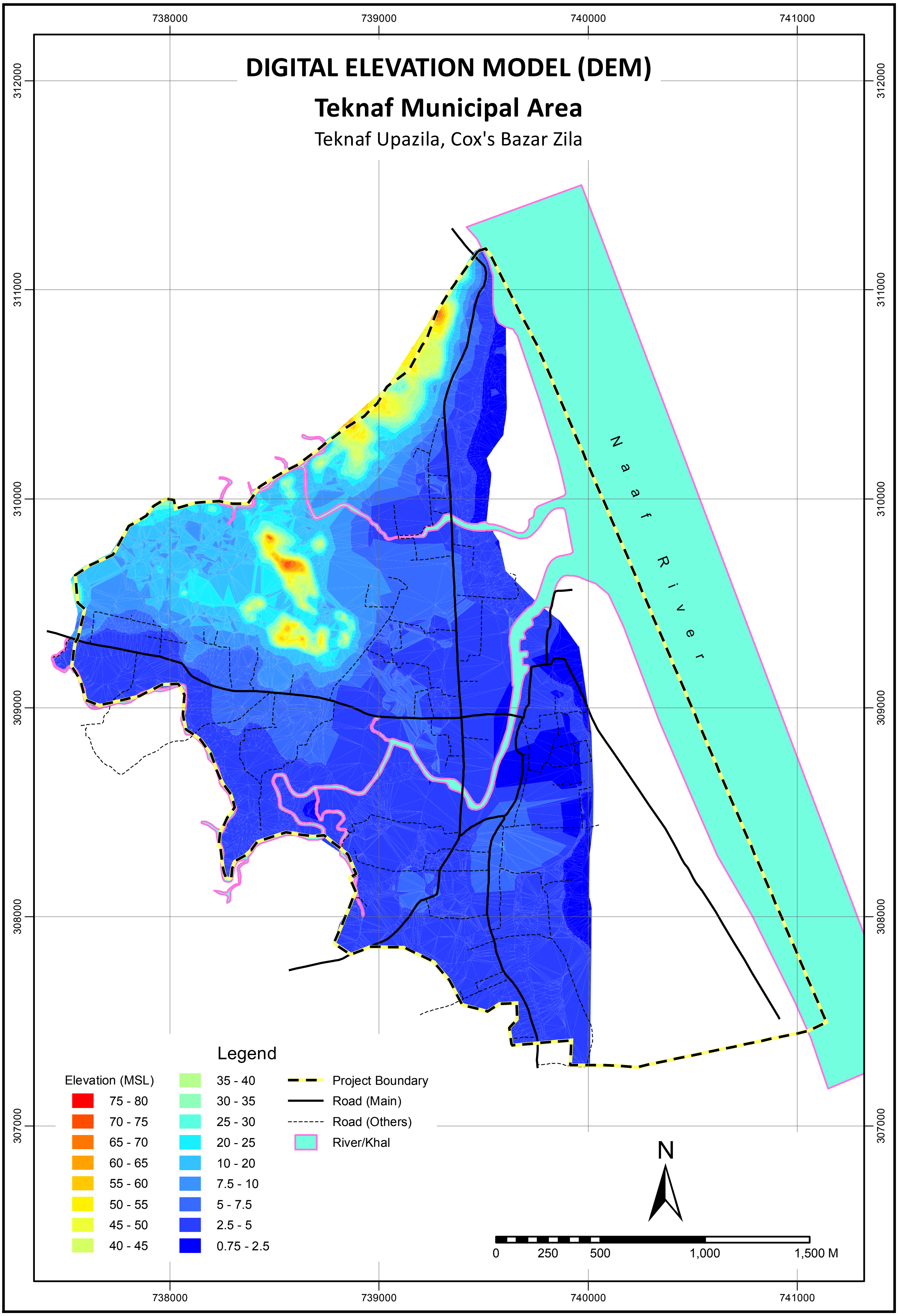
Land-use category and methodology applied for preparing land-use & contour maps and developing DEM were already presented in Article- 1.2.4.1. Landuse Map (Map-7 & 8), Contour Map (Map-9 & 10) and DEM (Map-11 & 12) of Teknaf Pourashova area were presented in the report.



Map-7: Landuse Map of Teknaf Municipal Area.



Map-9: Topographic (Contour) Map of Teknaf Municipal Area.



Map-11: Digital Elevation Model (DEM) of Teknaf Municipal Area.

1.2.5.2. Drainage and Water Supply

The Dakhin Nhila hill range lies between the Naf River on the east and the Bay of Bengal on the west. The Naf River flows along with the Bangladesh-Myanmar International Border and also runs roughly parallel to the hill range. Most of the streams observed are of consequent type and locally named chara. The streams are intermittent and dendrite in pattern. During the investigation the streams were dry. These streams are in youthful stage and demonstrated by their characteristic erosion features. The vertical erosion has been much faster than the lateral erosion and making the streams narrow and straight due to the strong current. Random orientation of boulders, pebbles, cobbles suggest that the erosion processes are active in the area. The streams of the eastern flank of the hill range flow into the Naf River and the streams of the western flank of the hill range flow into the Bay of Bengal. Ladhakhal, RangikhaliChara, Dumdumiakhal, etc. are flowing to the Naf river whereas Dakchara, Noakhalichara, Rajarchara are flowing to the Bay of Bengal.

1.2.5.3. Climate

Teknaf is subjected to tropical climate. So, uniform temperature is always present in this place in comparing with other part of Bangladesh. Teknaf region enjoys three distinct seasons namely the monsoon, the winter and the summer. The extent of rainfall is about 300 cm. annually. Bulk of the rainfall takes place during the period June to September. The maximum temperature is 38^0C, which is attained in the month of May. The weather from November to March is favorable to conduct fieldwork in Bangladesh.

1.2.6. Tectonic Setting of the Area

The hill ranges of Cox's Bazar and Teknaf areas are the part of the western extension of the Tertiary Folded Belt of Indo-Burman Orogeny (Figure 2). The upper Tertiary sediments of the area are arranged into long folds of sub-meridional trend. The area is characterized by a series of parallel structures which is the continuation of Arakan Yoma Anticlinorium and started to develop during Oligocene (Figure 3).

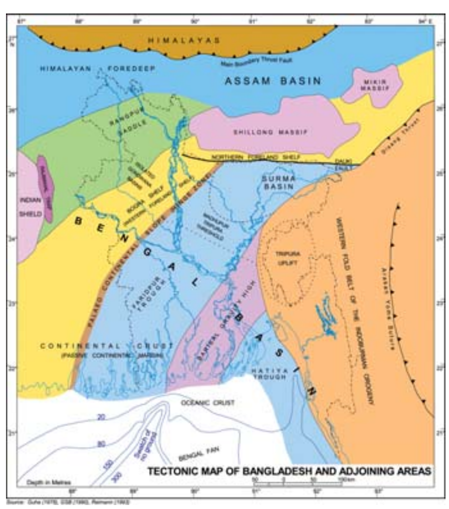


Figure 2: Tectonic setting of the Bengal basin.

The Indian Plate moved eastward and went underneath Eurasian Plate resulting east-west trending Himalayan Rangesin the north and north-south trending folded belts of Arakan-Yoma and Naga Lushai Ranges in the east. This happened possibly during Oligocene. The ranges came into prominent during the late phases of Himalayan upliftment in Plio-Pleistocene.

The regional strike of the folds trends in NNW-SSE direction. The folding of this zone is of complex type and possesses a number of peculiarities such as box and ridge like form of anticline, striking difference in width of syncline and anticlines, and en-echelon arrangement of structures.

Figure 3: Geological Structures of the eastern part of Bangladesh and surroundings.

1.2.7. Regional Geology

In Chittagong and Chittagong Hill Tracts the Upper Tertiary sandy-argillaceous sediments have been folded into a series of long submeridional (NNW-SSE) anticlines and synclines represented in the surface topography by elongated hill ranges and intervening valleys. The folded structures are characterized by en-echelon orientation with an increasing degree of intensity and complexity toward the east. Accordingly, the folded flank is divided into three parallel almost N-S trending zones from west to east as: (a) the Western Zone is characterized by simple box-like or similar shaped anticlines with steep flanks and gentle crests separated by gentle synclines, viz. Matamuhuri anticline, Semutang anticline, etc; (b) the Middle Zone is characterized by more compressed structures, other than just simple box-like folds, with ridge like asymmetric anticlines frequently associated with faults and separated by narrow synclines viz. Sitapahar anticline, Bandarban anticline, Gilasari anticline, Patiya anticline, Changohtung anticline, Tulamura anticline, Kaptai syncline, Alikadam syncline, etc; (c) The Eastern Zone is characterised by highly disturbed narrow anticlines with steep clipping flanks and mostly associated with thrust faults, viz. Belasari anticline, Subalong syncline, Utanchatra anticline, Barkal anticline, Mowdac anticline, Ratlong anticline, Kasalong syncline, Sangu Valley syncline and few others.

1.2.8. Geology of Cox's Bazar Town and Surroundings

The geology of Cox's Bazar area has been described into two parts, such as 1) geological structure on which Cox's Bazar town is located and 2) stratigraphy by which the subsurface ground and the hilly area of Cox's Bazar town is formed of.

1.2.8.1. Geological Structure

Cox's Bazar town is situated on the northeastern part of the Inani Anticline (Figure 3). The structure is bounded by latitudes from 21°5′N to 21°25′N and longitude from 92°0'E to 92°10′E. It is represented by NNW-SSE trending low hillocks attaining maximum elevation 54.86 m. Tectonically, Inani anticline is situated in the Chittagong Folded Belt of Bengal Foredeep. The structure runs along the coastline of the Bay of Bengal. The anticline is dissected into two parts by Rejukhal across the northern pitch. The southern pitch is represented by very low relief due to saddle separating Inani structure from Dakhin Nhila structure.

Inani is a narrow and elongated structure in which the Tipam Sandstone Formation is characterized by steep zone in both the flanks. Maximum 70° dip was recorded in the steep zone. In the crestal part the dip varies from 3° to 12°. The Tipam Sandstone Formation is unconformably underlain by the Boka Bil Formation in a gradual low dip. The oldest exposed rock is the Boka Bil Formation.

1.2.8.2. Stratigraphy

The Cox's Bazar district is bound in the west and south by the Bay of Bengal, in the east by the hill ranges of elevation around 100-200 m. The Basin of Matamuhuri River and Bakkhali river form the morphological pattern on the North of the district. The continent of the district of Cox's Bazar includes two distinct geological settings namely Tertiary Folded Belt and coastal deposits. The Tertiary Folded Belt extends north-south as part of the Indo-Burmese mobile belt that is characterized by long narrow folds (Alam et al 1990). Coastal Holocene deposits overlie the Tertiary rocks, resulting in different surfacial forms. The present day morphology of the area are believed to be influenced by the Holocene sea level rise, tidal and fluvial discharges and very special type of physical set up of the plain around The Tertiary hills represent the geological structures in Cox's Bazar area. Cox's Bazar town and surroundings predominantly consist of Dihing Formation and Dupi Tila Formation of Plio-Pleistocene age. The Formations are characterized by fine to medium grained poorly consolidated sandstone and clayey sandstone of variable colors ranging from yellow, brown to grey. To the south of Dihing and Dupi Tila Formation, the Girujan clay of Pleistocene and Neogene age is present followed by Tipam Sandstone Formation of Neogene age. The formations covers Ukhia Upazila on the south, part of Ramu Upazila on north and north east and a thin zone to the east of Cox's Bazar. The Girujan Clay Formation is grey to greenish grey, red mottled silty shale, shale and claystone inter bedded with subordinate thinly bedded siltstone and cross-bedded sandstone. The Tipam Sandstone Formation is fine to medium grained sandstone, siltstone and shale, massive to thinly bedded, locally cross-bedded and current-bedded. In the south the Giruan Clay and Tipam Sandstone Formations merge to the Boka Bil Formation of the Neogene age and the Bhuban Formation of Miocene age. The area includes Teknaf Upazila in south and eastern part of Cox's Bazar city. The formations are characterized by massive to thinly bedded shale, siltstone and sandstone.

Flood plain and coastal deposit of Holocene age overlies Late Tertiary formations at places presenting the surfacial form. Morphological pattern of the Northern Upazilas of the district such as Pekua and Chakaria is charaterized by the Matamuhari Basin. The major geomorphic units of the basin from east to the west are i) Fan ii) Deltaic Plain and iii) Estuarine plain (Huq and Ahmed, 1997). Kutubdia and a belt on the east bank of the Moheskhali channel include coastal deposit of Holocene age consisting of beach and dune sand overlying late Tertiary formations. The coastal deposit is also present at the southeast part of the district or the country and to the south of Teknaf beyond the hilly area. Alam et al (1999) presents the morphology of Cox's Bazar coastal plain. The schematic cross-section shows that the plain is elevated landward and gradually slope toward the sea. The elevation of the marginal part of the plain is of the order of 2 to 3 m above mean sea level. The characteristics of different landforms are shown in Table 3. Table shows that sediment of the plain varies from very fine silt to medium sand with finer particles at the flood plain and largest grain size for tidal creeks.

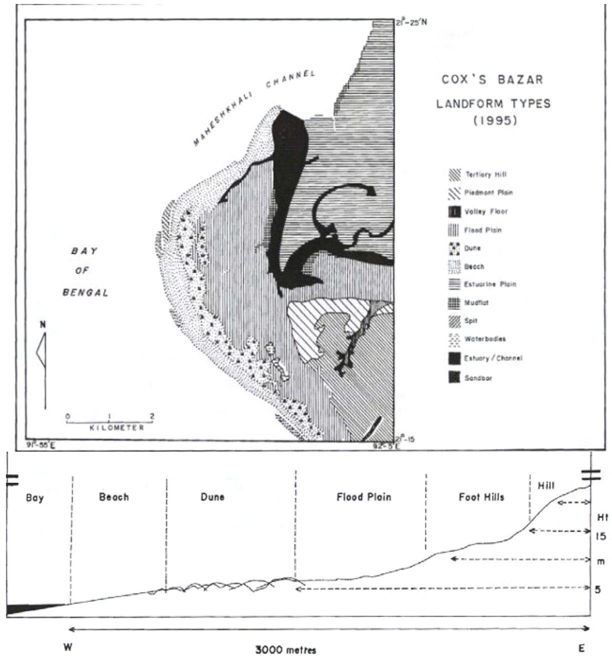


Figure 4: Morphology of the Cox's Bazar Sadar (after Alam et al, 1999)

Table 4: Landform Characteristics of the Cox's Bazar Coastal Plain (Alam et. al., 1999)

Feature	Height	Slope	Processes	Width	Mean Grain Size
Flood Plain	5	<1°	Mainly fluvial origin, flash flood and occasional marine wash over, minor rills are common	<5->3 km	Very fine sand to silt
Dunes	3-4	>10°	Undulating, develops parallel to the flood plain	highly variable	Fine Sand
Beach	2-3	4°-6°	Wave and wind actions are predominant with occasional storm surge induced flooding	<200m to >500m	Medium to Fine sand
Mudflat	≤1	<1°	Subject to erosion and accretion through regular tidal action and periodically submerged	50-200m	Clay to silty clay with very fine sand intercalations
Spit	1-2	Most cases steep, varies from 2°->4°	Exposed to wave and wind action and submerged to high spring tide	<50m from the ridge	Fine sand to silty clay
Tidal creek	0.5-1.5	Slopes gently down sea-ward	Limited wave action and exposed to regular tidal exchange	<10 m to 150m	Medium sand with occasional clay intercalation

1.2.9. Geology of Teknaf Town and Surroundings

The geology of Teknaf area has been described into two parts, such as 1) geological structure on which Cox's Bazar town is located and 2) stratigraphy by which the subsurface ground and the hilly area of Cox's Bazar town is formed of.

1.2.9.1. Geological Structure

Teknaf Town and surroundings are located on the Dakhin Nhila Anticline which is the southernmost structure of Chittagong-Tripura folded belt, mainly comprises of Neogene

Sedimentary rocks. It is the western most extension of Arakan-Yoma Anticlinorium's and separated from the main body of the Arakan-Yoma by several km wide flood plain of Naf River.

The Dakhin Nhila Anticline lies under Teknaf Upazila and Cox's Bazar District and bounded by latitudes from 20°52' to 21°07'N and longitudes from 92°08' to 92°18'E. The hills and valleys striking N I7°W and S 17°E represent the axial direction of the anticline. The maximum elevation is about 266m above mean sea level. The northern pitch is represented by low relief due to saddle separating from Inani Anticline, whereas southern pitch abruptly merges with the plain land. Dakhin Nhila Anticline is an elongated, asymmetric, and box like structure. It is a complicated structure due to the presence of longitudinal and transverse faults.

1.2.9.2. Stratigraphy

The oldest exposed rock in the Dakhin Nhila Anticline is the Upper Bhuban Formation that is about 545m thick. The exposed rock formations from older to younger are Upper Bhuban formation, Boka Bil Formation, Tipam Formation and Dupi Tila Formation. Mostly argillaceous sediments with little coverage of arenaceous sediments characterize the structure. The axis of the structure runs along NNW-SSE direction. Some portion of western flank and younger formation of southern pitch has been eroded away due to erosion by the Bay of Bengal.

The axes of folds run along NNW-SSE direction which is disrupted and complicated by the presence of numerous faults. It is generally observed that the intensity of folding increases towards the east. The development of Bengal Foredeep is directly related to the development of Himalayan in the north and the ArakanYoma Mountains in the east due to the northeastern collision of Indian plate with Eurasian plate. The movements of the Arakan Sub-plate bounded by the Ninety East Ridge and covering the eastern and southeastern part of Bangladesh, have been suggested to have result the formation of folds of the eastern flank of the Bengal Basin (Faruquee, 1975).

Folds of Chittagong and Chittagong Hill Tracts are the western extension of the Arakan Yoma Anticlinorium, which are known in Bangladesh as folded flank of Bengal Foredeep of Bengal Basin. The surface relief of the area is represented by north-south stretched hills of sedimentary cover.

From the above discussion, it is observed that the relative movement of the Indian and Burmese plate has developed the main east west compression in the region. The Burmese plate being overridden the plate has been serving as the main pushing agent and as a result the magnitude of force is higher in the east than the west.

Another major plate movement took place in the Pliocene that resulted in a large-scale movement along the Dauki Fault and the Dhubri Shear Zone. During the Eocene, basin wide emergence and maximum regression occurred in the Bengal Basin, followed by deposition of the Barail Group in the Oligocene. But during most of the Miocene the deep basin featured conspicuous subsidence and Marine transgression and during the late Miocene a new phase of structural and depositional development took place because of global eustatic regression. The onset of the final uplift and of structural deformation the Himalayan and Indo-Burmese orogenies as well as the renewed rise of the Shillong Plateau resulted in large-scale erosion and thus in the supply of huge quantities of coarse-grained detritus in the Pliocene (Reimann,1993).

This structure falls in the tropical climate zone and receives heavy shower during monsoon. The area is covered by dense mixed forest with gamari, Chittagong teak and bamboo, shrubs etc.

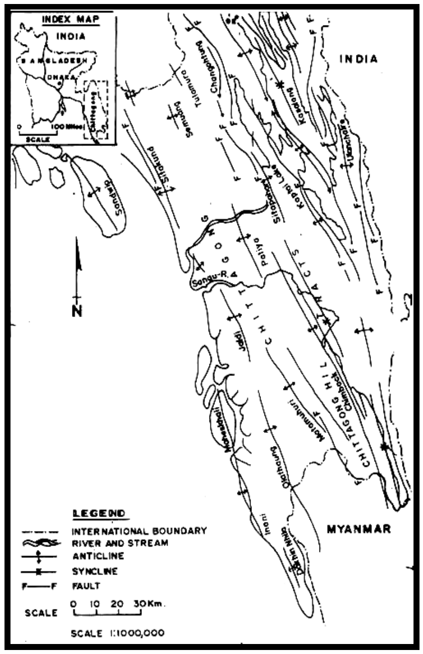
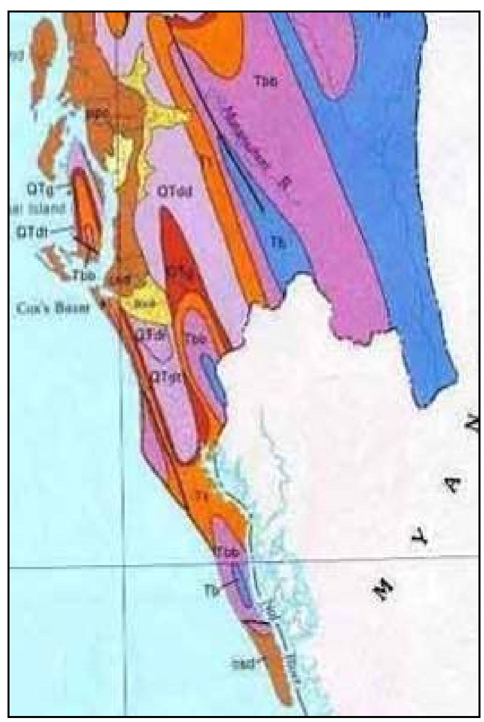
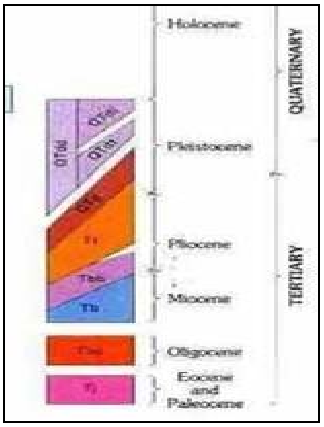


Figure 5: Structural map of Chittagong Hill Tracts





Abbreviations
csd – Beach and dune sand
ava – Valley alluvium and colluvium
QTg – Girujan Clay
Qtdi – Dihing Formation (Pleistocene and Pilocene)
QTdt-Dupi Tila Formation (Pleistocene and Pilocene)
Tt – Tipam Sandstone (Neogene)
Tbb – Boka Bil Formation (Neogene)
Tb – Bhuban Formation (Miocene)
csd – Beach and dune sand

Figure 6: Geological map of Bangladesh (Alam et al., 1990)

1.2.10. Physical setting and Human Interventions in the Municipalities

Cox's Bazar municipality was constituted in 1869 during the British Period and converted to town committee in 1959 during Pakistan Period and after the independence of Bangladesh it has become the municipality in 1972. Upto its current status, it is a class one municipality under the ministry of Local Government and Rural Development. The municipality covers an area of 6.85 sq km with the major landuses like *residential, commercial, agriculture, civic, recreational and hill & forest*. Present population of the municipality is about sixty thousand (projected based on 2001 BBS census) with 9 administrative wards. The trend of urban population growth of the municipality is steady over last four decades. According to BBS community series the decadal growth of the municipality is 30.4, 57.2, 33.7, 42.1 and 37.2 which was respectively for the decades of 1951-1961, 1961-1974, 1974-1981, 1981-1991 and 1991-2001.

A large portion of the municipality is covered with hilly areas with medium to low density forest. Other parts of the municipality are flat in nature with a large sea shore on the south western part of the municipality. Over last decade a number of physical interventions have taken place on across the sea beach through construction of residential hotels and restaurants. Apart from this, the residential settlement of the municipality has grown towards south west and south-east focusing the sea beach. This spatial growth is mainly due to the tourist attractions to the district and to the municipality in particular. As a result of creation of employment opportunities, immigration took place from neighboring districts and interventions have taken place on the hills where a number of settlements took place cutting forest and hills.

It is evident from the field investigation in the hilly part of the municipality are bring occupied by the immigrants and they are living in the places which are prone to landslide events. During the field survey about 65 houses in and around the hill sides with about 600 populations were identified which can be considered as vulnerable areas in respect of landslide hazard.

Teknaf Upazila is bounded by hilly area and Ukhia upazila on the north, the Bay of Bengal on the south and west, Naf river and Myanmar on the east. The upazila stands on the south-eastern extremity of Bangladesh and at a distance of 86 km to the south from Cox's Bazar Sadar. And the *Teknaf* (Town) *Municipality is the major urban center of the Upzila with an area of 4.05 sq kilometer with* 9 wards and 9 mahallas as administrative units. The density of population per sq km is 601. This municipality is very small in area consideration. However, this municipality plays an important role as a land port with neighboring country Myanmar. Moreover, shrimp cultivation and fish hatcheries in the region have made this municipality more busy area over the years. The pace of urbanization in Teknaf Municipality is not that active as in Cox's Bazar Municipality. The major landuse of the municipality is agriculture, residential with house mostly made of local materials, commercial and fisheries. However, the damage to the landslide events were devastating in nature since about 18 people died in 5 landslide events during last 3 years which is comparatively high in the context of Bangladesh. All these incidents took place since the settlements were just at the end of the hill cut slope.

1.3. Collection of Landslide Information for developing the Landslide Inventory

1.3.1. Overview of techniques used

1.3.1.1. Document Review and Field Investigation

Landslide risk evaluation aims to determine the "expected degree of loss due to a landslide" (specific risk) and the expected number of live lost, people injured, damage to property and disruption of economic activity (total risk) (Varnes et al., 1984). Considering the fact, the study team has used several techniques to develop the landslide inventory for the municipality of Cox's Bazar and Teknaf.

In the case of Teknaf and Cox's Bazar information related to past landslides has been collected from two different sources. Among these (a) from the newspaper records and records from different agency (b) in depth field survey in both of the municipalities.

An in-depth study was carried out on the records of landslide across Bangladesh particularly in the Chittagong hill tract region. This study was carried out from old newspapers both from local and national level. A detail description on the landslide events collected from newspaper & other sources are attached as **Annex-A**. Moreover, records from local fire service station and municipality were also taken under consideration for developing the landslide inventory for the study area as well as for other places in Bangladesh. Following is a list of Landslide events in different parts of Bangladesh.

Table 5: List of Rainfall Induced Landslides in Bangladesh

Sl No.	Date	Year	Location	Cause of Landslide	Latitude	Longitude	Fatalities
1	5th May	2003	Noabadi, Akhaura, Chittagong	Heavy Rain	23.8617	91.2189	31
2	15th June	2003	Cox's Bazaar	Heavy Rain	21.5867	92.0748	6
3	29th June	2003	Potiya, Chittagong	Heavy Rain	22.3000	91.9833	4

Sl No.	Date	Year	Location	Cause of Landslide	Latitude	Longitude	Fatalities
4	30th July	2003	Cox's Bazaar	Heavy Rain	24.4670	91.7500	6
5	11th June	2007	Chittagong City	Heavy Rain	22.315957	91.833194	128
6	11th June	2007	Rangamati	Heavy Rain	22.63678	92.145249	3
7	3rd March	2007	Cox's Bazaar (Sadar)	Heavy Rain			1
8	10th Septembe r	2007	Nabinagar in Chittagong	Heavy Rain	23.8916667	90.9733333	2
9	15th October	2007	Betbunia, Rangamati	Heavy Rain	22.533333	89.4	3
10	19th October	2007	Madamdevihat , Chittagong	Heavy Rain	22.894039	91.532741	2
11	19th October	2007	Dolhajra in Chokoria upazila, Chittagong	Heavy Rain	NA	NA	
12	30th June	2008	Moheshkhali	Heavy Rain	NA	NA	1
13	3rd July	2008	Cox's Bazaar, Moheshkhali, Teknaf	Heavy Rain	21.4400	92.0000	12
14	3rd July	2008	Moheshkhali	Heavy Rain	NA	NA	5
15	3rd July	2008	Teknaf	Heavy Rain	NA	NA	3
16	6th July	2008	Cox's Bazaar (Sadar)	Heavy Rain	NA	NA	3
17	6th July	2008	Teknaf	Heavy Rain	NA	NA	2
18	8th July	2008	Ramu, Chittagong	Heavy Rain	NA	NA	2
19	18th August	2008	Lalkhan Bazar in Chittagong	Heavy Rain	22.3399	91.8237	925 injured
20	18th August	2008	Cox's Bazar	Heavy Rain	NA	NA	2
21	18th May	2009	Sreemangal upazila, Moulvibazer.	Heavy Rain	24.3083	91.7333	6
22	31st July	2009	Lama village, Bandarban	Heavy Rain	22.2251	92.1900	10
23	15th June	2010	Teknaf, Ukhia,	Heavy Rain	NA	NA	5134 injured
24	15th June	2010	Ramu	Heavy Rain	NA	NA	
25	15th June	2010	Cox Bazar (Sadar)	Heavy Rain	NA	NA	

***Source:** *Different Daily Newspapers from Bangladesh and news web links (For Detail reference, please see annex-A)*

Apart from the listed/ recorded landslide events in the study area, one team was assigned in the field to identify the detailed landslide events in Teknaf and Cox's Bazar Municipality. A two member team was deployed to conduct detail landslide inventory. This inventory focused on the Locations (coordinates –latitude and longitude- or at least name of the area), Type of landslide. Using the Cruden & Varnes (1996) classification, specifying at least: material (Soil –earth or debris- or Rock), date (and if possible, time) of occurrence, Consequences (quantification of casualties, injuries and damage), existing landuse of the area, elements at risk etc. A detail inventory for both Cox's Bazar and Teknaf has been developed

In Cox's Bazar 147 points have been identified where landslide events took place during last 25 years. These landslide events are ranging from small slides to big events when whole structures were buried. Although the total number of casualties are not that in the municipality but there is a potential threat to people and property since existing settlements are located at many of the hills. Similarly about 18 areas have been identified in the municipality of Teknaf where landslides took place in the past. A good number of people died during the landslide events in Teknaf municipality. A detail list of the inventory on landslide events in Teknaf and Cox's Bazar is attached in Annex-B.

1.3.1.2. Meeting with local government and other stakeholders

The study team had a number of meetings with different stakeholders in the municipality of Cox's Bazar and Teknaf. The first meeting was arranged by Cox's Bazar municipality where the representatives from fire service and civil defense, forestry, Bangladesh metrological department, water development board, roads and highways department, Bangladesh Anser, Bangladesh red cross, ward councilor from different wards were present. The main idea of the consultation meeting was to share the idea of the landslide mapping project and also to get the views from different stakeholders from their experiences. Apart from these the representatives from different departments gave their opinion on the project implementation which has helped lot during the field survey. The study team also visited the Army Camp located near the Marin Drive where Sevier landslide even took place on 15th June when 6 army personnel died, 20 injured and vehicles & structures were damaged. The armed forces division shared their experiences in recovery process after the landslide event in the camp.

1.4. Explanation on classification of future risk levels used in Inventory of landslides.

For risk to be determined the elements at risk need to be assessed within the flow path of existing landslide locations assuming the probability of reoccurrence of respective landslides explained below under chapter 4. The Risk to elements at risk within the observed landslide sites explained below have been categorized based on the recommendation of the JTC-1 Report, produced by the joint ISSMGE, IAEG and ISRM Technical Committee on Landslide and Engineered Slopes as per the following table, It should be recognized that risk zones are dependent on the hazard, the elements at risk and risk control factors. If any one of those alter subsequently the risk zoning need to be revised.

Table 6: An Example of descriptors for risk zoning using property loss criteria

	Consequences to Property(with indicative approximate cost of damage)(1)				
Likelihood of reoccurrence	**1:Catastrophic 200%**	**2:Major 60%**	**3:Medium 20%**	**4:Minor 5%**	**5:Insignificant 0.5%**
Almost certain	Very High	Very High	Very High	High	Medium/Moderate or Low(2)
likely	Very High	Very High	High	Medium/Moderate	Low
Possible	Very High	High	Medium/Moderate	Medium/Moderate	Very Low
Unlikely	High	Medium	Low	Low	Very Low
Rare	Medium/Moderate	Low	Low	Very Low	Very Low
Barely credible	Low	Very Low	Very Low	Very Low	Very Low

1. as a percentage of the value of the property

2. for cell 5, may be sub-divided such that a consequence of less than 0.1%is low risk

1.5. Landslide Inventory developed through field mapping

As mentioned earlier, an in depth survey was carried out to do the landslide inventory on the municipalities. The inventory includes the Locations (coordinates –latitude and longitude- or at least name of the area), Type of landslide. Using the Cruden & Varnes (1996) classification, specifying at least: material (Soil –earth or debris- or Rock), date (and if possible, time) of occurrence, Consequences (quantification of casualties, injuries and damage), existing landuse of the area, elements at risk etc. Following is the detail description on the major landslides in Cox's Bazar and Teknaf Municipalities.

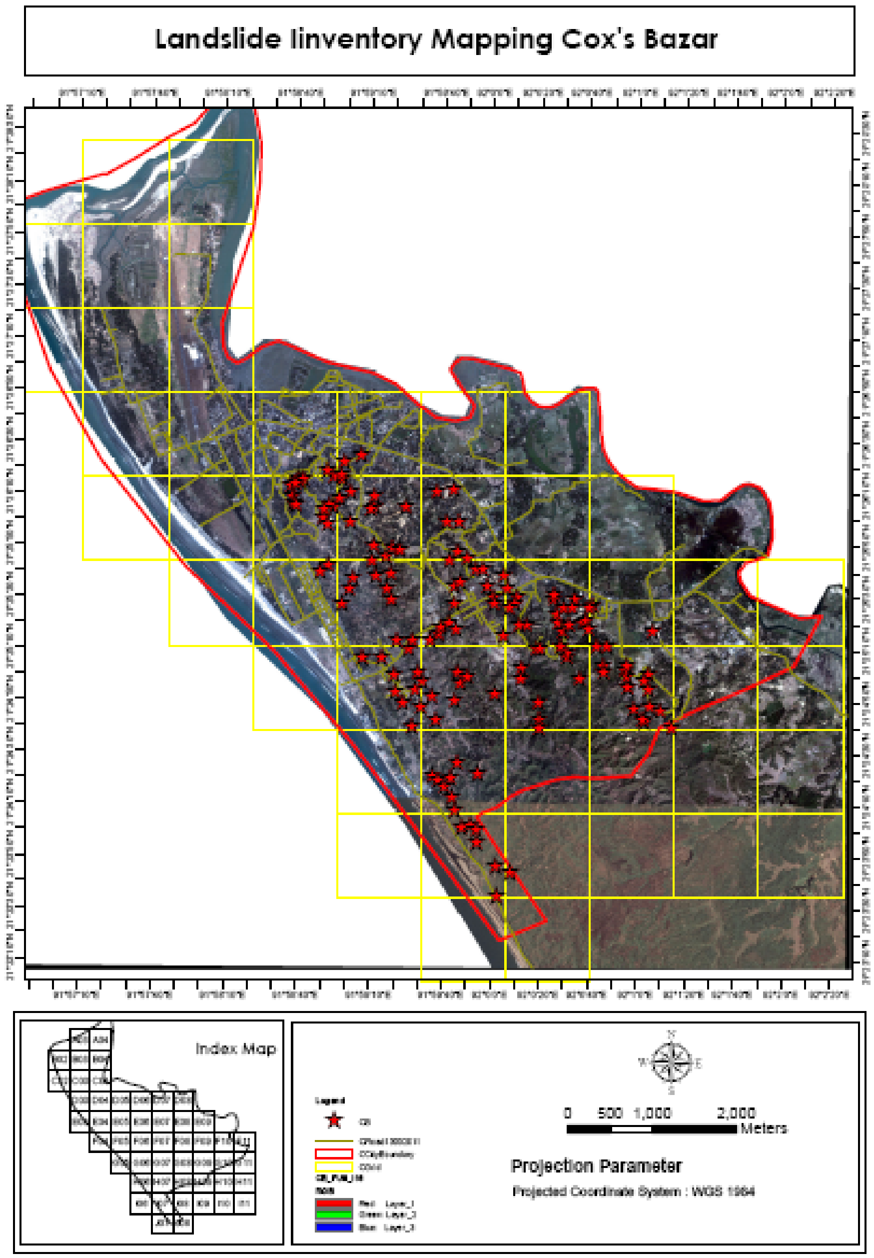
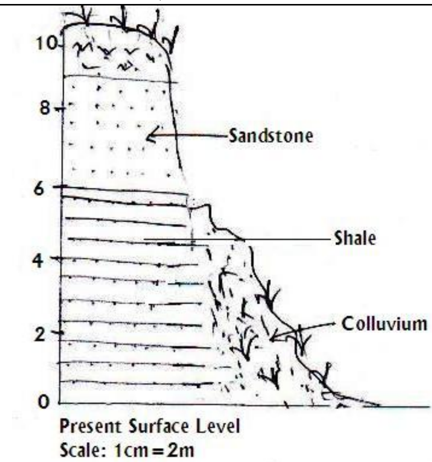


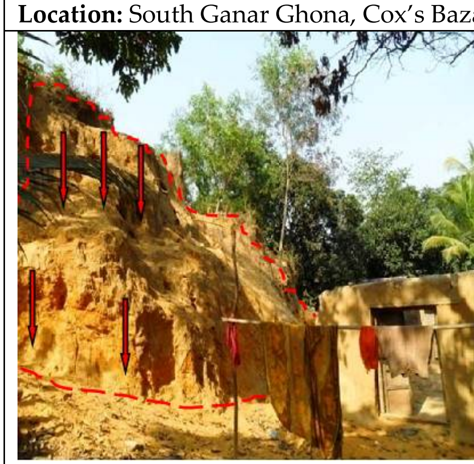
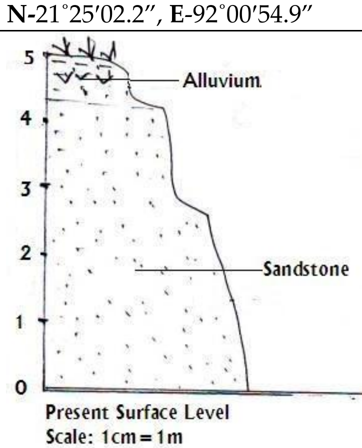
Figure 7: **Locations of Landslide Events at Cox's Bazar Municipality**

<table>
<tr><td>Landslide ID: 09
Location: South Ganar Ghona, Cox's Bazar district</td><td colspan="2">Coordinates:
N-21°25′00.5″, E-92°01′04.6″</td></tr>
<tr><td></td><td colspan="2">
</td></tr>
<tr><td>Date of Occurrence: 15 June 2010, 3 July 2008 and 11 June 2007.
(The Landslide Occurred around 6:00am due to heavy rain.</td><td colspan="2">Landslide History: Initiated movement in June 2007, Subsequently activated in July 2008 and June2010.</td></tr>
<tr><td colspan="3">Rainfall: June 11, 2007: 101 mm during 24 hours and 240mm during 7 days (continuous rain from 4 to 11 June).
July 3, 2008: 134 mm during 24 hours and 729mm during 7 days (continuous rain from 27 June to 3 July).
June 15, 2010:</td></tr>
<tr><td colspan="3">Geology: The failed slope is western scarp of a large escarpment with a height of around 15m. The height of the failed part of the slope is around 12m and width is around 60 m.
The mountain forming bed rock of the escarpment is formed of mainly two lithological units- lower bluish gray thinly laminated moderately weathered shale unit and upper moderately weathered yellowish brown cross-bedded to massive medium- to fine-grained sandstone and the top part of this unit about 3 m is highly weathered. The failed mass comprised of highly weathered rock and moderately weathered rock. After the slide at places a moderately weathered rock is exposed. The exposed rock units are mostly composed of light brown fine to medium grained sand, silt and clay. The height of the failure surface is around 12 m.

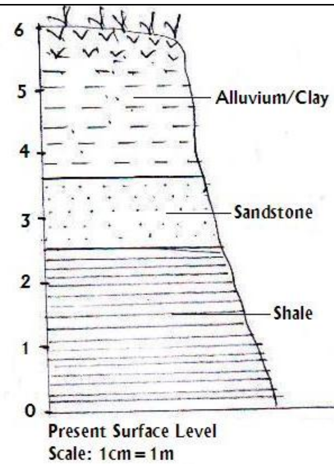
Fracturing: Three sets of joints are observed on failure surface of the bed rock and one is parallel to the bedding plane (158/15) and other two are almost vertical and perpendicular to each other (260/85 and 100/89). The joints are filled with weathered clay, silt and fine sand.

Overburden Deposits: Total overburden comprised of clay, silt and sand material. The material contains the relic structure of the bed rock which suggests it to be residual soil. The soil thickness of the residual soil layer which overlays the bed rock mass is around 1 m thick. The thickness of colluvial soil is around 4m.</td></tr>
<tr><td>Slope Characteristics</td><td colspan="2">The escarpment slope is near vertical and the upper part consists of highly weathered bed rock. Lower part consists of thinly laminated shale. Light brown color fine to medium grained sand which is about 3m in thickness present above the shale layer.
The failed mass is a part of the near vertical escarpment and the debris moved from the slope is underlain by the talus material, which seems to</td></tr>
</table>

	be the remnants of previous landslides. The slope of upper part of the hill is about 18˚and lower part is about 32˚. The upper part consists of highly weathered clay type rock. Lower part consists of sand and shale mass. The failed mass is a part of the upper portion. Thickness is around 4 meters.
Land use	The area is mostly covered with barren field with small to medium height trees and the landslide destroyed a part of the barren field around 40sqm. Some part of this area is used for tree and betel leaf gardening and three houses for human residence. The material has been accumulated with the fallen trees due to moving mass.
Hydrology	No natural drainage path is visible in the area of the landslide and area is dry.
Landslide Mechanism	The recent history shows that the excessive rainfall is the main triggering factor of the slide which can be described as "debris flow". The slide has been reactivated several times during monsoon period. The following can be postulated about the mechanisms. The escarpment from where the landslide occurred has three well developed joint systems. One is parallel to bedding plane and other two are vertical and almost perpendicular to each other. Joints are filled with fine clayey material. During the rainy season the clay filled joints get saturated extrusion of joints take place thus opening and widening the joints. During the dry season the water saturated joints will become dry and shrinks in volume. This reduces the cohesive strength and bonding .This phenomena has repeated several times during dry and wet periods until it has broken away from the main mass due to the combined effect of the gravity and loss of cohesion.
Impact of the landslide	No major impacts. Only a small portion of the hill got destroyed completely
Future Risks	In future this sliding can get repeated as there is a possibility of destabilization of the mass above the slope. The impact would be further destruction to the hill and garden. In the down slope around 50m away several human settlements are located and down slope movement of debris flow can create impact to houses and also people living there. The risk is moderate to high.

Landslide ID: 21 **Location:** South Ganar Ghona, Cox's Bazar district	**Coordinates:** **N-**21˚25′02.2″, **E**-92˚00′54.9″
	

Date of Occurrence: 15 June 2010. The Landslide Occurred around 5:00am due to heavy rain.	**Landslide History**: Landslide occurred here in June 2010.
Geology: The height of failed part of the slope is around 5m and width is around 20m. The exposed rock units are mostly composed of light brown silt, and fine to medium grained sand; locally contains debris derived from local bedrock. Lithology of this area is mainly Sand. The bed rock is massive and loose sediments in the upper part and lower part is well consolidated. The failed mass comprised of completely weathered rock and highly weathered rock. After the slide at places a moderately weathered rock is exposed. The height of the failure surface is around 5m. **Fracturing:** Sets of joints are not observed on failure surface of the rock. **Overburden Deposits:** Total overburden comprised of clay, silt and fine sand materials. The material contains the relic structure of the bed rock which suggests it to be residual soil. The soil thickness of the residual soil layer which overlays the bed rock mass is around 1m thick.	
Slope Characteristics	The escarpment slope is near vertical to incline and the upper part consists of highly to moderately weathered rock. Lower part consists of fine to medium grained sand and it is comparatively slightly weathered.
Land use	This area completely affected by human intervention. Several houses there. Some part of this area is used for gardening.
Hydrology	No natural drainage path is visible in the area of the landslide and area is dry.
Landslide Mechanism	The recent history shows that the excessive rainfall is the main triggering factor of the slide which can be described as "debris flow". The slide has been reactivated several times during monsoon period.
Impact of the landslide	One house in front of this hill got destroyed completely.
Future Risks	In future this sliding can get repeated as there is a possibility of destabilization of the mass above the slope. The impact would be further destruction to the house and garden. The risk is moderate to low.

Landslide ID: 47 **Location:** Adorsha Gram, Cox's Bazar district	**Coordinates:** **N-**21˚24'47.6", **E-**91˚59'30.9"
	
Date of Occurrence: 15 June 2010. **Rainfall:**	**Landslide History**: Landslide occurred here in June, 2010.

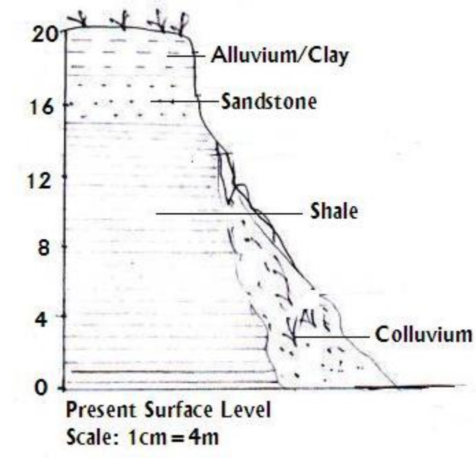
Geology: The failed slope is western scarp of a large escarpment with a height of around 25m. The height of the failed part of the slope is around 6m and width is around 20 m.

The mountain forming bed rock of the escarpment is formed of mainly two lithological units- lower bluish gray thinly laminated moderately weathered shale unit and upper moderately weathered yellowish brown cross-bedded to massive medium- to fine-grained sandstone and the top part of this unit about 2.5 m is highly weathered. The failed mass comprised of highly weathered rock and moderately weathered rock. After the slide at places a moderately weathered rock is exposed. The exposed rock units are mostly composed of light brown fine to medium grained sand, silt and clay. The height of the failure surface is around 6 m.

Fracturing: Three sets of joints are observed on failure surface of the bed rock and one is parallel to the bedding plane (165/5) and other two are almost vertical and perpendicular to each other (350/85 and 185/90). The joints are filled with weathered clay, silt and fine sand.

Overburden Deposits: Total overburden comprised of clay, silt and sand material. The material contains the relic structure of the bed rock which suggests it to be residual soil. The soil thickness of the residual soil layer which overlays the bed rock mass is around 1 m thick.

Slope Characteristics	Original slope 15˚.The upper part consists of highly weathered clay type rock. Lower part consists of sand and shale mass. The failed mass is a part of the upper portion. The slope of landslide is south west which is against the bed slope (North-east).
Land use	This area completely affected by human intervention. 12 houses there and about 80 people living here. Some part used for gardening.
Hydrology	No natural drainage path is visible in the area of the landslide and area is dry.
Landslide Mechanism	The recent history shows that the excessive rainfall is the main triggering factor of the slide. The slide has only been activated in June 2010 during monsoon period. The following can be postulated about the mechanisms. The escarpment from where the landslide occurred has three well developed joint systems. One is parallel to bedding plane and other two are vertical and almost perpendicular to each other. Joints are filled with fine clayey material. During the rainy season the clay filled joints get saturated extrusion of joints take place thus opening and widening the joints. During the dry season the water saturated joints will become dry and shrinks in volume. This reduces the cohesive strength and bonding .This phenomena has repeated several times during dry and wet periods until it has broken away from the main mass due to the combined effect of the gravity and loss of cohesion.
Impact of the landslide	Have major impacts. Three houses got destroyed completely.
Future Risks	In future this sliding can get repeated as there is a possibility of destabilization of the mass above the slope. The impact would be further destruction to the hill and human settlements and gardens. The risk is moderate to high.

Landslide ID: 70 **Location:** West Lar Para, Kolatoli Bypass., Cox's Bazar district	**Coordinates:** **N-**21˚25′35.8″ **E-**91˚59′47.0″
	
Date of Occurrence: 15 June, 2010 and 15 June, 2003.	**Landslide History**: Initiated movement in June 2003, Subsequently activated in June 2010 (Repetitive).

Rainfall: June 15, 2003: 77 mm during 24 hours and 771mm during 13 days (continuous rain from 3 to 15 June) June 15, 2010:

Geology: The failed slope is western scarp of a large escarpment with a height of around 25m. The height of the failed part of the slope is around 20m and width is around 50 m.

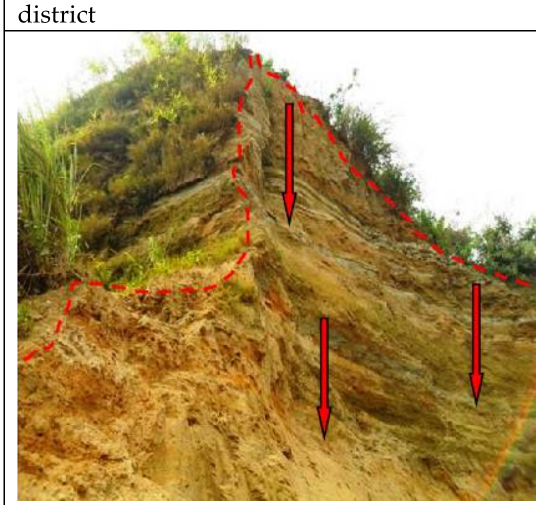
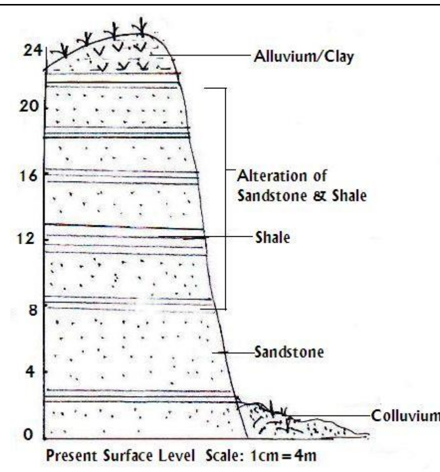
The mountain forming bed rock of the escarpment is formed of mainly two lithological units- lower bluish gray thinly laminated moderately weathered shale unit and upper moderately weathered yellowish brown cross-bedded to massive medium- to fine-grained sandstone and the top part of this unit about 3 m is highly weathered. The failed mass comprised of highly weathered rock and moderately weathered rock. After the slide at places a moderately weathered rock is exposed. The exposed rock units are mostly composed of light brown fine to medium grained sand, silt and clay. The height of the failure surface is around 20 m.

Fracturing: Three sets of joints are observed on failure surface of the bed rock and one is parallel to the bedding plane (345/7) and other two are almost vertical and perpendicular to each other (170/85 and 5/88). The joints are filled with weathered clay, silt and fine sand.

Overburden Deposits: Total overburden comprised of clay, silt and sand material. The material contains the relic structure of the bed rock which suggests it to be residual soil. The thickness of the residual soil layer which overlays the bed rock mass is around 2 m thick. The thickness of colluvial soil is around 8m.

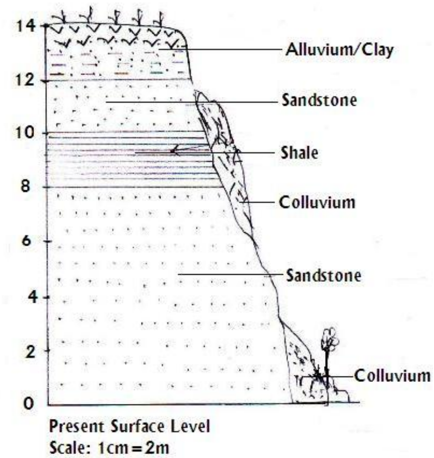
Slope Characteristics	The escarpment slope is inclined and the upper part consists of highly weathered bed rock. Lower part consists of laminated shale against the slope. Original slope 29˚.The upper part consists of highly weathered clay type rock. Lower part consists of sand and shale mass. The failed mass is a part of the upper portion. Thickness is around 8meters.
Land use	This area completely affected by human intervention. There are 5 houses and about 30 people living here. Some part used for gardening and rest of the area is barren field.
Hydrology	No natural drainage path is visible in the area of the landslide and area is dry.

Landslide Mechanism	The recent history shows that the excessive rainfall is the main triggering factor of the slide which can be described as "debris flow". The slide has been reactivated several times during monsoon period. The slide has been activated in June 2003 during monsoon period. The following can be postulated about the mechanisms. The escarpment from where the landslide occurred has three well developed joint systems. One is parallel to bedding plane and other two are vertical and almost perpendicular to each other. Joints are filled with fine clayey material. During the rainy season the clay filled joints get saturated extrusion of joints take place thus opening and widening the joints. During the dry season the water saturated joints will become dry and shrinks in volume. This reduces the cohesive strength and bonding .This phenomena has repeated several times during dry and wet periods until it has broken away from the main mass due to the combined effect of the gravity and loss of cohesion.
Impact of the landslide	Have major impacts. One house got destroyed completely and 2 people died in June 2003.
Future Risks	In future this sliding can get repeated as there is a possibility of destabilization of the mass above the slope. The impact would be further destruction to the hill. In the down slope around 20m away several human settlements are located and down slope movement of debris flow can create impact to houses and also people living there. The impact would be further destruction to the hill. The risk is moderate to high.

Landslide ID: 80 **Location:** Lar Para, Kolatoli Bypass., Cox's Bazar district	**Coordinates:** **N-**21˚25'30.2", **E-**92˚00'10.2"
	
Date of Occurrence: 15 June, 2010 and 3 July 2008.	**Landslide History**: Initiated movement in July 2008, Subsequently activated in June 2010.

Rainfall: July 3, 2008: 134 mm during 24 hours and 729mm during 7 days (continuous rain from 27 June to 3 July)
Geology: The failed slope is noth-western scarp of a large escarpment with a height of around 30m. The height of the failed part of the slope is around 24m and width is around 35 m. The mountain forming bed rock of the escarpment is formed of mainly two lithological units- bluish gray thinly

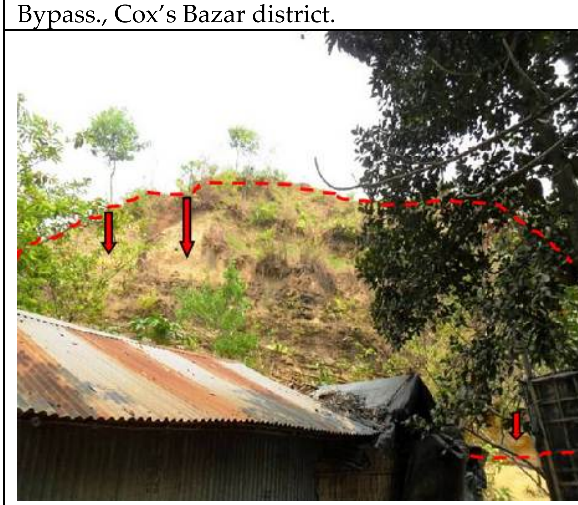
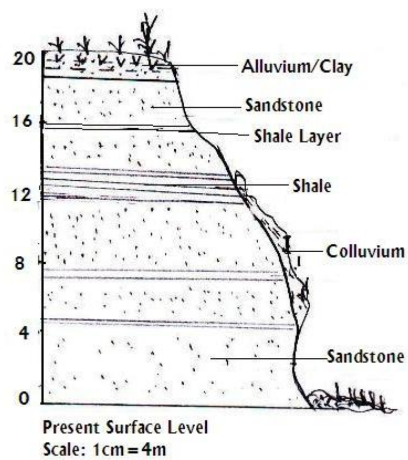
laminated shale unit and yellowish brown cross-bedded to massive medium- to fine-grained sandstone. Lithology of this area is mainly alteration of Shale and Sandstone. Top part of this unit about 2.5 m is highly weathered. The failed mass comprised of highly weathered rock and moderately weathered rock. After the slide at places a moderately weathered rock is exposed. The exposed rock units are mostly composed of light brown fine to medium grained sand, silt and clay. The height of the failure surface is around 24m. **Fracturing:** Three sets of joints are observed on failure surface of the bed rock and one is parallel to the bedding plane (330/5) and other two are almost vertical and perpendicular to each other (170/85 and 5/89). The joints are filled with weathered clay, silt and fine sand. **Overburden Deposits:** Total overburden comprised of clay, silt and sand material. The material contains the relic structure of the bed rock which suggests it to be residual soil. The soil thickness of the residual soil layer which overlays the bed rock mass is around 1 m thick. The soil thickness of the residual soil layer which overlays the bed rock mass is around 2m thick.	
Slope Characteristics	The escarpment slope is near vertical and the upper part consists of highly weathered bed rock. Lower part consists of fine to medium grained sand. The landslide slope is created against the bed slope. The joint system is almost vertical. The failed mass is a part of the near vertical escarpment and the debris moved from the slope. Original slope is about 45˚.The upper part consists of highly weathered clay type rock. Lower part consists of alteration of sand and shale mass. The failed mass is a part of the upper portion. Thickness is around 2m.
Land use	The area is mainly used for human settlements. There are more than 7 houses and more than 50 people live in this area. Some part of this area used for gardening.
Hydrology	No natural drainage path is visible in the area of the landslide and area is dry.
Landslide Mechanism	The recent history shows that the excessive rainfall is the main triggering factor of the slide which can be described as "debris flow". The slide has been activated in June 2008 during monsoon period. The following can be postulated about the mechanisms. The escarpment from where the landslide occurred has three well developed joint systems. One is parallel to bedding plane and other two are vertical and almost perpendicular to each other. Joints are filled with fine clayey material. During the rainy season the clay filled joints get saturated extrusion of joints take place thus opening and widening the joints. During the dry season the water saturated joints will become dry and shrinks in volume. This reduces the cohesive strength and bonding .This phenomena has repeated several times during dry and wet periods until it has broken away from the main mass due to the combined effect of the gravity and loss of cohesion.
Impact of the landslide	Have major impacts. One house got destroyed completely.
Future Risks	In future this sliding can get repeated as there is a possibility of destabilization of the mass above the slope. The impact would be further destruction to the hill. In the down slope around 10m away the local people residence is located and down slope movement of larger debris flow can create impact to houses and also people living there. The risk is moderate to high.

<table>
<tr><td>Landslide ID: 86
Location: South Dikkul, Lar Para, Kolatoli Bypass., Cox's Bazar district</td><td colspan="2">Coordinates:
N-21˚25′17.5″,
E-92˚00′29.1″</td></tr>
<tr><td></td><td colspan="2">
</td></tr>
<tr><td>Date of Occurrence: July 6, 2008.</td><td colspan="2">Landslide History: Landslide occurred here in July 2008.</td></tr>
<tr><td colspan="3">Rainfall: 64 mm during 24 hours and 927mm during 10 days (continuous rain from 27 June to 6 July)</td></tr>
<tr><td colspan="3">Geology: The failed slope is western scarp of a large escarpment with a height of around 15m. The height of the failed part of the slope is around 12m and width is around 60 m.
The mountain forming bed rock of the escarpment is formed of mainly two lithological units: bluish gray thinly laminated shale unit and yellowish brown cross-bedded to massive medium- to fine-grained sandstone. Sandstones comparatively loose and less compact. Top part of this unit about 3.5m is highly weathered. The failed mass comprised of highly weathered rock and moderately weathered rock. After the slide at places a moderately weathered rock is exposed. The exposed rock units are mostly composed of light brown fine to medium grained sand, silt and clay. The height of the failure surface is around 13 m.

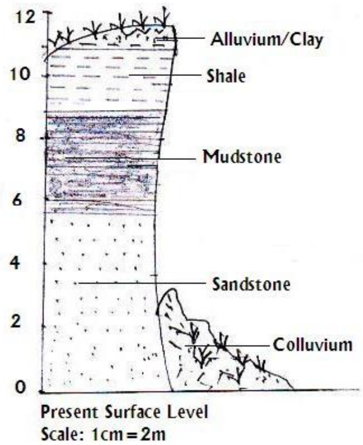
Fracturing: Three sets of joints are observed on failure surface of the bed rock and one is parallel to the bedding plane (345/7) and other two are almost vertical and perpendicular to each other (350/85 and 185/88). The joints are filled with weathered clay, silt and fine sand.

Overburden Deposits: Total overburden comprised of clay, silt and sand material. The material contains the relic structure of the bed rock which suggests it to be residual soil. The soil thickness of the residual soil layer which overlays the bed rock mass is around 1 m thick. The thickness of colluvial soil is around 8m.</td></tr>
<tr><td>Slope Characteristics</td><td colspan="2">The escarpment slope is near vertical to incline and the upper part consists of highly weathered bed rock (clay type rock). Lower part consists of fine to medium grained sand. Soil mass accumulated against the slope. Original slope 32˚. The failed mass is a part of the upper portion. Thickness is around 8m.</td></tr>
<tr><td>Land use</td><td colspan="2">The area is mainly used for human settlements. There are more than 5 houses and more than 30 people live in this area. Some part of this area used for gardening. The material has been accumulated with the fallen trees due to moving mass.</td></tr>
<tr><td>Hydrology</td><td colspan="2">No natural drainage path is visible in the area of the landslide and area is dry.</td></tr>
</table>

Landslide Mechanism	The recent history shows that the excessive rainfall is the main triggering factor of the slide which can be described as "debris flow". The slide has only been activated in June 2009 during monsoon period. The following can be postulated about the mechanisms. The escarpment from where the landslide occurred has three well developed joint systems. One is parallel to bedding plane and other two are vertical and almost perpendicular to each other. Joints are filled with fine clayey material. During the rainy season the clay filled joints get saturated extrusion of joints take place thus opening and widening the joints. During the dry season the water saturated joints will become dry and shrinks in volume. This reduces the cohesive strength and bonding .This phenomena has repeated several times during dry and wet periods until it has broken away from the main mass due to the combined effect of the gravity and loss of cohesion.
Impact of the landslide	No major impacts. Only a house got destroyed partially.
Future Risks	In future this sliding can get repeated as there is a possibility of destabilization of the mass above the slope. The impact would be further destruction to the hill. In the down slope around 10m away the local human residence is located and down slope movement of larger debris flow can create impact to houses and also people living there. The risk is moderate to high.

Landslide ID: 87 **Location:** South Dikkul, Lar Para, Kolatoli Bypass., Cox's Bazar district.	**Coordinates:** **N-**21˚25'20.4", **E-** 92˚00'27.2"
	
Date of Occurrence: June 19, 2004 and July 8, 2006.	**Landslide History**: Initiated movement in June 2004, Subsequently activated in July 2006.
Rainfall: June 19, 2004: 142 mm during 24 hours and 447mm during 4 days (continuous rain from 15 to 19 June) July 8, 2006: 100 mm during 24 hours.	
Geology: The failed slope is south-eastern scarp of a large escarpment with a height of around 24m. The height of the failed part of the slope is around 20m and width is around 40 m. The mountain forming bed rock of the escarpment is formed of mainly two lithological units: bluish gray thinly laminated shale unit and yellowish brown cross-bedded to massive medium- to fine-grained sandstone. Sandstones comparatively loose and less compact. Top part of this section about	

3 m is highly weathered. The failed mass comprised of highly weathered rock and moderately weathered rock. After the slide at places a moderately weathered rock is exposed. The exposed rock units are mostly composed of light brown fine to medium grained sand, silt and clay. The height of the failure surface is around 20 m. **Fracturing:** Three sets of joints are observed on failure surface of the bed rock and one is parallel to the bedding plane (350/10) and other two are almost vertical and perpendicular to each other (350/80 and 185/85). The joints are filled with weathered clay, silt and fine sand. **Overburden Deposits:** Total overburden comprised of clay, silt and sand material. The material contains the relic structure of the bed rock which suggests it to be residual soil. The soil thickness of the residual soil layer which overlays the bed rock mass is around 1.5 m thick.	
Slope Characteristics	The escarpment slope is near vertical to incline and the upper part consists of highly weathered bed rock (clay type rock). Lower part consists of fine to medium grained sand. Soil mass accumulated against the slope. Original slope 32˚. The failed mass is a part of the upper portion. Thickness is around 7m.
Land use	The area is mainly used for human settlements. There are more than 7 houses and more than 35 people live in this area. Some part of this area used for gardening. The material has been accumulated with the fallen trees due to moving mass.
Hydrology	No natural drainage path is visible in the area of the landslide and area is dry.
Landslide Mechanism	The recent history shows that the excessive rainfall is the main triggering factor of the slide which can be described as "debris flow". The slide has been activated in June 2004 during monsoon period. The following can be postulated about the mechanisms. The escarpment from where the landslide occurred has three well developed joint systems. One is parallel to bedding plane and other two are vertical and almost perpendicular to each other. Joints are filled with fine clayey material. During the rainy season the clay filled joints get saturated extrusion of joints take place thus opening and widening the joints. During the dry season the water saturated joints will become dry and shrinks in volume. This reduces the cohesive strength and bonding .This phenomena has repeated several times during dry and wet periods until it has broken away from the main mass due to the combined effect of the gravity and loss of cohesion.
Impact of the landslide	No major impacts. Only a kitchen got destroyed partially.
Future Risks	In future this sliding can get repeated as there is a possibility of destabilization of the mass above the slope. The impact would be further destruction to the hill. In the down slope around 10m away the local human residence is located and down slope movement of larger debris flow can create impact to houses and also people living there. The risk is moderate to high.

Landslide ID: 90 **Location:** South Dikkul, Lar Para, Cox's Bazar district.	**Coordinates:** **N**-21˚25′31.8″ **E**-92˚00′25.7″
	
Date of Occurrence: July 3, 2008.	**Landslide History**: Subsequently activated in July 2008.

Rainfall: 134 mm during 24 hours and 729mm during 7 days (continuous rain from 27 June to 3 July)

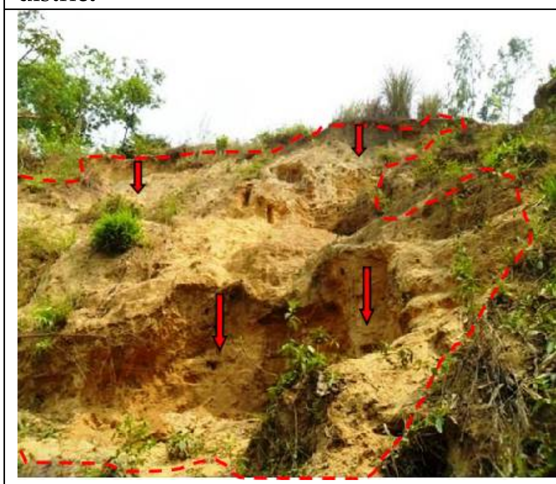
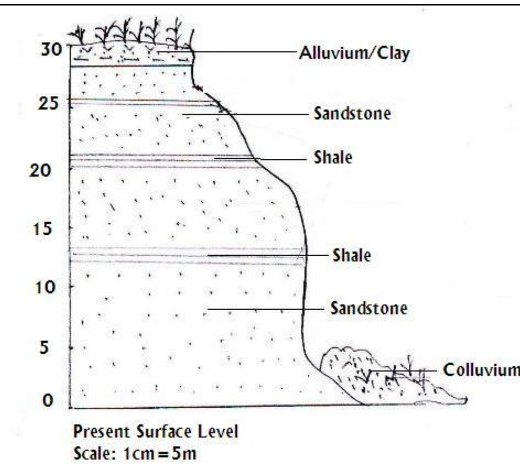
Geology: The failed slope is western scarp of a large escarpment with a height of around 15m. The height of the failed part of the slope is around 11m and width is around 30 m.
The mountain forming bed rock of the escarpment is formed of mainly three lithological units- bluish gray thinly laminated shale unit, dark gray mudstone and yellowish brown cross-bedded to massive medium- to fine-grained sandstone. The failed mass comprised of highly weathered rock and moderately weathered rock. After the slide at places a moderately weathered rock is exposed. The exposed rock units are mostly composed of light brown fine to medium grained sand, silt and clay. The height of the failure surface is around 11 m.

Fracturing: Three sets of joints are observed on failure surface of the bed rock and one is parallel to the bedding plane (350/10) and other two are almost vertical and perpendicular to each other (350/80 and 185/85). The joints are filled with weathered clay, silt and fine sand.

Overburden Deposits: Total overburden comprised of clay, silt and sand material. The material contains the relic structure of the bed rock which suggests it to be residual soil. The soil thickness of the residual soil layer which overlays the bed rock mass is around 0.5 m thick.

Slope Characteristics	The escarpment slope is vertical and the upper part consists of highly weathered bed rock (clay type rock). Original slope 36˚. Middle part consists of thick mudstone layer. Lower part consists of fine to medium grained sand. Soil mass accumulated against the slope. Thickness is around 2m.
Land use	The area is mainly used for human settlements. There are more than 2 houses and more than 15 people live in this area. Some part of this area used for gardening.
Hydrology	No natural drainage path is visible in the area of the landslide and area is dry.
Landslide Mechanism	The recent history shows that the excessive rainfall is the main triggering factor of the slide which can be described as "debris flow". The slide has been activated in June 2009 during monsoon period. The following can be postulated about the mechanisms.

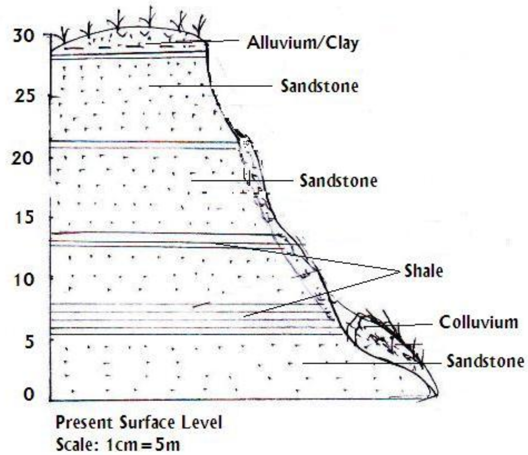
	The escarpment from where the landslide occurred has three well developed joint systems. One is parallel to bedding plane and other two are vertical and almost perpendicular to each other. Joints are filled with fine clayey material. During the rainy season the clay filled joints get saturated extrusion of joints take place thus opening and widening the joints. During the dry season the water saturated joints will become dry and shrinks in volume. This reduces the cohesive strength and bonding .This phenomena has repeated several times during dry and wet periods until it has broken away from the main mass due to the combined effect of the gravity and loss of cohesion.
Impact of the landslide	No major impacts. Only a tree garden destroyed partially.
Future Risks	In future this sliding can get repeated as there is a possibility of destabilization of the mass above the slope. The impact would be further destruction to the hill. In the down slope around 15m away the local human residence is located and down slope movement of larger debris flow can create impact to houses and also people living there. The risk is moderate to high.

Landslide ID: 93 **Location:** South Dikkul, Lar Para, Cox's Bazar district	**Coordinates:** **N**-21˚25′26.2″, **E**-92˚00′33.2″
	
Date of Occurrence: 15 June 2010 and 3 July 2008.	**Landslide History**: Initiated movement in July 2008, Subsequently activated in June 2010.

Rainfall: July 6, 2008: 64 mm during 24 hours and 927mm during 10 days (continuous rain from 27 June to 6 July)

Geology: The failed slope is northern scarp of a large escarpment with a height of around 40m. The height of the failed part of the slope is around 30m and width is around 50 m.
The mountain forming bed rock of the escarpment is formed of mainly two lithological units- bluish gray thinly laminated shale unit and upper yellowish brown cross-bedded to massive medium- to fine-grained sandstone and the top part of this unit about 4 m is highly weathered. The failed mass comprised of highly weathered rock and moderately weathered rock. After the slide at places a moderately weathered rock is exposed. The exposed rock units are mostly composed of light brown fine to medium grained sand, silt and clay. Sandstones comparatively loose and less compact. The height of the failure surface is around 30 m.
Fracturing: Three sets of joints are observed on failure surface of the bed rock and one is parallel to

the bedding plane (350/10) and other two are almost vertical and perpendicular to each other (350/80 and 185/85). The joints are filled with weathered clay, silt and fine sand. **Overburden Deposits:** Total overburden comprised of clay, silt and sand material. The material contains the relic structure of the bed rock which suggests it to be residual soil. The soil thickness of the residual soil layer which overlays the bed rock mass is around 2 m thick.	
Slope Characteristics	The escarpment slope is inclined and the upper part consists of highly weathered bed rock (clay type rock). Lower part consists of fine to medium grained sand. Original slope 31˚. The failed mass is a part of the upper portion. Thickness is around 3m.
Land use	The area is mainly used for human residence. There are more than 4 houses and more than 20 people live in this area. Some part of this area used for tree gardening. The material has been accumulated with the fallen trees due to moving mass.
Hydrology	No natural drainage path is visible in the area of the landslide and area is dry.
Landslide Mechanism	The recent history shows that the excessive rainfall is the main triggering factor of the slide which can be described as "debris flow". The slide has been activated in June 2008 during monsoon period. The following can be postulated about the mechanisms. The escarpment from where the landslide occurred has three well developed joint systems. One is parallel to bedding plane and other two are vertical and almost perpendicular to each other. Joints are filled with fine clayey material. During the rainy season the clay filled joints get saturated extrusion of joints take place thus opening and widening the joints. During the dry season the water saturated joints will become dry and shrinks in volume. This reduces the cohesive strength and bonding .This phenomena has repeated several times during dry and wet periods until it has broken away from the main mass due to the combined effect of the gravity and loss of cohesion.
Impact of the landslide	No major impacts. Only a kitchen got destroyed partially.
Future Risks	In future this sliding can get repeated as there is a possibility of destabilization of the mass above the slope. The impact would be further destruction to the hill. In the down slope around 20m away the local human residence is located and down slope movement of larger debris flow can create impact to houses and also people living there. The risk is moderate to high.

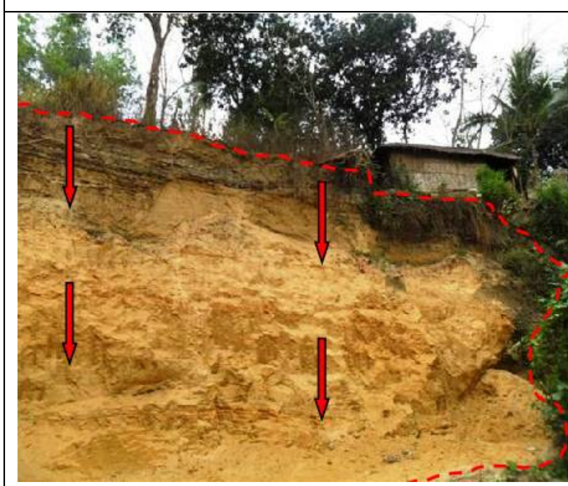
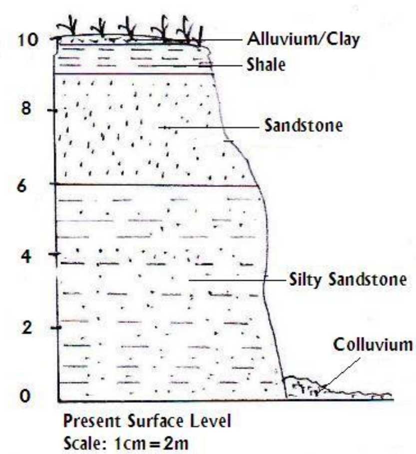
Landslide ID: 95 **Location:** South Dikkul, Lar Para, Cox's Bazar district	**Coordinates:** **N**-21°25′21.1″ **E**-92°00′37.6″
	
Date of Occurrence: 15 June 2010 and July 3, 2008.	**Landslide History**: Initiated movement in July 2008, Subsequently activated in June 2010.

Rainfall: July 3, 2008: 134 mm during 24 hours and 729mm during 7 days (continuous rain from 27 June to 3 July)

Geology: The failed slope is north-western scarp of a large escarpment with a height of around 40m. The height of the failed part of the slope is around 30m and width is around 60m.
The mountain forming bed rock of the escarpment is dark gray shale but highly to moderately weathered on the surface exposure. The bed rock is thinly laminated and highly weathered in the upper part and lower part is well consolidated. The failed mass comprised of completely weathered rock and highly weathered rock. After the slide at places a moderately weathered rock is exposed. The exposed rock units are mostly composed of light brown silt, clay and fine to medium grained sand. Lithology of this area is mainly Shale and Sandstone. Sandstones comparatively loose and less compact. The height of the failure surface is around 30 m.
Fracturing: Three sets of joints are observed on failure surface of the bed rock and one is parallel to the bedding plane (350/10) and other two are almost vertical and perpendicular to each other (350/80 and 185/85). The joints are filled with weathered clay, silt and fine sand.
Overburden Deposits: Total overburden comprised of clay, silt and sand material. The material contains the relic structure of the bed rock which suggests it to be residual soil. The soil thickness of the residual soil layer which overlays the bed rock mass is around 2m thick

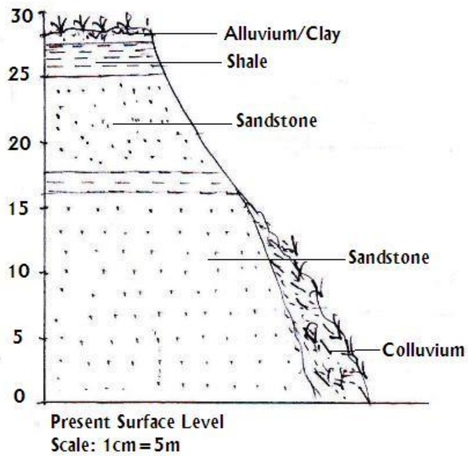
Slope Characteristics	The escarpment slope is near vertical to incline and the upper part consists of highly weathered bed rock (clay type rock). Lower part consists of fine to medium grained sand. Original slope 20°. The failed mass is a part of the upper portion. Thickness is around 10m.
Land use	The area is mainly used for human residence. There are more than 3 houses and more than 17 people live in this area. Some part of this area used for tree gardening.
Hydrology	No natural drainage path is visible in the area of the landslide and area is dry.
Landslide Mechanism	The recent history shows that the excessive rainfall is the main triggering factor of the slide which can be described as "debris flow". The slide has been activated in June 2009 during monsoon period. The following can be postulated about the mechanisms.

	The escarpment from where the landslide occurred has three well developed joint systems. One is parallel to bedding plane and other two are vertical and almost perpendicular to each other. Joints are filled with fine clayey material. During the rainy season the clay filled joints get saturated extrusion of joints take place thus opening and widening the joints. During the dry season the water saturated joints will become dry and shrinks in volume. This reduces the cohesive strength and bonding .This phenomena has repeated several times during dry and wet periods until it has broken away from the main mass due to the combined effect of the gravity and loss of cohesion.
Impact of the landslide	Have major impacts. A house got destroyed completely but no injured.
Future Risks	In future this sliding can get repeated as there is a possibility of destabilization of the mass above the slope. The impact would be further destruction to the hill. In the down slope around 10m away the local human residence is located and down slope movement of larger debris flow can create impact to houses and also people living there. The risk is moderate to high.

Landslide ID: 97 **Location:** South Haji Para, Cox's Bazar district	**Coordinates:** **N**-21˚25'26.6" **E**-92˚00'40.0"
	
Date of Occurrence: 15 June 2010 and 10 June 2006.	**Landslide History**: Initiated movement in June 2006, Subsequently activated in June 2010.

Rainfall: June 10, 2006: 113 mm during 24 hours and 477mm during 7 days (continuous rain from 4 to 10 June).
Geology: The failed slope is eastern scarp of a large escarpment with a height of around 12m. The height of the failed part of the slope is around 10m and width is around 30m. The mountain forming bed rock of the escarpment is formed of mainly two lithological units- bluish gray thinly laminated moderately weathered shale unit and moderately weathered yellowish brown cross-bedded to massive medium- to fine-grained sandstone and the top part of this unit about 1 m is highly weathered. The failed mass comprised of highly weathered rock and moderately weathered rock. After the slide at places a moderately weathered rock is exposed. The exposed rock units are mostly composed of light brown fine to medium grained sand, silt and clay. Sandstones comparatively loose and lower portion comprises of clayey silt materials. The height of the failure surface is around 10 m. **Fracturing:** Three sets of joints are observed on failure surface of the bed rock and one is parallel to

the bedding plane (350/10) and other two are almost vertical and perpendicular to each other (350/80 and 185/85). The joints are filled with weathered clay, silt and fine sand. **Overburden Deposits:** Total overburden comprised of clay, silt and sand material. The material contains the relic structure of the bed rock which suggests it to be residual soil. The soil thickness of the residual soil layer which overlays the bed rock mass is around 0.5 m thick.	
Slope Characteristics	The escarpment slope is vertical and the upper part consists of highly weathered bed rock (clay type rock). Lower part consists of fine to medium grained sand and silty clay. Original slope 23˚.
Land use	The area is mainly used for human residence. There are more than 7 houses and more than 42 people live in this area. Some part of this area used for tree gardening.
Hydrology	No natural drainage path is visible in the area of the landslide and area is dry.
Landslide Mechanism	The recent history shows that the excessive rainfall is the main triggering factor of the slide which can be described as "debris flow". The slide has been activated in June 2006 during monsoon period. The following can be postulated about the mechanisms. The escarpment from where the landslide occurred has three well developed joint systems. One is parallel to bedding plane and other two are vertical and almost perpendicular to each other. Joints are filled with fine clayey material. During the rainy season the clay filled joints get saturated extrusion of joints take place thus opening and widening the joints. During the dry season the water saturated joints will become dry and shrinks in volume. This reduces the cohesive strength and bonding .This phenomena has repeated several times during dry and wet periods until it has broken away from the main mass due to the combined effect of the gravity and loss of cohesion.
Impact of the landslide	Have major impacts. Two houses got destroyed completely but no injured.
Future Risks	In future this sliding can get repeated as there is a possibility of destabilization of the mass above the slope. The impact would be further destruction to the hill. In the down slope around 10m away the local human residence is located and down slope movement of larger debris flow can create impact to houses and also people living there. The risk is moderate to high.

Landslide ID: 98 **Location:** South Haji Para, Cox's Bazar district	**Coordinates:** **N**-21˚25′21.3″ **E**-92˚00′38.7″
	
Date of Occurrence: 15 June 2010 and June 19, 2004.	**Landslide History**: Initiated movement in June 2004, Subsequently activated in June 2010.

Rainfall: June 19, 2004: 142 mm during 24 hours and 447mm during 4 days (continuous rain from 15 to 19 June)

Geology: The failed slope is northern scarp of a large escarpment with a height of around 30m. The height of the failed part of the slope is around 28m and width is around 40m.
The mountain forming bed rock of the escarpment is formed of mainly two lithological units- bluish gray thinly laminated shale unit and r yellowish brown cross-bedded to massive medium- to fine-grained sandstone and the top part of this section about 3 m is highly weathered. The failed mass comprised of highly weathered rock and moderately weathered rock. After the slide at places a moderately weathered rock is exposed. The exposed rock units are mostly composed of light brown fine to medium grained sand, silt and clay. Sandstones comparatively loose and less compact. The height of the failure surface is around 28 m.
Fracturing: Three sets of joints are observed on failure surface of the bed rock and one is parallel to the bedding plane (350/10) and other two are almost vertical and perpendicular to each other (350/80 and 185/85). The joints are filled with weathered clay, silt and fine sand.
Overburden Deposits: Total overburden comprised of clay, silt and sand material. The material contains the relic structure of the bed rock which suggests it to be residual soil. The soil thickness of the residual soil layer which overlays the bed rock mass is around 1 m thick. The residual soil thickness is about 1m and colluviums soil is about 11m.

Slope Characteristics	The escarpment slope is near vertical to incline and the upper part consists of highly weathered bed rock (clay type rock). Lower part consists of fine to medium grained sand. Original slope 20˚. The failed mass is a part of the near vertical escarpment and the debris moved from the slope is underlain by the talus material, which seems to be the remnants of previous landslides. The failed mass is a part of the upper portion. Thickness is around 11 meters.
Land use	The area is mainly used for human residence. There are more than 10 houses and more than 60 people live in this area. Some part of this area used for tree gardening.
Hydrology	No natural drainage path is visible in the area of the landslide and area is dry.
Landslide Mechanism	The recent history shows that the excessive rainfall is the main

	triggering factor of the slide which can be described as "debris flow". The slide has been activated in June 2004 during monsoon period. The following can be postulated about the mechanisms. The escarpment from where the landslide occurred has three well developed joint systems. One is parallel to bedding plane and other two are vertical and almost perpendicular to each other. Joints are filled with fine clayey material. During the rainy season the clay filled joints get saturated extrusion of joints take place thus opening and widening the joints. During the dry season the water saturated joints will become dry and shrinks in volume. This reduces the cohesive strength and bonding .This phenomena has repeated several times during dry and wet periods until it has broken away from the main mass due to the combined effect of the gravity and loss of cohesion.
Impact of the landslide	Have major impacts. One house got destroyed completely but no injured.
Future Risks	In future this sliding can get repeated as there is a possibility of destabilization of the mass above the slope. The impact would be further destruction to the hill. In the down slope around 10m away the local human residence is located and down slope movement of larger debris flow can create impact to houses and also people living there. The risk is moderate to high.

<table>
<tr><td>Landslide ID: 99
Location: South Haji Para, Cox's Bazar district</td><td>Coordinates:
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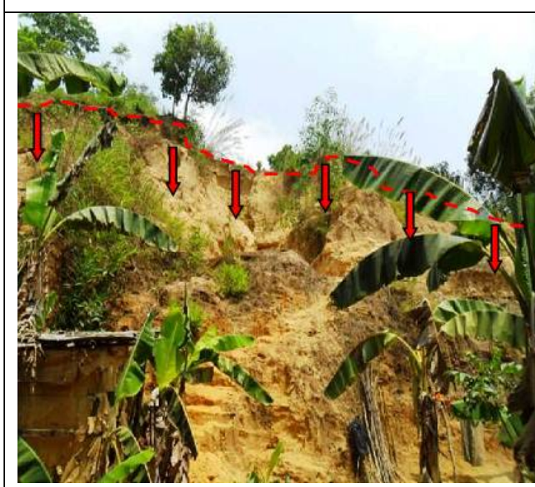
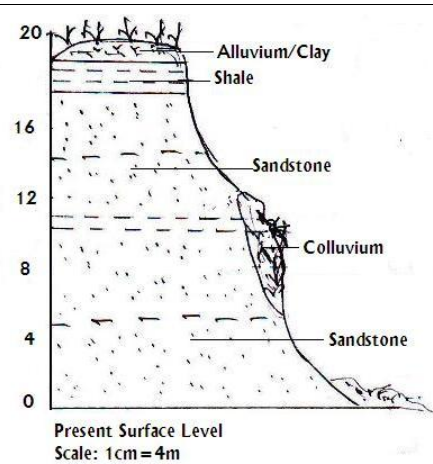
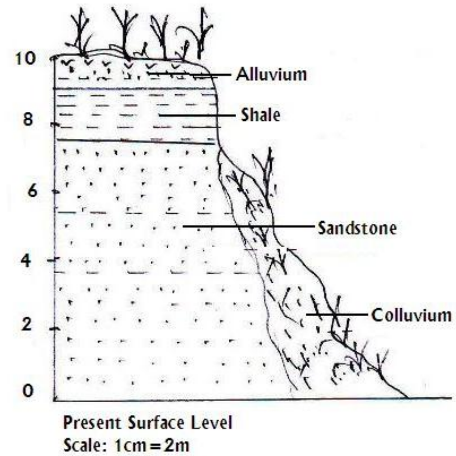
E-92˚00'39.9"</td></tr>
<tr><td></td><td>
</td></tr>
<tr><td>Date of Occurrence: 15 June 2010 and July 3, 2008.</td><td>Landslide History: Initiated movement in July 2008, Subsequently activated in June 2010.</td></tr>
<tr><td colspan="2">Rainfall: July 3, 2008: 134 mm during 24 hours and 729mm during 7 days (continuous rain from 27 June to 3 July)</td></tr>
<tr><td colspan="2">Geology: The failed slope is southern scarp of a large escarpment with a height of around 25m. The height of the failed part of the slope is around 21m and width is around 30m.
The mountain forming bed rock of the escarpment is formed of mainly two lithological units- bluish gray thinly laminated shale unit and yellowish brown cross-bedded to massive medium- to fine-grained sandstone. Top part of this section about 2.5 m is highly weathered. The failed mass comprised of highly weathered rock and moderately weathered rock. After the slide at places a</td></tr>
</table>

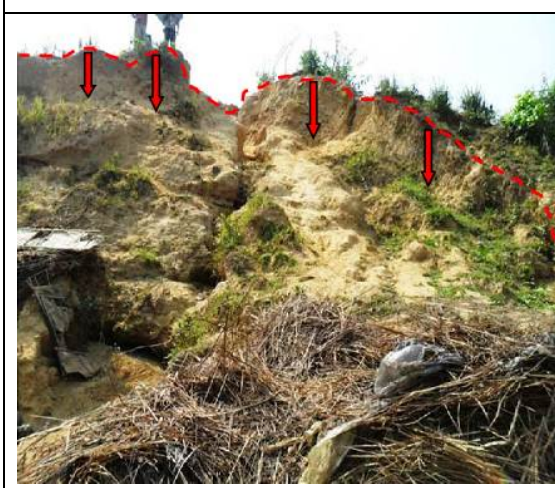
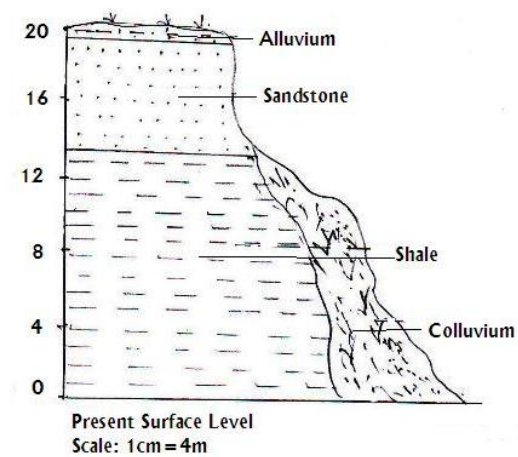
moderately weathered rock is exposed. The exposed rock units are mostly composed of light brown fine to medium grained sand, silt and clay. The height of the failure surface is around 21 m. **Fracturing:** Three sets of joints are observed on failure surface of the bed rock and one is parallel to the bedding plane (350/10) and other two are almost vertical and perpendicular to each other (350/80 and 185/85). The joints are filled with weathered clay, silt and fine sand. **Overburden Deposits:** Total overburden comprised of clay, silt and sand material. The material contains the relic structure of the bed rock which suggests it to be residual soil. The soil thickness of the residual soil layer which overlays the bed rock mass is around 1 m thick and the residual soil thickness is around 6m.	
Slope Characteristics	The escarpment slope is near vertical to incline and the upper part consists of highly weathered bed rock (clay type rock). Lower part consists of fine to medium grained sand. Original slope 34˚. The failed mass is a part of the near vertical escarpment and the debris moved from the slope is underlain by the talus material, which seems to be the remnants of previous landslides. The failed mass is a part of the upper portion. Thickness is around 6 meters.
Land use	The area is mainly used for human residence. There are more than 5 houses and more than 28 people live in this area. Some part of this area used for tree gardening.
Hydrology	No natural drainage path is visible in the area of the landslide and area is dry.
Landslide Mechanism	The recent history shows that the excessive rainfall is the main triggering factor of the slide which can be described as "debris flow". The slide has been activated in June 2008 during monsoon period. The following can be postulated about the mechanisms. The escarpment from where the landslide occurred has three well developed joint systems. One is parallel to bedding plane and other two are vertical and almost perpendicular to each other. Joints are filled with fine clayey material. During the rainy season the clay filled joints get saturated extrusion of joints take place thus opening and widening the joints. During the dry season the water saturated joints will become dry and shrinks in volume. This reduces the cohesive strength and bonding .This phenomena has repeated several times during dry and wet periods until it has broken away from the main mass due to the combined effect of the gravity and loss of cohesion.
Impact of the landslide	Have major impacts. One house got destroyed completely but no injured.
Future Risks	In future this sliding can get repeated as there is a possibility of destabilization of the mass above the slope. The impact would be further destruction to the hill. In the down slope around 15m away the local human residence is located and down slope movement of larger debris flow can create impact to houses and also people living there. The risk is moderate to high.

Landslide ID: 100 **Location:** South Haji Para, Cox's Bazar district	**Coordinates:** **N**-21˚25′11.5″ **E**-92˚00′43.3″
	
Date of Occurrence: 14 June 2010 **Rainfall:**	**Landslide History**: Subsequently activated in June 2010.

Geology: The failed slope is southern scarp of a large escarpment with a height of around 12m. The height of the failed part of the slope is around 10m and width is around 30m.
The mountain forming bed rock of the escarpment is formed of mainly two lithological units- bluish gray thinly laminated shale unit and yellowish brown cross-bedded to massive medium- to fine-grained sandstone. Top part of this section about 3 m is highly weathered. The failed mass comprised of highly weathered rock and moderately weathered rock. After the slide at places a moderately weathered rock is exposed. Sandstones comparatively loose and less compact. The exposed rock units are mostly composed of light brown fine to medium grained sand, silt and clay. The height of the failure surface is around 10 m.
Fracturing: Three sets of joints are observed on failure surface of the bed rock and one is parallel to the bedding plane (350/10) and other two are almost vertical and perpendicular to each other (350/80 and 185/85). The joints are filled with weathered clay, silt and fine sand.
Overburden Deposits: Total overburden comprised of clay, silt and sand material. The material contains the relic structure of the bed rock which suggests it to be residual soil. The soil thickness of the residual soil layer which overlays the bed rock mass is around 1 m thick.

Slope Characteristics	The escarpment slope is near vertical to incline and the upper part consists of highly weathered bed rock (clay type rock). Lower part consists of fine to medium grained sand. Original slope 30˚. The failed mass is a part of the near vertical escarpment and the debris moved from the slope is underlain by the talus material, which seems to be the remnants of previous landslides. The failed mass is a part of the upper portion. Thickness is around 7 meters.
Land use	The area is covered with forest and the landslide destroyed a part of the forest patch around 20sqm. Some part of this area is used for betel leaf gardening. The material has been accumulated with the fallen trees due to moving mass.
Hydrology	A water canal (natural drainage path) is visible in the area of the landslide and the flow of this water canal is monsoonal.
Landslide Mechanism	The recent history shows that the excessive rainfall is the main triggering factor of the slide which can be described as "debris flow".

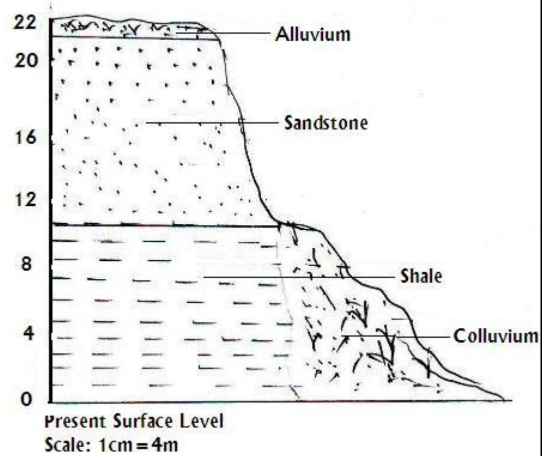
	The slide has been activated in June 2010 during monsoon period. The following can be postulated about the mechanisms. The escarpment from where the landslide occurred has three well developed joint systems. One is parallel to bedding plane and other two are vertical and almost perpendicular to each other. Joints are filled with fine clayey material. During the rainy season the clay filled joints get saturated extrusion of joints take place thus opening and widening the joints. During the dry season the water saturated joints will become dry and shrinks in volume. This reduces the cohesive strength and bonding .This phenomena has repeated several times during dry and wet periods until it has broken away from the main mass due to the combined effect of the gravity and loss of cohesion.
Impact of the landslide	No major impacts. Only a small patch of forest (around 20sqm) got destroyed completely.
Future Risks	In future this sliding can get repeated as there is a possibility of destabilization of the mass above the slope. The impact would be further destruction to the hill. In the down slope around 10m away the betel leaf garden is located and down slope movement of larger debris flow can create impact to forests and also betel leaf garden. The risk is moderate to low.

Landslide ID: 103 **Location:** Badshar Ghuna, Cox's Bazar district	**Coordinates:** **N**-21˚26′0.4″ **E**-91˚58′50.2″
	
Date of Occurrence: 15 June 2010 **Rainfall:**	**Landslide History**: Subsequently activated in june 2010.

Geology: The failed slope is north-western scarp of a large escarpment with a height of around 25m. The height of the failed part of the slope is around 20m and width is around 30m.

The mountain forming bed rock of the escarpment is formed of mainly two lithological units- lower bluish gray thinly laminated moderately weathered shale unit and upper moderately weathered yellowish brown cross-bedded to massive medium- to fine-grained sandstone. Top part of this unit about 2 m is highly weathered. The failed mass comprised of highly weathered rock and moderately weathered rock. After the slide at places a moderately weathered rock is exposed. The exposed rock units are mostly composed of light brown fine to medium grained sand, silt and clay. The height of the failure surface is around 20 m.

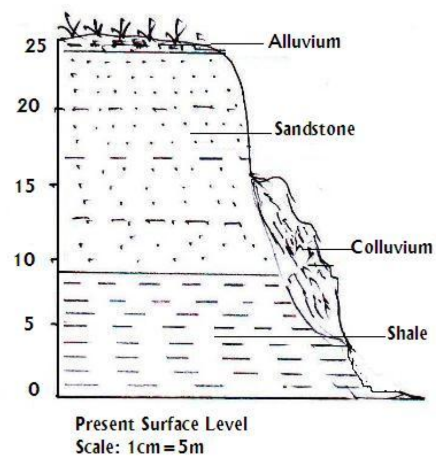
Fracturing: Three sets of joints are observed on failure surface of the bed rock and one is parallel to the bedding plane (340/5) and other two are almost vertical and perpendicular to each other (250/89 and 70/89). The joints are filled with weathered clay, silt and fine sand. **Overburden Deposits:** Total overburden comprised of clay, silt and sand material. The material contains the relic structure of the bed rock which suggests it to be residual soil. The soil thickness of the residual soil layer which overlays the bed rock mass is around 1 m thick. The colluvial soil is about 10m.	
Slope Characteristics	The escarpment slope is near vertical and the upper part consists of highly weathered rock. Lower part consists of thinly laminated shale. Light brown color fine to medium grained sand which is about 5m in thickness present above the shale layer. Original slope 34˚. The failed mass is a part of the upper portion. Thickness is around 10 meters.
Land use	The area is mainly used for human residence. There are more than 2 houses and more than 15 people live in this area. Some part of this area is barren field. Due to sand on surface vegetation is low in this area.
Hydrology	No natural drainage path is visible in the area of the landslide and area is dry.
Landslide Mechanism	The recent history shows that the excessive rainfall is the main triggering factor of the slide which can be described as "debris flow". The slide has been activated in June 2010 during monsoon period. The following can be postulated about the mechanisms. The escarpment from where the landslide occurred has three well developed joint systems. One is parallel to bedding plane and other two are vertical and almost perpendicular to each other. Joints are filled with fine clayey material. During the rainy season the clay filled joints get saturated extrusion of joints take place thus opening and widening the joints. During the dry season the water saturated joints will become dry and shrinks in volume. This reduces the cohesive strength and bonding .This phenomena has repeated several times during dry and wet periods until it has broken away from the main mass due to the combined effect of the gravity and loss of cohesion.
Impact of the landslide	Have major impacts. One house got destroyed completely but no injured.
Future Risks	In future this sliding can get repeated as there is a possibility of destabilization of the mass above the slope. The impact would be further destruction to the hill. In the down slope around 8m away the human residence is located and down slope movement of larger debris flow can create impact to houses and also people living there. The risk is moderate to high.

Landslide ID: 104 **Location:** Badshar Ghuna, Cox's Bazar district	**Coordinates:** **N**-21˚25′58.6″ **E**-91˚58′52.2″
	
Date of Occurrence: 15 June 2010 **Rainfall:**	**Landslide History**: Subsequently activated in June 2010.

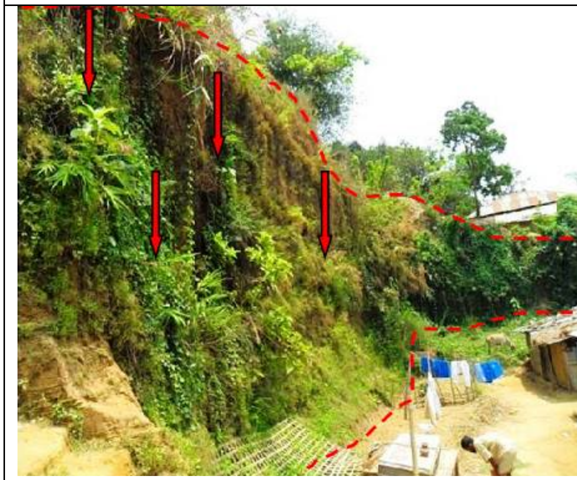
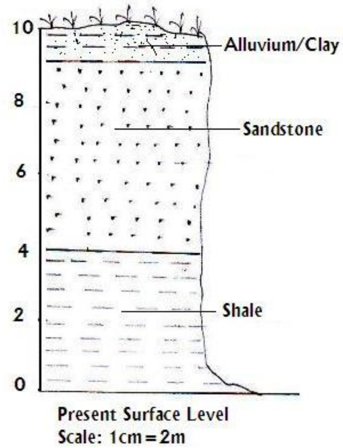
Geology: The failed slope is southern scarp of a large escarpment with a height of around 25m. The height of the failed part of the slope is around 22m and width is around 35m.
The mountain forming bed rock of the escarpment is dark gray shale but highly to moderately weathered on the surface exposure. The bed rock is thickly laminated and moderately weathered in the upper part and lower part is well consolidated. The failed mass comprised of highly weathered rock. After the slide at places a moderately weathered rock is exposed. The exposed rock units are mostly composed of light brown silt, clay and fine to medium grained sand. Lithology of this area is mainly Shale and Sandstone. Sandstones comparatively loose and less compact. The height of the failure surface is around 22 m.
Fracturing: Three sets of joints are observed on failure surface of the bed rock and one is parallel to the bedding plane (340/5) and other two are almost vertical and perpendicular to each other (250/89 and 70/89). The joints are filled with weathered clay, silt and fine sand.
Overburden Deposits: Total overburden comprised of clay, silt and sand material. The material contains the relic structure of the bed rock which suggests it to be residual soil. The residual soil thickness is about 1m and colluviul soil is about 10m.

Slope Characteristics	The escarpment slope is near vertical to incline and the upper part consists of highly weathered rock. Middle part consists of fine to medium grained sand. Lower part consists of thinly laminated shale. Light brown color fine to medium grained sand which is about 10m in thickness present above the shale layer. Original slope 30˚. The failed mass is a part of the upper portion. Thickness is around 10 meters.
Land use	The area is mainly used for human residence. There are more than 8 houses and more than 43 people live in this area. Some part of this area is barren field. Due to sand on surface vegetation is low in this area.
Hydrology	No natural drainage path is visible in the area of the landslide and area is dry.
Landslide Mechanism	The recent history shows that the excessive rainfall is the main triggering factor of the slide which can be described as "debris flow".

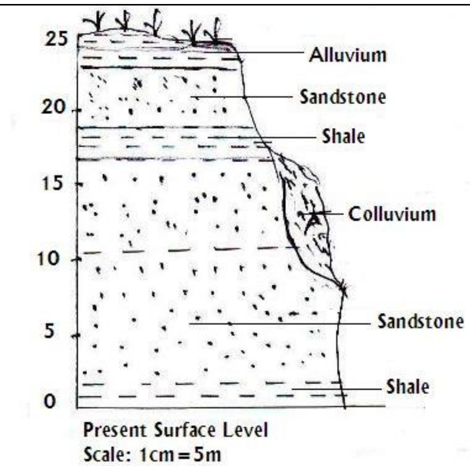
	The slide has been activated in June 2010 during monsoon period. The following can be postulated about the mechanisms. The escarpment from where the landslide occurred has three well developed joint systems. One is parallel to bedding plane and other two are vertical and almost perpendicular to each other. Joints are filled with fine clayey material. During the rainy season the clay filled joints get saturated extrusion of joints take place thus opening and widening the joints. During the dry season the water saturated joints will become dry and shrinks in volume. This reduces the cohesive strength and bonding .This phenomena has repeated several times during dry and wet periods until it has broken away from the main mass due to the combined effect of the gravity and loss of cohesion.
Impact of the landslide	No major impacts.
Future Risks	In future this sliding can get repeated as there is a possibility of destabilization of the mass above the slope. The impact would be further destruction to the hill. In the down slope around 8m away the human residence is located and down slope movement of larger debris flow can create impact to houses and also people living there. The risk is moderate to high.

Landslide ID: 107 **Location:** Badshar Ghuna, Cox's Bazar district	**Coordinates:** **N**-21°26′4.4″ **E**-91°58′50.7″
	
Date of Occurrence: 15 June 2010 and June 11, 2007.	**Landslide History**: Initiated movement in June 2007, Subsequently activated in June 2010.
Rainfall: June 11, 2007: 101 mm during 24 hours and 240mm during 7 days (continuous rain from 4 to 11 June)	
Geology: The failed slope is eastern scarp of a large escarpment with a height of around 30m. The height of the failed part of the slope is around 25m and width is around 40m. The mountain forming bed rock of the escarpment is formed of mainly two lithological units- lower bluish gray thinly laminated moderately weathered shale unit and upper moderately weathered yellowish brown cross-bedded to massive medium- to fine-grained sandstone. Top part of this section about 3 m is highly weathered. The failed mass comprised of highly weathered rock and moderately weathered rock. After the slide at places a moderately weathered rock is exposed. The exposed rock units are mostly composed of light brown fine to medium grained sand, silt and clay. Sandstones comparatively loose and less compact. The height of the failure surface is around 25 m.	

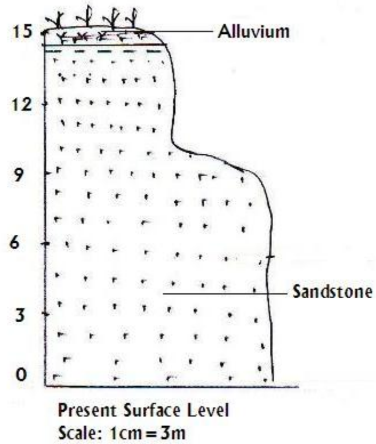
Fracturing: Three sets of joints are observed on failure surface of the bed rock and one is parallel to the bedding plane (340/5) and other two are almost vertical and perpendicular to each other (250/89 and 70/89). The joints are filled with weathered clay, silt and fine sand. **Overburden Deposits:** Total overburden comprised of clay, silt and sand material. The material contains the relic structure of the bed rock which suggests it to be residual soil. The soil thickness of the residual soil layer which overlays the bed rock mass is around 1 m thick. The alluvial soil thikness is around 8m.	
Slope Characteristics	The escarpment slope is near vertical to incline and the upper part consists of highly weathered rock. Lower part consists of thinly laminated shale. Light brown color fine to medium grained sand which is about 15m in thickness present above the shale layer. The failed mass is a part of the near vertical escarpment and the debris moved from the slope is underlain by the talus material, which seems to be the remnants of previous landslides Original slope 32˚. The failed mass is a part of the upper portion. Thickness is around 8 meters.
Land use	The area is mainly used for human residence. There are more than 5 houses and more than 30 people live in this area. Some part of this area is barren field. Due to sand on surface vegetation is low in this area.
Hydrology	No natural drainage path is visible in the area of the landslide and area is dry.
Landslide Mechanism	The recent history shows that the excessive rainfall is the main triggering factor of the slide which can be described as "debris flow". The slide has been activated in June 2007 during monsoon period. The following can be postulated about the mechanisms. The escarpment from where the landslide occurred has three well developed joint systems. One is parallel to bedding plane and other two are vertical and almost perpendicular to each other. Joints are filled with fine clayey material. During the rainy season the clay filled joints get saturated extrusion of joints take place thus opening and widening the joints. During the dry season the water saturated joints will become dry and shrinks in volume. This reduces the cohesive strength and bonding .This phenomena has repeated several times during dry and wet periods until it has broken away from the main mass due to the combined effect of the gravity and loss of cohesion.
Impact of the landslide	No major impacts.
Future Risks	In future this sliding can get repeated as there is a possibility of destabilization of the mass above the slope. The impact would be further destruction to the hill. In the down slope around 8m away the human residence is located and down slope movement of larger debris flow can create impact to houses and also people living there. The risk is moderate to high.

<table>
<tr><td>Landslide ID: 108
Location: East Light House para, Cox's Bazar district</td><td>Coordinates:
N-21˚25′42.2″
E-91˚58′52.4″</td></tr>
<tr><td></td><td>
</td></tr>
<tr><td>Date of Occurrence: 15 June 2010
Rainfall:</td><td>Landslide History: Subsequently activated in June 2010.</td></tr>
<tr><td colspan="2">Geology: The failed slope is south-western scarp of a large escarpment with a height of around 12m. The height of the failed part of the slope is around 10m and width is around 40m.
The mountain forming bed rock of the escarpment is formed of mainly two lithological units- lower bluish gray thinly laminated moderately weathered shale unit and upper moderately weathered yellowish brown cross-bedded to massive medium- to fine-grained sandstone and the top part of this unit about 3 m is highly weathered. The failed mass comprised of highly weathered rock and moderately weathered rock. After the slide at places a moderately weathered rock is exposed. The exposed rock units are mostly composed of light brown fine to medium grained sand, silt and clay. The height of the failure surface is around 10 m.
Fracturing: Three sets of joints are observed on failure surface of the bed rock and one is parallel to the bedding plane (340/15) and other two are almost vertical and perpendicular to each other (160/89 and 70/85). The joints are filled with weathered clay, silt and fine sand.
Overburden Deposits: Total overburden comprised of clay, silt and sand material. The material contains the relic structure of the bed rock which suggests it to be residual soil. The soil thickness of the residual soil layer which overlays the bed rock mass is around 1 m thick.</td></tr>
<tr><td>Slope Characteristics</td><td>The escarpment slope is near vertical and the upper part consists of highly weathered bed rock. Lower part consists of thinly laminated shale. Light brown color fine to medium grained sand which is about 5m in thickness present above the shale layer.
Original slope 25˚. The failed mass is a part of the upper portion.</td></tr>
<tr><td>Land use</td><td>The area is mainly used for human residence. There are more than 4 houses and more than 27 people live in this area. Some part of this area is used for gardening.</td></tr>
<tr><td>Hydrology</td><td>No natural drainage path is visible in the area of the landslide and area is dry.</td></tr>
<tr><td>Landslide Mechanism</td><td>The recent history shows that the excessive rainfall is the main triggering factor of the slide which can be described as "debris flow". The slide has been activated during monsoon period.
The following can be postulated about the mechanisms.
The escarpment from where the landslide occurred has three well</td></tr>
</table>

	developed joint systems. One is parallel to bedding plane and other two are vertical and almost perpendicular to each other. Joints are filled with fine clayey material. During the rainy season the clay filled joints get saturated extrusion of joints take place thus opening and widening the joints. During the dry season the water saturated joints will become dry and shrinks in volume. This reduces the cohesive strength and bonding .This phenomena has repeated several times during dry and wet periods until it has broken away from the main mass due to the combined effect of the gravity and loss of cohesion.
Impact of the landslide	Have major impacts. One house got destroyed completely and one child died during June 2010 landslide.
Future Risks	In future this sliding can get repeated as there is a possibility of destabilization of the mass above the slope. The impact would be further destruction to the hill. In the down slope around 5m away the human residence is located and down slope movement of larger debris flow can create impact to houses and also people living there. The risk is moderate to high.

Landslide ID: 109 **Location:** East Light House para, Cox's Bazar district	**Coordinates:** **N**-21˚25′40.2″ **E**-91˚58′49.3″
	
Date of Occurrence: 15 June 2010 and July 3, 2008.	**Landslide History**: Initiated movement in July 2008, Subsequently activated in June 2010.
Rainfall: July 3, 2008: 134 mm during 24 hours and 729mm during 7 days (continuous rain from 27 June to 3 July)	
Geology: The failed slope is northern scarp of a large escarpment with a height of around 30m. The height of the failed part of the slope is around 25m and width is around 40m. The mountain forming bed rock of the escarpment is formed of mainly two lithological units- bluish gray thinly laminated moderately weathered shale unit and upper moderately weathered yellowish brown cross-bedded to massive medium- to fine-grained sandstone and the top part of this unit about 3.5 m is highly weathered. The failed mass comprised of highly weathered rock and moderately weathered rock. After the slide at places a moderately weathered rock is exposed. The exposed rock units are mostly composed of light brown fine to medium grained sand, silt and clay. Sandstones comparatively loose and less compact. The height of the failure surface is around 25 m. **Fracturing:** Three sets of joints are observed on failure surface of the bed rock and one is parallel to the bedding plane (340/15) and other two are almost vertical and perpendicular to each other (160/89	

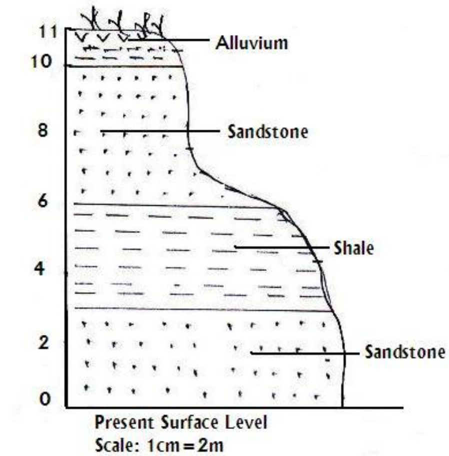
and 70/85). The joints are filled with weathered clay, silt and fine sand. **Overburden Deposits:** Total overburden comprised of clay, silt and sand material. The material contains the relic structure of the bed rock which suggests it to be residual soil. The soil thickness of the residual soil layer which overlays the bed rock mass is around 1 m thick and the alluvial soil thickness is around 7m.	
Slope Characteristics	The escarpment slope is near vertical and the upper part consists of highly weathered bed rock. Lower part consists of thinly laminated shale. Light brown color fine to medium grained sand which is about 15m in thickness present above the shale layer. Original slope 32˚. The failed mass is a part of the near vertical escarpment and the debris moved from the slope is underlain by the talus material, which seems to be the remnants of previous landslides The failed mass is a part of the upper portion. Thickness is around 7 meters.
Land use	The area is mainly used for human residence. There are more than 5 houses and more than 33 people live in this area. Some part of this area is used for gardening.
Hydrology	No natural drainage path is visible in the area of the landslide and area is dry.
Landslide Mechanism	The recent history shows that the excessive rainfall is the main triggering factor of the slide which can be described as "debris flow". The slide has been activated during monsoon period. The following can be postulated about the mechanisms. The escarpment from where the landslide occurred has three well developed joint systems. One is parallel to bedding plane and other two are vertical and almost perpendicular to each other. Joints are filled with fine clayey material. During the rainy season the clay filled joints get saturated extrusion of joints take place thus opening and widening the joints. During the dry season the water saturated joints will become dry and shrinks in volume. This reduces the cohesive strength and bonding .This phenomena has repeated several times during dry and wet periods until it has broken away from the main mass due to the combined effect of the gravity and loss of cohesion.
Impact of the landslide	Have major impacts. One house got destroyed completely during June 2010 landslide.
Future Risks	In future this sliding can get repeated as there is a possibility of destabilization of the mass above the slope. The impact would be further destruction to the hill. In the down slope around 10m away the human residence is located and down slope movement of larger debris flow can create impact to houses and also people living there. The risk is moderate to high.

Landslide ID: 112 **Location:** Pahartoli, Cox's Bazar district	**Coordinates:** **N**-21°26′8.2″ **E**-91°58′57.1″
	
Date of Occurrence: 15 June 2010 **Rainfall:**	**Landslide History**: Subsequently activated in June 2010.

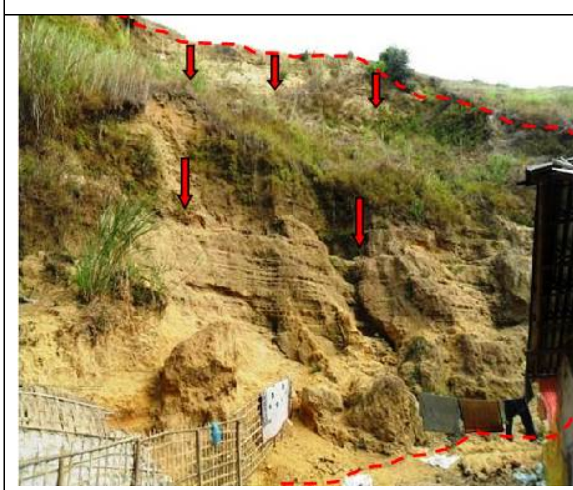
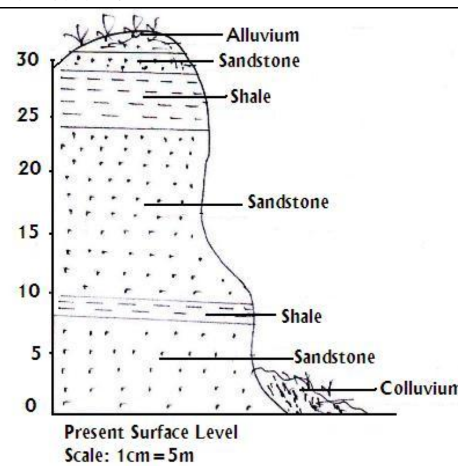
Geology: The failed slope is north-western scarp of a large escarpment with a height of around 20m. The height of the failed part of the slope is around 15m and width is around 30m.
The mountain forming bed rock of the escarpment is formed of mainly moderately weathered yellowish brown cross-bedded to massive medium- to fine-grained sandstone and the top part of this unit about 3 m is highly weathered. The failed mass comprised of highly weathered rock and moderately weathered rock. After the slide at places a moderately weathered rock is exposed. The exposed rock units are mostly composed of light brown fine to medium grained sand, silt and clay. Sandstones comparatively loose and less compact. The height of the failure surface is around 15 m.
Fracturing: Sets of joints are not observed on failure surface of the bed rock.
Overburden Deposits: Total overburden comprised of clay, silt and sand material. The material contains the relic structure of the bed rock which suggests it to be residual soil. The soil thickness of the residual soil layer which overlays the bed rock mass is around 1 m thick.

Slope Characteristics	The escarpment slope is near vertical and the upper part consists of highly weathered bed rock. Lower part consists of fine to medium grained sand. Original slope 32°. The failed mass is a part of the upper portion.
Land use	The area is mainly used for human residence. There are more than 6 houses and more than 25 people live in this area. Some part of this area is used for gardening.
Hydrology	No natural drainage path is visible in the area of the landslide and area is dry.
Landslide Mechanism	The recent history shows that the excessive rainfall is the main triggering factor of the slide which can be described as "debris flow". The slide has been activated during monsoon period.
Impact of the landslide	Have major impacts. One house got destroyed completely during June 2010 landslide.
Future Risks	In future this sliding can get repeated as there is a possibility of destabilization of the mass above the slope. The impact would be further destruction to the hill. In the down slope around 10m away the human residence is located

	and down slope movement of larger debris flow can create impact to houses and also people living there. The risk is moderate to high.

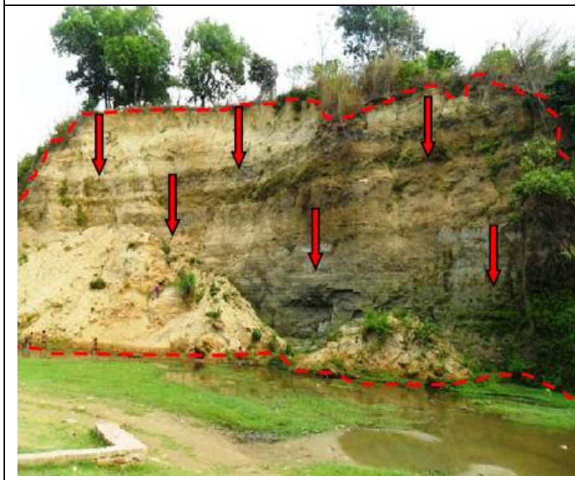
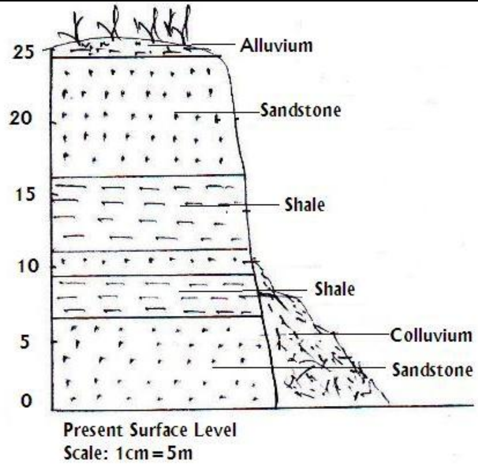
<table>
<tr><td>Landslide ID: 116
Location: Pahartoli, Cox's Bazar district</td><td>Coordinates:
N-21˚25′59.3″
E-91˚59′01.5″</td></tr>
<tr><td></td><td>
</td></tr>
<tr><td>Date of Occurrence: 15 June 2010 and June 11, 2007.</td><td>Landslide History: Initiated movement in June 2007, Subsequently activated in June 2010.</td></tr>
<tr><td colspan="2">Rainfall: June 11, 2007: 101 mm during 24 hours and 240mm during 7 days (continuous rain from 4 to 11 June)</td></tr>
<tr><td colspan="2">Geology: The failed slope is eastern scarp of a large escarpment with a height of around 20m. The height of the failed part of the slope is around 11m and width is around 40m.
The mountain forming bed rock of the escarpment is formed of mainly two lithological units- bluish gray thinly laminated moderately weathered shale unit and moderately weathered yellowish brown cross-bedded to massive medium- to fine-grained sandstone and the top part of this unit about 4 m is highly weathered. The failed mass comprised of highly weathered rock and moderately weathered rock. After the slide at places a moderately weathered rock is exposed. The exposed rock units are mostly composed of light brown fine to medium grained sand, silt and clay. The height of the failure surface is around 11 m.
Fracturing: Three sets of joints are observed on failure surface of the bed rock and one is parallel to the bedding plane (340/15) and other two are almost vertical and perpendicular to each other (160/89 and 70/85). The joints are filled with weathered clay, silt and fine sand.
Overburden Deposits: Total overburden comprised of clay, silt and sand material. The material contains the relic structure of the bed rock which suggests it to be residual soil. The soil thickness of the residual soil layer which overlays the bed rock mass is around 1 m thick.</td></tr>
<tr><td>Slope Characteristics</td><td>The escarpment slope is near vertical and the upper part consists of highly weathered bed rock. Middle part consists of thinly laminated shale. Lower part consists of fine to medium grained sand. Light brown color fine to medium grained sand which is about 4m in thickness present above the shale layer Original slope 12˚. The failed mass is a part of the near vertical escarpment and the debris moved from the slope is underlain by the talus material, which seems to be the remnants of previous landslides. The failed mass is a part of the upper portion.</td></tr>
<tr><td>Land use</td><td>The area is mainly used for human residence. There are more than 6 houses and more than 30 people live in this area. Some part of this area is used for gardening.</td></tr>
</table>

Hydrology	No natural drainage path is visible in the area of the landslide and area is dry.
Landslide Mechanism	The recent history shows that the excessive rainfall is the main triggering factor of the slide which can be described as "debris flow". The slide has been activated during monsoon period. The following can be postulated about the mechanisms. The escarpment from where the landslide occurred has three well developed joint systems. One is parallel to bedding plane and other two are vertical and almost perpendicular to each other. Joints are filled with fine clayey material. During the rainy season the clay filled joints get saturated extrusion of joints take place thus opening and widening the joints. During the dry season the water saturated joints will become dry and shrinks in volume. This reduces the cohesive strength and bonding .This phenomena has repeated several times during dry and wet periods until it has broken away from the main mass due to the combined effect of the gravity and loss of cohesion.
Impact of the landslide	Have major impacts. Two houses got destroyed completely.
Future Risks	In future this sliding can get repeated as there is a possibility of destabilization of the mass above the slope. The impact would be further destruction to the hill. In the down slope around 20m away the human residence is located and down slope movement of larger debris flow can create impact to houses and also people living there. The risk is moderate to high.

Landslide ID: 124 **Location:** Sahittika Palli, Cox's Bazar district	**Coordinates:** **N**-21˚26′11.4″ **E**-91˚59′37.0″
	
Date of Occurrence: 15 June 2010 **Rainfall:**	**Landslide History**: Subsequently activated in June 2010.

Geology: The failed slope is southern scarp of a large escarpment with a height of around 32m. The height of the failed part of the slope is around 29m and width is around 60m.
The mountain forming bed rock of the escarpment is formed of mainly two lithological units- bluish gray thinly laminated moderately weathered shale unit and moderately weathered yellowish brown cross-bedded to massive medium- to fine-grained sandstone and the top part of this unit about 2.5 m is highly weathered. The failed mass comprised of highly weathered rock and moderately weathered

rock. After the slide at places a moderately weathered rock is exposed. The exposed rock units are mostly composed of light brown fine to medium grained sand, silt and clay. The height of the failure surface is around 29 m. **Fracturing:** Three sets of joints are observed on failure surface of the bed rock and one is parallel to the bedding plane (20/14) and other two are almost vertical and perpendicular to each other (200/85 and 110/89). The joints are filled with weathered clay, silt and fine sand. **Overburden Deposits:** Total overburden comprised of clay, silt and sand material. The material contains the relic structure of the bed rock which suggests it to be residual soil. The soil thickness of the residual soil layer which overlays the bed rock mass is around 1 m thick and the alluvial soil thickness is around 4m.	
Slope Characteristics	The escarpment slope is near vertical and the upper part consists of highly weathered bed rock (clay type rock). Lower part consists of fine to medium grained sand and thickness is around 24m. Original slope 38˚. The failed mass is a part of the upper portion. Thickness is around 4 meters.
Land use	The area is mainly used for human residence. There are more than 7 houses and more than 30 people live in this area. Some part of this area is used for gardening.
Hydrology	No natural drainage path is visible in the area of the landslide and area is dry.
Landslide Mechanism	The recent history shows that the excessive rainfall is the main triggering factor of the slide which can be described as "debris flow". The slide has been activated during monsoon period. The following can be postulated about the mechanisms. The escarpment from where the landslide occurred has three well developed joint systems. One is parallel to bedding plane and other two are vertical and almost perpendicular to each other. Joints are filled with fine clayey material. During the rainy season the clay filled joints get saturated extrusion of joints take place thus opening and widening the joints. During the dry season the water saturated joints will become dry and shrinks in volume. This reduces the cohesive strength and bonding .This phenomena has repeated several times during dry and wet periods until it has broken away from the main mass due to the combined effect of the gravity and loss of cohesion.
Impact of the landslide	Have major impacts. One house got destroyed completely.
Future Risks	In future this sliding can get repeated as there is a possibility of destabilization of the mass above the slope. The impact would be further destruction to the hill. In the down slope around 10m away the human residence is located and down slope movement of larger debris flow can create impact to houses and also people living there. The risk is moderate to high.

<table>
<tr><td>Landslide ID: 129
Location: Barachara, South kolatoli, Cox's Bazar district</td><td>Coordinates:
N-21˚23′46.7″
E-92˚00′02.0″</td></tr>
<tr><td></td><td>
</td></tr>
<tr><td>Date of Occurrence: 15 June 2010
Rainfall:</td><td>Landslide History: Subsequently activated in June 2010.</td></tr>
</table>

Geology: The failed slope is southern scarp of a large escarpment with a height of around 25m. The height of the failed part of the slope is around 25m and width is around 120m.

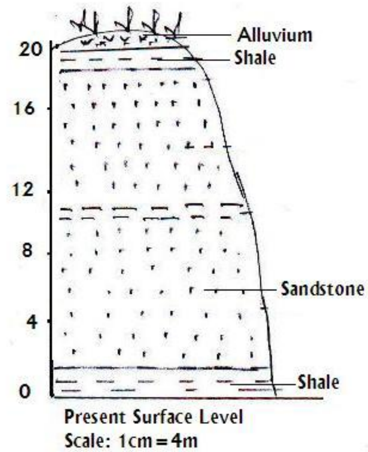
The mountain forming bed rock of the escarpment is formed of mainly two lithological units- bluish gray thinly laminated moderately weathered shale unit and moderately weathered yellowish brown cross-bedded to massive medium- to fine-grained sandstone and the top part of this unit about 3 m is highly weathered. The failed mass comprised of highly weathered rock and moderately weathered rock. After the slide at places a moderately weathered rock is exposed. The exposed rock units are mostly composed of light brown fine to medium grained sand, silt and clay. The height of the failure surface is around 25 m.

Fracturing: Three sets of joints are observed on failure surface of the bed rock and one is parallel to the bedding plane (345/5) and other two are almost vertical and perpendicular to each other (260/70 and 100/89). The joints are filled with weathered clay, silt and fine sand.

Overburden Deposits: Total overburden comprised of clay, silt and sand material. The material contains the relic structure of the bed rock which suggests it to be residual soil. The soil thickness of the residual soil layer which overlays the bed rock mass is around 1.5m thick. The colluvial soil thickness is about 8m.

Slope Characteristics	The escarpment slope is near vertical and the upper part consists of highly weathered rock. Middle part consists of thinly laminated shale and lower part consists fine to medium grained sand. Original slope 31˚. The failed mass is a part of the upper portion. Thickness is around 8 meters.
Land use	The area is mainly used for human residence. There are more than 2houses and more than 11 people live in this area. Some part of this area is used for gardening and some part is used for paddy field.
Hydrology	Natural drainage path is visible in the area of the landslide. A stream locally named chhara is flowing perennially .
Landslide Mechanism	The recent history shows that the excessive rainfall is the main triggering factor of the slide which can be described as "debris flow". The slide has been activated during monsoon period. The following can be postulated about the mechanisms. The escarpment from where the landslide occurred has three well

	developed joint systems. One is parallel to bedding plane and other two are vertical and almost perpendicular to each other. Joints are filled with fine clayey material. During the rainy season the clay filled joints get saturated extrusion of joints take place thus opening and widening the joints. During the dry season the water saturated joints will become dry and shrinks in volume. This reduces the cohesive strength and bonding .This phenomena has repeated several times during dry and wet periods until it has broken away from the main mass due to the combined effect of the gravity and loss of cohesion.
Impact of the landslide	No major impacts. Only some part of tree garden got destroyed completely.
Future Risks	In future this sliding can get repeated as there is a possibility of destabilization of the mass above the slope. The impact would be further destruction to the hill. The risk is moderate to high.

<table>
<tr><td>Landslide ID: 143
Location: Baidder Ghuna, Cox's Bazar district</td><td>Coordinates:
N-21°26′16.9″
E-91°58′54.6″</td></tr>
<tr><td></td><td>
</td></tr>
<tr><td>Date of Occurrence: 15 June 2010 and July 3, 2008.</td><td>Landslide History: Initiated movement in July 2008, Subsequently activated in June 2010.</td></tr>
<tr><td colspan="2">Rainfall: July 3, 2008: 134 mm during 24 hours and 729mm during 7 days (continuous rain from 27 June to 3 July)</td></tr>
<tr><td colspan="2">Geology: The failed slope is northern scarp of a large escarpment with a height of around 3om. The height of the failed part of the slope is around 20m and width is around 40m.
The mountain forming bed rock of the escarpment is formed of mainly two lithological units- bluish gray thinly laminated moderately weathered shale unit and moderately weathered yellowish brown cross-bedded to massive medium- to fine-grained sandstone and the top part of this unit about 3 m is highly weathered. The failed mass comprised of highly weathered rock and moderately weathered rock. After the slide at places a moderately weathered rock is exposed. The exposed rock units are mostly composed of light brown fine to medium grained sand, silt and clay. The height of the failure surface is around 20 m.
Fracturing: Three sets of joints are observed on failure surface of the bed rock and one is parallel to the bedding plane (340/5) and other two are almost vertical and perpendicular to each other (250/89 and 70/89). The joints are filled with weathered clay, silt and fine sand.
Overburden Deposits: Total overburden comprised of clay, silt and sand material. The material</td></tr>
</table>

contains the relic structure of the bed rock which suggests it to be residual soil. The soil thickness of the residual soil layer which overlays the bed rock mass is around 1 m thick.	
Slope Characteristics	The escarpment slope is near vertical and the upper part consists of highly weathered bed rock. Middle part consists of fine to medium grained sand and lower part consists of thinly laminated shale. The failed mass is a part of the upper portion.
Land use	The area is mainly used for human residence. There are more than 15 houses and more than 76 people live in this area. Some part of this area is used for gardening.
Hydrology	No natural drainage path is visible in the area of the landslide and area is dry.
Landslide Mechanism	The recent history shows that the excessive rainfall is the main triggering factor of the slide which can be described as "debris flow". The slide has been activated during monsoon period. The following can be postulated about the mechanisms. The escarpment from where the landslide occurred has three well developed joint systems. One is parallel to bedding plane and other two are vertical and almost perpendicular to each other. Joints are filled with fine clayey material. During the rainy season the clay filled joints get saturated extrusion of joints take place thus opening and widening the joints. During the dry season the water saturated joints will become dry and shrinks in volume. This reduces the cohesive strength and bonding .This phenomena has repeated several times during dry and wet periods until it has broken away from the main mass due to the combined effect of the gravity and loss of cohesion.
Impact of the landslide	Have major impacts. One house got destroyed completely and one people died during 2008 landslide.
Future Risks	In future this sliding can get repeated as there is a possibility of destabilization of the mass above the slope. The impact would be further destruction to the hill. In the down slope around 8m away the human residence is located and down slope movement of larger debris flow can create impact to houses and also people living there. The risk is moderate to high.

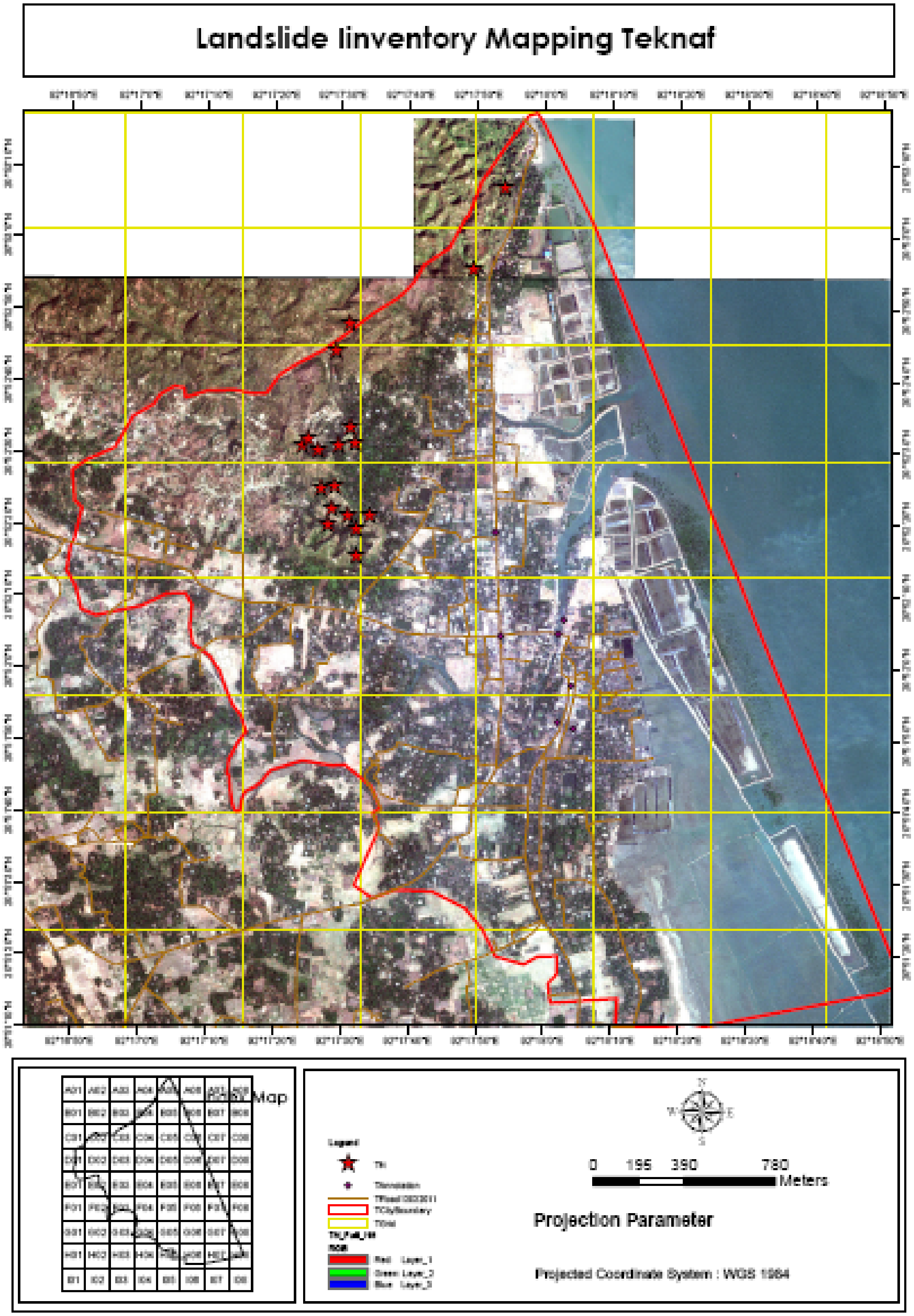
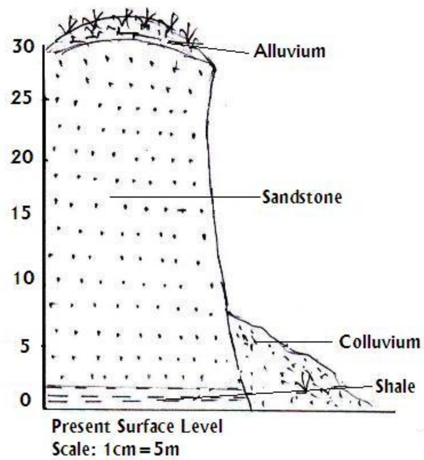
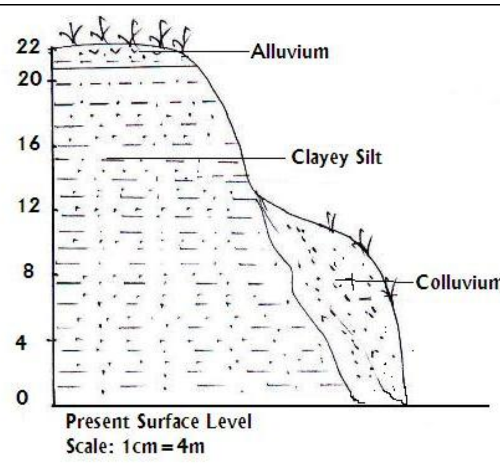


Figure 8: Locations of Landslide Events at Teknaf Municipality

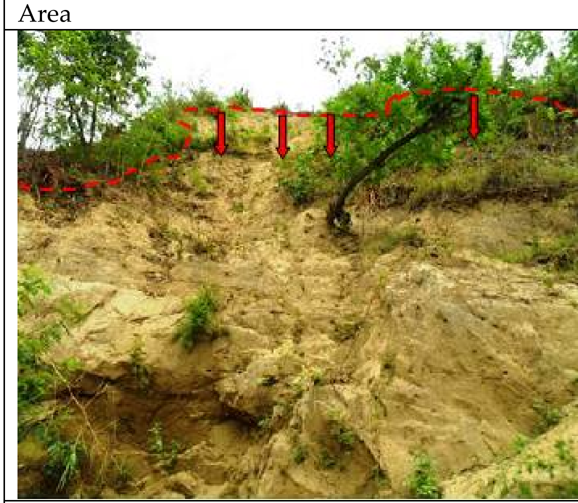
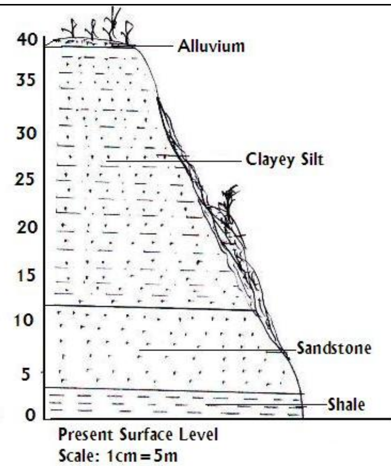
<table>
<tr><td>Landslide ID: 03
Location: Fakirer Mura, Puran Pallan Para, Teknaf Municipal Area</td><td>Coordinates:
N-20°52′21.4″
E-92°17′34.2″</td></tr>
<tr><td></td><td>
</td></tr>
<tr><td>Date of Occurrence: June 15, 2010 and July 6, 2008</td><td>Landslide History: Initiated movement in July 2008, Subsequently activated in June 2010 .</td></tr>
<tr><td colspan="2">Rainfall: July 6, 2008: 209 mm during 24 hours and 1332mm during 12 days (continuous rain from 25 June to 6 July)</td></tr>
<tr><td colspan="2">Geology: The failed slope is north-eastern scarp of a large escarpment with a height of around 35m. The height of the failed part of the slope is around 30m and width is around 50 m.
The mountain forming bed rock of the escarpment is formed of mainly two lithological units- lower bluish gray thinly laminated moderately weathered shale unit and upper moderately weathered yellowish brown cross-bedded to massive medium- to fine-grained sandstone and the top part of this unit about 3.5 m is highly weathered. The failed mass comprised of highly weathered rock and moderately weathered rock. After the slide at places a moderately weathered rock is exposed. The exposed rock units are mostly composed of light brown fine to medium grained sand, silt and clay. The sandstone rock is massive and poorly consolidated in the upper part and lower part is well consolidated. The height of the failure surface is around 30 m.
Fracturing: Three sets of joints are observed on failure surface of the bed rock and one is parallel to the bedding plane (115/78) and other two are almost vertical and perpendicular to each other (205/89 and 92/4). The joints are filled with weathered clay, silt and fine sand.
Overburden Deposits: Total overburden comprised of clay sand material. The material contains the relic structure of the bed rock which suggests it to be residual soil. The soil thickness of the residual soil layer which overlays the bed rock mass is around 1 m thick. The colluvial soil thickness is around 8m.</td></tr>
<tr><td>Slope Characteristics</td><td>The escarpment slope is near vertical and the upper part consists of highly weathered bed rock. Lower part consists of fine to medium grained sand.
The original slope of the hill is about 48°. The upper part consists of highly weathered clay type rock. Lower part consists of sand and shale mass. The failed mass is a part of the near vertical escarpment and the debris moved from the slope is underlain by the talus material, which seems to be the remnants of previous landslides.
The failed mass is a part of the upper portion. Thickness is around 8 meters.</td></tr>
<tr><td>Land use</td><td>This area completely affected by human intervention. There are 4 houses and about 24 people live there. Some part used for gardening.</td></tr>
</table>

Hydrology	No natural drainage path is visible in the area of the landslide and area is dry.
Landslide Mechanism	The recent history shows that the excessive rainfall is the main triggering factor of the slide which can be described as "debris flow". The slide has been reactivated several times during monsoon period. The following can be postulated about the mechanisms. The escarpment from where the landslide occurred has three well developed joint systems. One is parallel to bedding plane and other two are vertical and almost perpendicular to each other. Joints are filled with fine clayey material. During the rainy season the clay filled joints get saturated extrusion of joints take place thus opening and widening the joints. During the dry season the water saturated joints will become dry and shrinks in volume. This reduces the cohesive strength and bonding .This phenomena has repeated several times during dry and wet periods until it has broken away from the main mass due to the combined effect of the gravity and loss of cohesion.
Impact of the landslide	No major impacts. Only a small portion of the hill got destroyed.
Future Risks	In future this sliding can get repeated as there is a possibility of destabilization of the mass above the slope. The impact would be further destruction to the forest. In the down slope around 10m away the local people residence is located and down slope movement of debris flow and boulder can create impact to people house and also people living there. The risk is moderate to low. The impact would be further destruction to the hill.

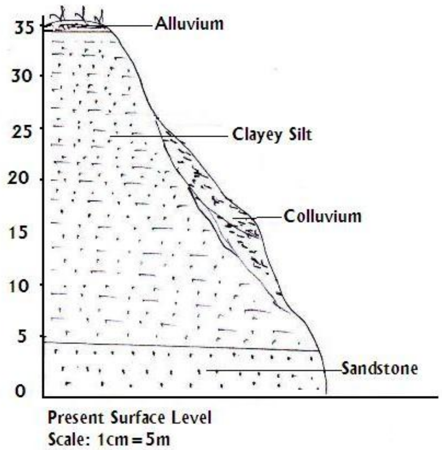
Landslide ID: 04 **Location:** Puran Pallan Para, Teknaf Municipal Area	**Coordinates:** **N**-20°52′21.3″ **E**-92°17′30.9″
	
Date of Occurrence: June 15, 2010 **Rainfall:**	**Landslide History**: Subsequently activated in June 2010.

Geology: The failed slope is north-eastern scarp of a large escarpment with a height of around 30m. The height of the failed part of the slope is around 22m and width is around 30 m.
The mountain forming bed rock of the escarpment is formed of mainly moderately weathered yellowish brown clayey silt and the top part of this unit about 4 m is highly weathered. The failed mass comprised of highly weathered rock and moderately weathered rock. After the slide at places a

moderately weathered rock is exposed. The exposed rock units are mostly composed of light brown fine to very fine grained sand, silt and clay. The height of the failure surface is around 22 m. **Fracturing: S**ets of joints are not observed on failure surface of the bed rock. **Overburden Deposits:** Total overburden comprised of clay, silt and sand material. The material contains the relic structure of the bed rock which suggests it to be residual soil. The soil thickness of the residual soil layer which overlays the bed rock mass is around 1 m thick. The alluvial soil thickness is around 11m.	
Slope Characteristics	The escarpment slope is near vertical to incline and the upper part consists of highly weathered rock. Lower part consists of clayey silt, clay and very fine grained sand. The failed mass is a part of the upper portion. Thickness is around 11m.
Land use	This area completely affected by human intervention. There are 1 houses and about 8 people live there. Some part of this area is used for gardening. Some part of this area is highly vegetated.
Hydrology	A natural drainage path (Chhara) is visible in the area of the landslide and the water flow is perennial.
Landslide Mechanism	The recent history shows that the excessive rainfall is the main triggering factor of the slide which can be described as "debris flow". The slide has been reactivated several times during monsoon period.
Impact of the landslide	No major impacts. Only a small portion of the hill got destroyed.
Future Risks	In future this sliding can get repeated as there is a possibility of destabilization of the mass above the slope. The impact would be further destruction to the forest. In the down slope around 10m away the local people residence is located and down slope movement of debris flow can create impact to people house and also people living there. The risk is moderate to high.

Landslide ID: 06 **Location:** Puran Pallan Para, Teknaf Municipal Area	**Coordinates:** **N**-20°52'31.1" **E**-92°17'29.5"
	
Date of Occurrence: June 15, 2010 **Rainfall:**	**Landslide History**: Subsequently activated in June 2010.
Geology: The failed slope is south-western scarp of a large escarpment with a height of around 45m. The height of the failed part of the slope is around 40m and width is around 60 m. The mountain forming bed rock of the escarpment is formed of mainly three lithological units- bluish	

gray thinly laminated moderately weathered shale unit, moderately weathered yellowish brown cross-bedded to massive medium- to fine-grained sandstone and light yellowish color clayey silt. Top part of this unit about 5 m is highly weathered. The failed mass comprised of highly weathered rock and moderately weathered rock. After the slide at places a moderately weathered rock is exposed. The exposed rock units are mostly composed of light brown fine to medium grained sand, silt and clay. The height of the failure surface is around 40 m. **Fracturing:** Three sets of joints are observed on failure surface of the bed rock and one is parallel to the bedding plane (235/9) and other two are almost vertical and perpendicular to each other (225/89 and 135/89). The joints are filled with weathered clay, silt and fine sand. **Overburden Deposits:** Total overburden comprised of clay, silt and fine sand. The material contains the relic structure of the bed rock which suggests it to be residual soil. The soil thickness of the residual soil layer which overlays the bed rock mass is around 1 m thick. Colluvial soil is about 10m.	
Slope Characteristics	The escarpment slope is near vertical and the upper part consists of highly weathered rock. Lower part consists of thinly laminated shale. Light brown color fine to medium grained sand which is about 8m in thickness present above the shale layer. The failed mass is a part of the upper portion. Thickness is around 10 meters.
Land use	This area completely affected by human intervention. There are 1 houses and about 8 people live there. Some part of this area is used for gardening.
Hydrology	No natural drainage path is visible in the area of the landslide and area is dry. However some water is observed seeping from the exposed joints.
Landslide Mechanism	The recent history shows that the excessive rainfall is the main triggering factor of the slide which can be described as "debris flow". The slide has been reactivated several times during monsoon period. The following can be postulated about the mechanisms. The escarpment from where the landslide occurred has three well developed joint systems. One is parallel to bedding plane and other two are vertical and almost perpendicular to each other. Joints are filled with fine clayey material. During the rainy season the clay filled joints get saturated extrusion of joints take place thus opening and widening the joints. During the dry season the water saturated joints will become dry and shrinks in volume. This reduces the cohesive strength and bonding .This phenomena has repeated several times during dry and wet periods until it has broken away from the main mass due to the combined effect of the gravity and loss of cohesion.
Impact of the landslide	Have major impacts. 2 houses got destroyed completely. 7 people dead and 1 people injured.
Future Risks	In future this sliding can get repeated as there is a possibility of destabilization of the mass above the slope. The impact would be further destruction to the forest. In the down slope around 10m away the local people residence is located and down slope movement of debris flow can create impact to people house and also people living there. The risk is moderate to high.

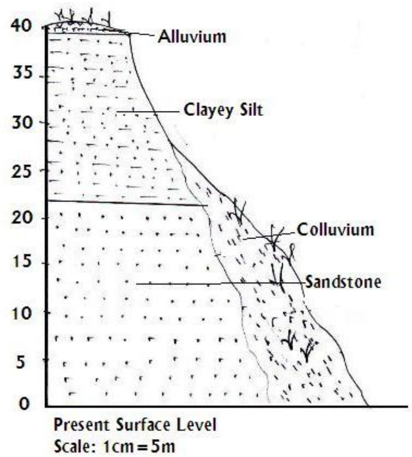
Landslide ID: 08 **Location:** Puran Pallan Para, Teknaf Municipal Area	**Coordinates:** **N**-20°52′22.2″ **E**-92°17′28.6″
	
Date of Occurrence: July 6, 2008.	**Landslide History**: Subsequently activated in July 2008.

Rainfall: 209 mm during 24 hours and 1332mm during 12 days (continuous rain from 25 June to 6 July)

Geology: The failed slope is north-eastern scarp of a large escarpment with a height of around 40m. The height of the failed part of the slope is around 35m and width is around 50 m.
The mountain forming bed rock of the escarpment is formed of mainly two lithological units- yellowish brown cross-bedded to massive medium- to fine-grained sandstone and light yellowish color clayey silt. Top part of this unit about 5 m is highly weathered. The failed mass comprised of highly weathered rock and moderately weathered rock. After the slide at places a moderately weathered rock is exposed. The exposed rock units are mostly composed of light brown fine to medium grained sand, silt and clay. The height of the failure surface is around 35 m.
Fracturing: Sets of joints are not observed on failure surface of the bed rock.
Overburden Deposits: Total overburden comprised of clay, silt and fine sand. The material contains the relic structure of the bed rock which suggests it to be residual soil. The soil thickness of the residual soil layer which overlays the bed rock mass is around 1 m thick. Colluvial soil is about 15m.

Slope Characteristics	The escarpment slope is near vertical to incline and the upper part consists of highly weathered rock. Lower part consists of claye silt and fine grained sand. The failed mass is a part of the upper portion. Thickness is around 15 meters.
Land use	This area completely affected by human intervention. There are 1 houses and about 8 people live there. Some part of this area is used for gardening.
Hydrology	No natural drainage path is visible in the area of the landslide and area is dry. However some water is observed seeping from the exposed joints.
Landslide Mechanism	The recent history shows that the excessive rainfall is the main triggering factor of the slide which can be described as "debris flow". The slide has been reactivated several times during monsoon period.
Impact of the landslide	No major impacts. Only a small part of hill got destroyed.
Future Risks	In future this sliding can get repeated as there is a possibility of destabilization of the mass above the slope. The impact would be further

	destruction to the forest. In the down slope around 10m away the local people residence is located and down slope movement of debris flow can create impact to people house and also people living there. The risk is moderate to high.

Landslide ID: 11 **Location:** Puran Pallan Para, Teknaf Municipal Area	**Coordinates:** **N**-20°52′33.7″ **E**-92°17′31.3″
	
Date of Occurrence: July 6, 2008.	**Landslide History**: Subsequently activated in July 2008.

Rainfall: 209 mm during 24 hours and 1332mm during 12 days (continuous rain from 25 June to 6 July)

Geology: The failed slope is north-eastern scarp of a large escarpment with a height of around 40m. The height of the failed part of the slope is around 35m and width is around 50 m.
The mountain forming bed rock of the escarpment is formed of mainly two lithological units- yellowish brown cross-bedded to massive medium- to fine-grained sandstone and light yellowish color clayey silt. Top part of this unit about 5 m is highly weathered. The sandstone rock is massive and poorly consolidated in the upper part and lower part is well consolidated. The failed mass comprised of completely weathered rock and highly weathered rock. After the slide at places a moderately weathered rock is exposed. The height of the failure surface is around 35 m.
Fracturing: Sets of joints are not observed on failure surface of the bed rock.

Overburden Deposits: Total overburden comprised of clay, silt and fine sand. The material contains the relic structure of the bed rock which suggests it to be residual soil. The soil thickness of the residual soil layer which overlays the bed rock mass is around 1 m thick. Colluvial soil is about 10m.

Slope Characteristics	The escarpment slope is near vertical to incline and the upper part consists of highly weathered rock. Lower part consists of light brown color fine to medium grained sand which is about 22m in thickness. Light yellowish color clayey silt which is about 17m in thickness present above the sand layer. The failed mass is a part of the upper portion. Thickness is around 10 meters.
Land use	This area completely affected by human intervention. There are 4 houses and about 25 people live there. Some part of this area is used for gardening.
Hydrology	No natural drainage path is visible in the area of the landslide and area is dry.
Landslide Mechanism	The recent history shows that the excessive rainfall is the main triggering

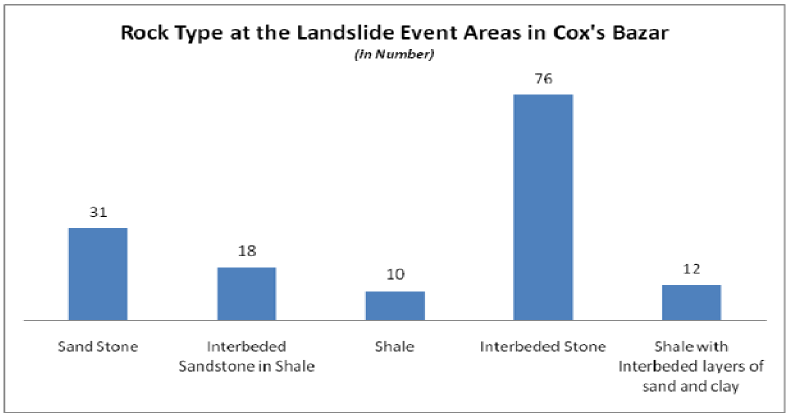
	factor of the slide which can be described as "debris flow". The slide has been reactivated several times during monsoon period.
Impact of the landslide	No major impacts. Only a small part of hill got destroyed.
Future Risks	In future this sliding can get repeated as there is a possibility of destabilization of the mass above the slope. The impact would be further destruction to the forest. In the down slope around 10m away the local people residence is located and down slope movement of debris flow can create impact to people house and also people living there. The risk is moderate to high.

1.6. Attributes that can be derived from the mapping of past landslides and inventorying past landslides for landslide hazard Mapping in two cities.

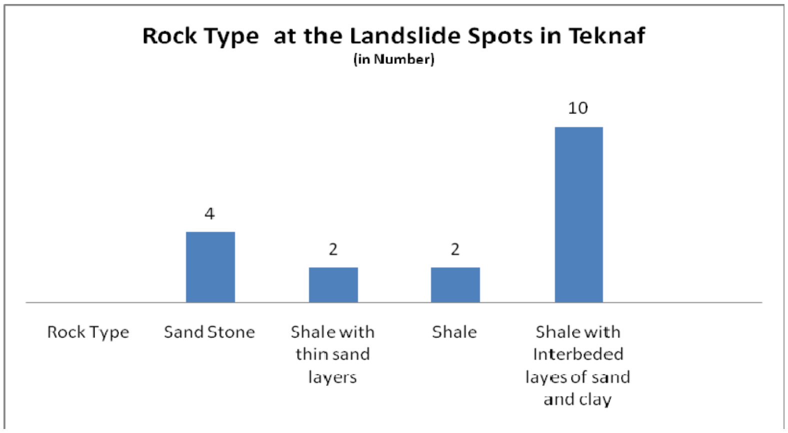
The project team has analyzed the past landslides reported in the Inventory (around 147 landslide events in Cox's bazar and 18 landslide events in Teknaf) to see whether there is a correlation between events in two municipalities. The results of the analysis are given below;

Geology attributes

a) Cox's Bazar



b) Teknaf

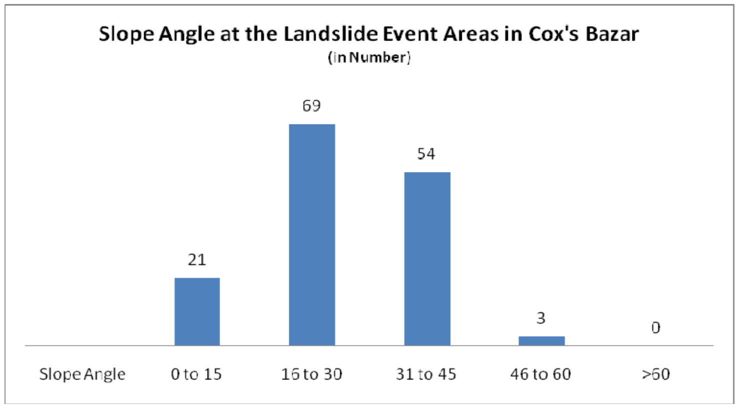


It is seen from the past landslide Inventory that there are 4-5 categories of rock types observed on the failed slopes but predominant rock types to be shale and sandstones. All other rock types are variations of the same with thinner inter-bedding and presently highly to completely weathered. It is seen that all such main Rock types also are subjected to weathering to a different degree or covered with a Residual soil layer where the relic structure was intact .In certain cases it have had a colluviums layer that has been accumulated on the slope, which overlay the weathered bed rock layer or the residual soil layer. Since the mapping has been carried out several months in some cases year or more, it is difficult to establish the proper boundaries or to postulate the situation within the failure mass. However it is evident that the major impact in destabilizing the slope is due to inter-bedding of clay and sand layers in predominant rock types of Shale and Sandstone weathering penetrated along the thinner layers to a greater depth. Apparently these inter-bedded layers are result of weathering along the bedding plane which usually occurs in a near horizontal angle. Combination of weathering along bedding planes and two fracture zones observed in the area are influencing the detachment of rock mass from the main bed rock and tend to destabilize under gravity. It is easy to have water saturation along such layers and interplay of several joints with bedding plane always create wedge failures or down slope movement of blocks. However since majority of the layer is in highly weathered condition or covered with residual soil or weathered colluviums now we see it as a mass dislocation containing a mixture of rock and soil so it is imperative to see such movements as Debris flows. The vegetation *(see Plate:03)* also play a major role in destabilization of such mass as root systems developed in whether thin layers can help expansion of joint systems as well as bedding planes which help water penetration deep in to rock mass which always increases the potential of failure.

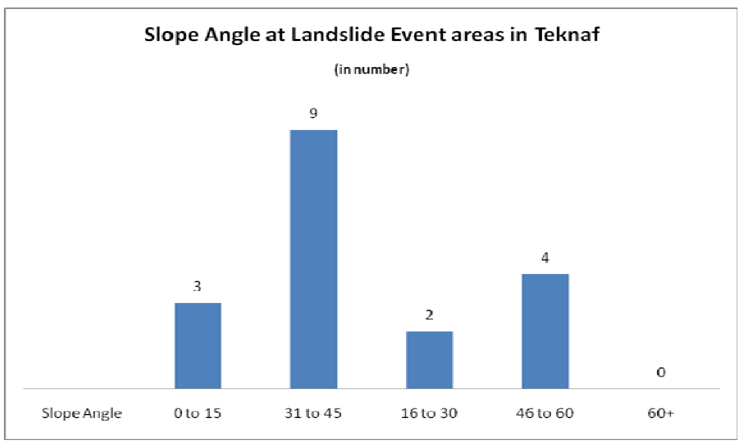

Plate 3: Root systems developed in joints and in think inter-bedded layers

Geo-morphology and slope category attributes

A) Cox's Bazar



B) Teknaf



The project team has taken an attempt to analyses the slope angles of failed slopes to see whether any dominance could be seen in the various slope angles .From the evidence of the past landslides it is seen that the most dominant category among failed slopes is the slopes between slope angle of 16-30. Similar correlation can be seen in both municipality areas. The other dominant category is the slopes with slope angle of 31-45. The slopes with slope angle of 45 or less than 15 are less dominant among failed slope categories. The other factor evident from the past landslides is the fact that when the slope angle increases number of landslides in slopes higher than 45 becomes less. It is mainly due to the fact that, when the slope becomes higher the probability of retention of any weaker layer or soil mass is becoming less and under gravity such slopes tend to get eroded systematically. So the retained mass thickness will not be so high and such slopes probably will not fail easily. In certain cases apparently there are block failures which have been occurred along near vertical joints along escarpment slopes elsewhere but such failures have not been seen as the dominant failure mode within the two target cities.

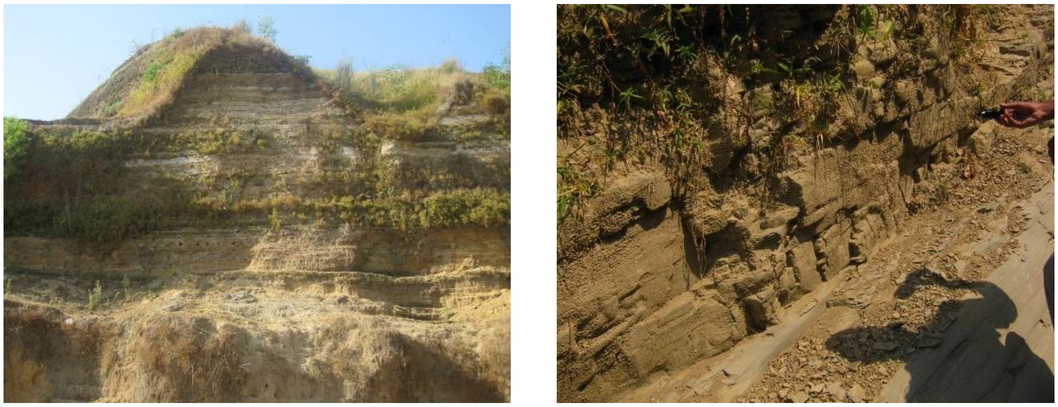
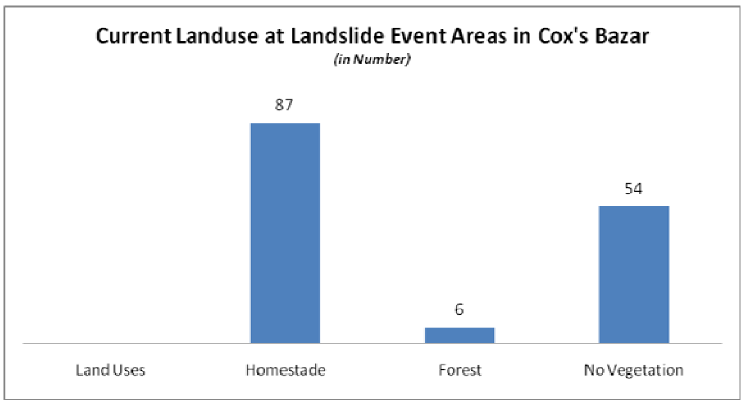
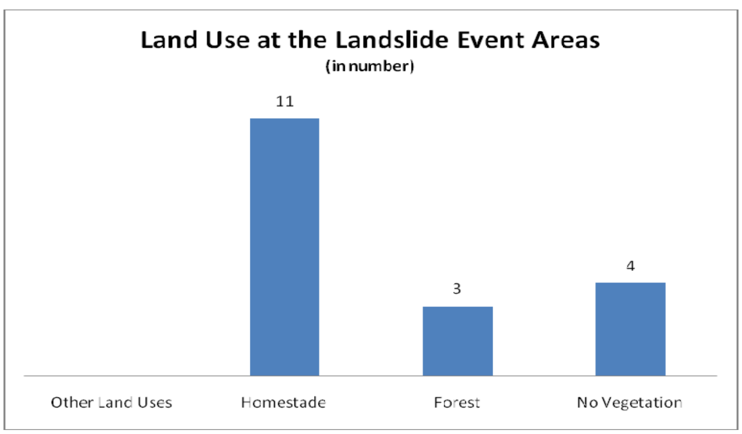


Plate 4: Land use attributes

a) Cox's Bazar



b) Teknaf

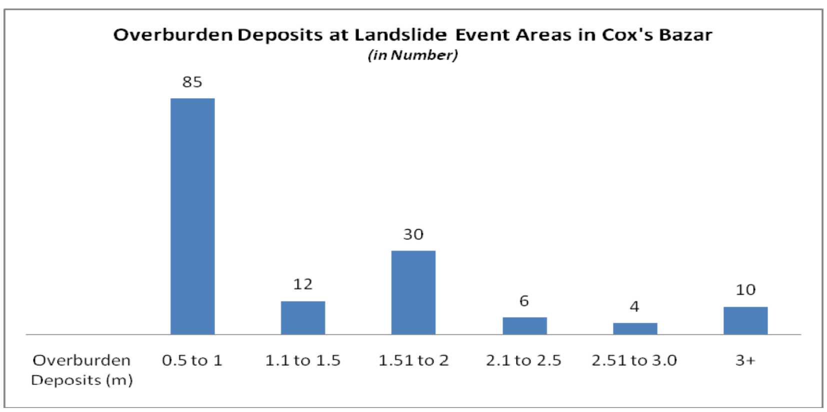


The project team has observed several land use classes in the area subjected to mapping in two target municipalities. However the dominant land use classes seen in failed slopes are either abandoned land after cultivation or land covered with homesteads. This is seen as major reason for death of people as near settlements always communities used to grow vegetables; fruit trees such as banana on slopes and such land use practices are responsible for destabilization of slopes. The abandoned slopes also are previously used land for cultivation of vegetables; lentils etc and absence of vegetation cover increased the water percolation which increases the potential for destabilization. Many types of human activities caused disturbances to natural slope such as cultivation, removal of earth for construction purposes, excavations etc. The human settlement areas are mainly subjected to land sliding due to such human interventions *(pl. see Plate 05)*. Thick forests areas have not been subjected to landslides and however partially forested areas were subjected to landslides.

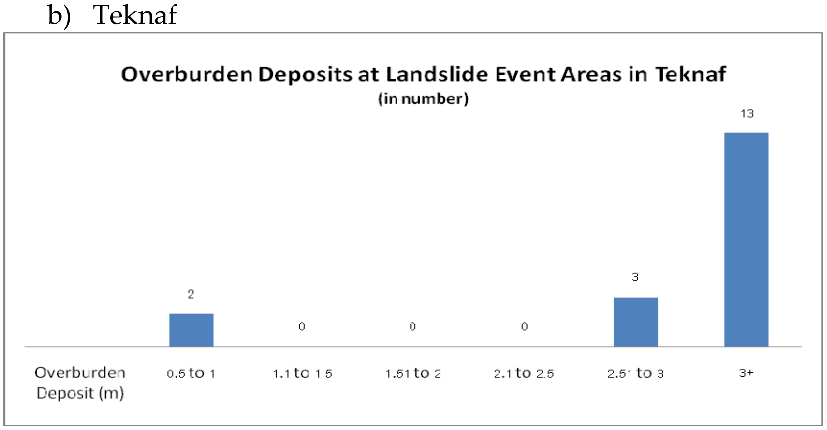
Plate 5: Various types of excavations done by communities on slopes for cultivation purposes and settlements on hill slopes

Attributes of Overburden deposits

a) Cox's Bazar



b) Teknaf



Overburden deposits usually are consists of colluviums, residual soil and completely weathered rock. In certain cases weathering penetrated highly in to rock mass and thick overburden has failed under gravity. It is seen from the past landslides thicker the overburden tendency for failure becomes also higher. Communities used to stay in areas closer to thick overburden layer as it can be used for cultivation purposes but such slopes also have seen as most vulnerable slopes for landslides.

1.7. Conclusions

The following conclusions can be made from the analysis of historical events reported in the Cox's Bazaar and Tecknaf Municipalities.

a. Most prominent rock type occurs in both municipality areas are shale and sandstones. The landslides are mostly seen in such dominant rock types but probability of occurrence is higher in the above rock types when they consist of thin inter-bedded layers of sand and clay. It may be due to the fact that such thin layers have a higher tendency for water percolation and resultant penetration of weathering deep in to rock mass.
b. Landslides also are influenced by rock fracturing. Combination of occurrence of bedding planes and fracture systems within a same area has a higher tendency for wedge failures. Weathering along joint places in particular filling in fractures increases the potential for land sliding. Often in such areas block failures may occur.
c. Homesteads and abandoned land areas are the key land uses reported as most vulnerable land users. In most cases the farmers have the tendency to use the land and abandoned the same after few seasons and move to a new location. Such general tendency of people for cultivation on slopes needs to be stopped as a prevention measure. Often disturbances to natural slopes also are due to other human interventions such as excavations for construction, removal of earth etc but this sort of human interventions may increase the potential for destabilization of slopes.
d. In certain places thick overburden has been observed. Such observed slopes are comprised of colluviums, residual soil and completely weathered rock. It is seen from the past landslides that thicker the overburden tendency for failure becomes also higher.
e. Findings of this study will become a very good input to landslide hazard mapping. In particular the analysis carried out on slopes, geology, thickness of overburden etc will be used in finalizing the rating system for finding the attributes for hazard occurrence.

1.8. General Recommended future actions for systematic maintenance of landslide inventory.

1. It is necessary to have a systematic recording of landslides and conducting of mapping and inventorying them soon after the occurrence of landslides. Many useful evidences will be destroyed or not be available when mapping is undertaken after some times as the areas will be disturbed to a great extent.

2. It is useful to identify a nodal agency for landslide risk management as there is a need for a depositary of all landslide related reports and evidences. The same institutions

should be empowered to undertake inventorying the events and developing the database. It is critical to have more information on causative factors and development of scientific factual information which can be used for designing safer slopes.

3. It is critical to undertake community level interventions to increase the awareness on landslide issue. Mostly communities living in landslide prone areas need to understand the fact that when living in landslide prone areas, if they undertake activities to disturb the slope that will increase their vulnerability further.

Chapter-2
Precipitation Threshold Value

Executive Summary

Rainfall is a recognized trigger of landslides, and investigators have long attempted to determine the amount of precipitation needed to trigger slope failures. Based on the used rainfall measurements, empirical rainfall thresholds can be grouped in three broad categories: (i) thresholds that combine precipitation measurements obtained for a specific rainfall event, (ii) thresholds that consider the antecedent conditions, and (iii) other thresholds.

Considerable efforts have been made to understand the triggers for land sliding in natural systems, with quite variable results. Review of the literature reveals that no unique set of measurements exists to characterize the rainfall conditions that are likely (or not likely) to trigger slope failures.

Rainfall data since 1950s and landslide records were collected to formulate rainfall threshold values for this area. Following conclusions and recommendations could be made considering the rainfall and landslide data available in these two locations having referred to number of references on this topic.

Cox's Bazaar and Teknaf show that around 130mm during 24 hrs rainfall or 300mm rainfall during 48 hrs rainfall could cause a landslide in Cox's Bazaar and Teknaf. However, globally the last night rain causes landslides to occur in the early morning. Then, the day before could also be considered as 24 hrs rainfall and in that case, rainfall would be 170mm/24 hrs. This value exactly fits with Corominas and Moya (1999) values defined for Spain and Brand et al. (1988) values for Hong Kong. Further, it also has some close relationship with Bandara (2008) findings for Sri Lanka an evacuation warning. However, if hourly rainfall could be found, it would be a supporting data for a better prediction.

Further, when the two locations such as Teknaf and Cox's Bazaar taken separately, the following results could be estimated.

Data from Teknaf gives around 170mm during 24 hrs rainfall or 420mm rainfall during 48 hrs rainfall could cause a landslide. However, the day before could also be considered as 24 hrs rainfall and in that case, rainfall would be 250mm/24 hrs.

Data from Cox's Bazaar gives around 96mm during 24 hrs rainfall or 185mm rainfall during 48 hrs rainfall could cause a landslide. However, the day before could also be considered as 24 hrs rainfall and in that case, rainfall would be 90mm/24 hrs.

ADPC team has formulated the threshold values mentioned in this report using the available data which needs improvement as more data becomes available. Whenever a landslide happens in the concerned area, it is a must to collect this information and update the proposed thresholds.

ADPC team is in the process of setting up the Community Based system for early warning in two pilot communities. The precipitation threshold values recommended to be used as follows;

*Warning limit for Alert - 75 mm in Teknaf and 50mm rainfall for 24 hours for Cox's Bazaar – Increase vigilance and observe appearance of any symptoms of slope destabilization on critical slopes. If such symptoms can be observed immediately move out from the critical slope area. Otherwise use this limit for having vigilance.

Note – If Cox's bazaar gets generally higher rainfall in this range, then every rainy day is an alert day. On the other hand, since Cox's Bazaar is so urbanized, this range rainfall could cause heavy damages due to landslides. If we take average daily rainfall in Cox's Bazaar since 1950, it is around 9.8363 mm per day. Maximum daily rainfall occurs in June and July and it is also around 30-40 mm per day. So having a rainfall more than 50 mm could be considered as an alert situation.

*Warning limit for getting ready for evacuation to safer location from high risk locations- 100 mm in Teknaf and 75mm rainfall for 24 hours for Cox's Bazaar– Get ready for evacuation, under short notice

*Warning for Evacuation) - 150 mm in Teknaf and 90mm rainfall for 24 hours for Cox's Bazaar –Warning for evacuation to safer places.

The critical locations where these warnings should be imposed will be identified through landslide hazard mapping in Cox's Bazaar and Teknaf.

Note - Sometimes, previous night rain can also be continuing till the disaster happens. Then, we may see a very small value next day, but landslide too occurs. This has happened in Teknaf. Considering these facts, as the range is too high from 100 to 200, we can go for 150mm for additional safety.

Hourly rainfall data is very important these days as heavy intense short term rainfalls are causing no of landslides all over the world. Once hourly rainfall data will be available such data also needed to be factored in to above EW limits. In future, data interval for recording should be on hourly basis. Local Met Department should be advised to collect data using hourly precipitation. As it is not the practice of Met Department of Bangladesh to release such data, it is recommended if the focal agency could discuss and agree on releasing hourly data at least during monsoon periods for this kind of nationally important disastrous situations.

It should be noted that the main set back in defining the geology related specific thresholds is the availability of rainfall data. Because the rainfall data for Teknaf and Cox's Bazaar represents the two regions and site specific sets of data is not available. Even if we use different geology to prepare thresholds, finally we have the same rainfall data. Therefore it should be encouraged the community participation in collecting rainfall data for further improvements of these proposed thresholds.

It is strongly recommended that at least two automatic rain gauges have to be made available at respective target municipalities. ADPC has already made a request to NGI for the same under RECLAIM project but it may be better if similar request can be made by

Geological Survey of Bangladesh too. It is good if the automatic rain gauges could be set up soon before the commencement of the next monsoon rains.

It is essential a Nodal Agency or responsible agency can be identified for EW for landslides. The same agency should continue data processing and updating the accuracy of threshold limits in the future.

2. Precipitation Threshold Value

2.1. Introduction

More than 300 people have been killed in landslides in Chittagong in recent years. Nineteen people, 12 of them children, died in landslides in Cox's Bazaar district in the first half of July 2010 alone. On 3 July, this year, 14 people died in rain-induced landslides at Teknaf and Ukhia sub-districts of Cox's Bazaar, while two people in one family were buried alive under mud the following day. On 14 July two more died under a mudslide at Himchhari in the same district. In June 2007, a landslide at Mati Jharna colony of Lalkhan Bazar, right in the heart of Chittagong, killed 127 people and injured 100 more during annual monsoon of 2008, when a hill collapsed on to an adjacent slum.

As seen from the above the incidents of landslides are becoming a very frequent disaster event in hill districts of Bangladesh. Landslides usually do not bring significant negative impacts on the development initiatives like other major disaster events such as earthquakes and floods and the area affected is comparatively not very large. Therefore less attention has been given to landslide problems in many of the countries in Asia. During past few years we have seen escalation of landslide events in Bangladesh not only in number but also in magnitude. Usually Bangladesh is regarded as a flat country which gets affected often by flood and cyclone events. However in addition to such frequent hazards; now we need to consider that landslide events also continue to result in human sufferings, property losses as seen from the events that occurred during the recent past. Such increases have been reported especially in the southern areas of Bangladesh. As population increases and societies become more complex, the economic and societal losses due to such events may continue to rise unless proper attention is given at early stages as increasing anthropogenic activities in the mountain areas can add to the existing vulnerability of communities further.

Like in other countries one of the reasons for aggravation of landslide problem in Bangladesh is lack of awareness on the causative factors trigger mechanism of landslides etc. This is a common problem for at risk communities living in landslide prone areas as well as for most of the regulatory authorities, planning authorities as well as for service sector. In most cases unplanned human activities or illegal settlements in hazard prone areas are seen as reasons for high socio-economic impacts due to various hazard events. In case of landslides the authorities involved in human settlement planning and development do not have an approach for integrating the landslide risk reduction measures in land use planning due to lack of awareness on most essential important factors. As well the authorities responsible for infrastructure development in the service sector such as water, power and energy, road development etc do not give adequate attention to landslide problem and its potential impact due to same reason. The professionals involved in land use planning or other development control and development programs see this as a new problem and do not have adequate knowledge on causative factors or measures to reduce the impact for socio-economic development of hill districts of Bangladesh. Usually when the development decisions are taken in hilly areas, the landslide proneness and issues related to reduction of impacts or creation of much needed awareness on the issues in general is not considered as an important factor. In most cases, the impact of landslides is visible when the services are disrupted or several deaths are reported caused by landslide events.

The Project initiated by CDMP on "Rainfall Triggered Landslide Hazard Zonation in Cox's Bazaar and Teknaf Municipalities as well as Introducing Community-based Early Warning System for Landslide Hazard Management" can be considered as a major step by Bangladesh authorities for promoting landslide risk reduction for sustainable development of hill country districts of Bangladesh. This will help in much needed awareness on the causative factors and interventions for reducing the landslide risk. This also will promote a dialogue between decision makers at city level, landslide professionals with vulnerable communities living in landslide prone areas about the theoretical and practical aspects and issues related to landslide hazard mitigation and increased preparedness. The proposed program activities are designed to be implemented through a consultative process to arrive at a suitable strategy which can be replicated within all landslide prone areas of Bangladesh. This report on "Development of precipitation threshold limits for landslide prone areas in Cox bazar and Technaf Municipalities"is a fulfilment of one of the main activities of the above project.

This activity will have following objectives;

- Development of a methodology for determining the threshold levels
- Investigate and provide an overview of definition of thershold limits by other countries prone to landslides
- Analysis of Rainfall data pertinenet to historical landslides recorded within the two municiplaities
- Determination of thershold limits of two municiplaities

2.2. General Approach for establishment of Rainfall Thresholds of Landslides

Rainfall is a recognized trigger of landslides, and investigators have long attempted to determine the amount of precipitation needed to trigger slope failures, a problem of scientific and societal interest. Rainfall thresholds can be defined on physical (process-based, conceptual) or empirical (historical, statistical) basis. Empirical rainfall thresholds are defined studying rainfall events that have resulted in landslides. The thresholds are usually obtained by drawing lower-bound lines to the rainfall conditions that resulted in landslides plotted in Cartesian, semi-logarithmic, or logarithmic coordinates. Most commonly, the thresholds are drawn visually, i.e., without any rigorous mathematical, statistical, or physical criterion. Where information on rainfall conditions that did not result in slope failures is available, thresholds are defined as the best separators of rainfall conditions that resulted and did not result in slope instability. Empirical rainfall thresholds for the initiation of landslides have been proposed at the global (world-wide), regional, and local scale. Review of the literature reveals that no unique set of measurements exists to characterize the rainfall conditions that are likely (or not likely) to trigger slope failures (see Table 1). Language inconsistencies and disagreement on the requisite rainfall and landslide variables make it difficult to compare the thresholds. Based on the used rainfall measurements, empirical rainfall thresholds can be grouped in three broad categories: (i) thresholds that combine precipitation measurements obtained for a specific rainfall event, (ii) thresholds that consider the antecedent conditions, and (iii) other thresholds.

2.3. Literature review on the Existing Threshold Definitions

2.3.1. Impact of Rain Fall on Slope Instability

Studies performed elsewhere on the impact of rainfall on slope instability indicates that moderate showers of long duration are more dangerous than high intensity showers of short duration because a shower of long duration provides sufficient time for the rainwater to infiltrate to the critical depth in a given slope. The above findings show that rainfall intensities that are less than the coefficient of permeability of the soil may not saturate the soil below the root zone. Rainfall intensities that are significantly higher than the soil absorption capacity may also not penetrate through the soil within a given duration due to the runoff *(www.fao.org/docrep/T1765E/t1765e0q.htm)*.

Evaluation of changing effective stress conditions due to pore water pressure variations is rather a complex problem, especially if they are addressed within the impacts of slope's vegetation and the nature of the sub-soil. According to previous studies, the best approach to evaluate the impact of ground water conditions is to measure the in-situ suction and the pore water pressure. However, cost of instrumentation that can accurately measure these parameters has overridden the incorporation of these parameters into the suggested evaluation methodology, specifically at the selected scale of mapping.

2.3.2. Understanding the triggers for Establishment of Rainfall Threshold values

Rainfall threshold values vary from region to region due to differences in exiting soil characteristics and climatological patterns in different areas. Therefore, a complete study of the rainfall patterns in landslide prone areas and their records of landslides will help predict reasonable threshold values of rainfall and use them as a tool for landslide forecasting. With this, therefore, collection of critical rainfall values with sufficient geological data pertinent to previous landslides in the two cities namely Teknaf and Cox's Bazaar is of paramount importance in establishing precipitation threshold limits. It can be subsequently used for developing landslide EWS for the benefit of the people who are vulnerable to landslides in both cities.

Considerable efforts have been made to understand the triggers for land sliding in natural systems, with quite variable results. For example, working in Puerto Rico, Larsen and Simon found that storms with a total precipitation of 100–200 mm, about 14 mm of rain per hour for several hours, or 2–3 mm of rain per hour for about 100 hours can trigger landslides in that environment. Rafi Ahmad, working in Jamaica, found that for rainfall of short duration (about 1 hour) intensities of greater than 36 mm/h were required to trigger landslides. On the other hand, for long rainfall durations, low average intensities of about 3 mm/h appeared to be sufficient to cause land sliding as the storm duration approached approximately 100 hours. Corominas and Moya (1999) found that the following thresholds exist for the upper basin of the Llobregat River, Eastern Pyrenees area. Without antecedent rainfall, high intensity and short duration rains triggered debris flows and shallow slides developed in colluviums and weathered rocks. A rainfall threshold of around 190 mm in 24 h initiated failures whereas more than 300 mm in 24-48 h were needed to cause widespread shallow land sliding. With antecedent rain, moderate intensity precipitation of at least 40 mm in 24 h reactivated mudslides and both rotational and translational slides affecting clayey and silt-clayey formations. In this case, several weeks and 200 mm of precipitation were needed to cause landslide reactivation. A similar approach is reported by Brand et al. (1988) for Hong Kong, who found that if the 24 hour antecedent rainfall exceeded 200 mm then the rainfall threshold for a large landslide event was 70 mm hr-1.

Finally, Caine (1980) established a worldwide threshold:

I = 14.82 D - 0.39

where: I is the rainfall intensity (mm h-1), D is duration of rainfall (h)

This threshold applies over time periods of 10 minutes to 10 days. It is possible to modify the formula to take into consideration areas with high mean annual precipitations by considering the proportion of mean annual precipitation represented by any individual event.

2.3.3. Rainfall and climate variables used in the literature for the definition of rainfall thresholds

Project team has carried out a literature survey to obtain information on the rainfall and climate variables used in the literature for the definition of rainfall thresholds for the initiation of landslides. Table 7 lists the variable, the units of measure most commonly used for the parameter, and the author(s) who first introduced the parameter. It shows that the nomenclature used is not consistent in the literature, and different definitions have been used for the same or similar variables.

Table 7: Rainfall and climate variables used in the literature for the definition of rainfall thresholds for the initiation of landslides.

VARIABLE	DESCRIPTION	UNITS	FIRST INTRODUCED
D	Rainfall duration. The duration of the rainfall event or rainfall period.	h, or days	Caine (1980)
D_C	Duration of the critical rainfall event.	h	Aleotti (2004)
$E_{(h),(d)}$	Cumulative event rainfall. The total rainfall measured from the beginning of the rainfall event to the time of failure. Also known as storm rainfall. "h" indicates the considered period in hours; "d" indicates the considered period in days.	mm	Innes (1983)
E_{MAP}	Normalized cumulative event rainfall. Cumulative event rainfall divided by MAP (E_{MAP}=E/MAP). Also known as normalized storm rainfall.	-	Guidicini and Iwasa (1977)

VARIABLE	DESCRIPTION	UNITS	FIRST INTRODUCED
C	Critical rainfall. The total amount of rainfall from the time of a distinct increase in rainfall intensity (t_0) to the time of the triggering of the first landslide (t_f).	mm	Govi and Sorzana (1980)
C_{MAP}	Normalized critical rainfall. Critical rainfall divided by MAP (C_{MAP}=C/MAP).	-	Govi and Sorzana (1980)
R	Daily rainfall. The total amount of rainfall for the day of the landslide event.	mm	Crozier and Eyles (1980)
R_{MAP}	Normalized daily rainfall. Daily rainfall divided by MAP (R_{MAP}=R/MAP).	mm	Terlien (1998)
I	Rainfall intensity. The amount of precipitation in a period, i.e., the rate of precipitation over the considered period. Depending on the duration of the measuring period, rainfall intensity measures peak or average precipitation rates.	mm/h	Caine (1980)
I_{MAP}	Normalized rainfall intensity. Rainfall intensity divided by MAP (I_{MAP}=I/MAP).	1/h	Cannon (1988)
I_{MAX}	Maximum hourly rainfall intensity. The maximum hourly rainfall intensity.	mm/h	Onodera et al. (1974)
I_P	Peak rainfall intensity. The highest rainfall intensity (rainfall rate) during a rainfall event. Available from detailed rainfall records.	mm/h	Wilson et al. (1992)
$\hat{I}_{(h)}$	Mean rainfall intensity for final storm period. "h" indicates the considered period, in hours, most commonly from 3 to 24 hours.	mm/h	Govi and Sorzana (1980)
I_C	Critical hourly rainfall intensity.	mm/h	Heyerdahl et al. (2003)
I_f	Rainfall intensity at the time of the slope failure. Available from detailed rainfall records.	mm/h	Aleotti (2004)
I_{fMAP}	Normalized rainfall intensity at the time of the slope failure. Rainfall intensity at the time of the slope failure divided by MAP (I_{fMAP}=I_f/MAP).	1/h	Aleotti (2004)
$A_{(d)}$	Antecedent rainfall. The total (cumulative) precipitation measured before the landslide triggering rainfall event. "d" indicates the considered period in days.	mm	Govi and Sorzana (1980)
A_{MAP}	Normalized antecedent rainfall. Antecedent rainfall divided by MAP (A_{MAP}=A/MAP).	-	Aleotti (2004)
$A_{(y)}$	Antecedent yearly precipitation up to date of the event. The total (cumulative) yearly precipitation measured before the landslide triggering rainfall event.	mm	Guidicini and Iwasa (1977)
$A_{(y)MAP}$	Normalized antecedent yearly precipitation up to date of the event. Antecedent yearly precipitation divided by MAP ($A_{(y)MAP}$=$A_{(y)}$/MAP).	-	Guidicini and Iwasa (1977)
F_C	Sum of normalized antecedent yearly precipitation and normalized event rainfall (F_C=$A_{(y)MAP}$+E_{MAP}). Also known as "final coefficient".	-	Guidicini and Iwasa (1977)

VARIABLE	DESCRIPTION	UNITS	FIRST INTRODUCED
MAP	Mean annual precipitation. For a rain gauge, the long term yearly average precipitation, obtained from historical rainfall records. A proxy for local climatic conditions.	mm	Guidicini and Iwasa (1977)
RDs	Average number of rainy-days in a year. For a rain gauge, the long term yearly average of rainy (or wet) days, obtained from historical rainfall records. A proxy for local climatic conditions.	#	Wilson and Jayko (1997)
RDN	Rainy-day normal. For a rain gauge, the ratio between the MAP and the average number of rainy-days in a year (RDN=MAP/RDs).	mm/#	Wilson and Jayko (1997)
N	Ratio between the MAP of two different (distant) areas.	-	Barbero et al. (2004)
Y	Relationship between Normalized cumulative rainfall before a particular landslide (7 days prior or 3 days prior) and days	mm/day	Nawagamuwa et al. (2011)

The database of rainfall thresholds for the possible occurrence of landslides was compiled through a thorough review of the existing literature on rainfall induced landslides. References section lists the main references collected.

Table 8: Landslide Inventory (Landslide Catalogue) used in defining the Threshold limits

ID	Day	Month	Year	Location	Closest Rainfall Station	Trigger	Latitude	Longitude	Fatalities	Injuries/damage	Source
1	30	5	1990	Jhagar beel area of Rangamati district.	Rangamati					link road embankment	Banglapedia
2	12	7	1997	Charaipada of Bandarban	Rangamati					90,000-sq m was affected	
3	11	8	1999	Bandarban	Rangamati	Heavy and incessant rainfall			7		
4	13	8	1999	Gopaipur, Chittagong	Chittagong	Heavy and incessant rainfall			10		
5	15	8	1999	Chittaputti area, Chittagong	Chittagong	Heavy and incessant rainfall				50 houses completely,300 houses partly	
6	24	6	2000	Chittagong University campus	Chittagong	deluge of mud and water			13	20 people injured	
7	5	5	2003	Noabadi, Akhaura	Chittagong	Heavy rains	23.8617	91.2189	31		Durham
8	15	6	2003	Cox's Bazaar	Cox's Bazar	Heavy rains	21.5867	92.0748	6		Durham and Daily Star
9	29	6	2003	Patiya, S. Bangladesh		Heavy rains	22.3	91.9833	4		Durham and Daily Star
10	30	7	2003	Cox's Bazaar	Cox's Bazar	Heavy rains	24.467	91.75	6		Durham and Daily Star
11	9	6	2005	Baromari in sherpur					1		bdnews24
12	3	8	2005	OR Nizam Road Housing Society of the port city's Panchlaish area, Brahmanbaria		Heavy rains			2	2	bdnews24

ID	Day	Month	Year	Location	Closest Rainfall Station	Trigger	Latitude	Longitude	Fatalities	Injuries/damage	Source
13	13	10	2005	Akabpur village, bordering India's Tripura state area, under Kasba upazila of Brahmanbaria district		During digging soil			1	3	bdnews24
14	31	10	2005	Shantinagar area adjacent to the Bangladesh Cooperative Housing Society in Bayezid Bostami thana in the port city	Chittagong	Rains			2	1	bdnews24
15	3	1	2006	Jhinaigati upazilla in Sherpur		massive landslide			Atleast 4	4	bdnews24
16	8	7	2006	Satkania upazila, Chittagong	Chittagong	Rains			2	1	bdnews24
17	11	6	2007	Chittagong	Chittagong	Rain	22.315	91.833	128		The Daily Star,
18	11	6	2007	Rangamati	Rangamati	Heavy rain	22.636	92.145	3		The Daily Star,
19	10	9	2007	Nabinagar in Chittagong	Chittagong	Rains	23.891	90.973	2		The Daily Star,
20	15	10	2007	Betbunia		Rains	22.533	89.4	3	2	Press TV, The Daily Star,
21	3	7	2008	Cox's Bazaar, Moheshkhali, Teknaf	Cox's Bazar, Teknaf	Heavy rains	21.44	92	20 (total)		The Daily Star,
22	3	7	2008	Teknaf upazila headquarters, Ukhia upazila	Teknaf	Rains			9+1		The Daily Star,
23	3	7	2008	valley in Dumperang of Teknaf Sadar	Teknaf	Rains			4		The Daily Star,
24	3	7	2008	Fakirer Mura	Teknaf	Rains			5		The Daily Star,

ID	Day	Month	Year	Location	Closest Rainfall Station	Trigger	Latitude	Longitude	Fatalities	Injuries/damage	Source
25	6	7	2008	Kalyanpara in Teknaf upazila of Cox's Bazar,Mahajanpara in Cox's Bazar	Cox's Bazar, Teknaf	Heavy rains			4+1		The Daily Star,
26	18	8	2008	Matijharna in Chittagong,Cox Bazar	Chittagong, Cox's bazar	Heavy monsoon rains	22.3399	91.8237	11	25 injured	The Daily Star,
27	23	8	2008	Motijharna of Lalkhan Bazar in the port city	Chittagong	Earthquake-rain?	22.344	91.8188	no		The Daily Star,
28	29	3	2009	Tero Kheda upazila in Khulna		Rains			3	2	The Daily Star,
29	9	5	2009	Shankha river at Bandarban,	Rangamati	Rains					The Daily Star,
30	18	5	2009	Sreemangal upazila, Moulvibazer.		Heavy rain	24.3083	91.7333	6		The Daily Star,
31	31	7	2009	Harinmara of Lama in Bandarban	Rangamati	4days Heavy rain	22.2251	92.19	10	50 houses destroyed	The Daily Star,
32	8	4	2010	Dhalirchara of Ramu upazila in Cox's Bazar	Cox's Bazar	cutting a hill to build their house			2		bdnews24
33	15	6	2010	Teknaf, Ukhia,Ramu, Cox's Bazar and Bandarban districts)	Cox's Bazar, Teknaf, Rangmati	Heavy rain			56	34 injured	The Daily Star,
34	16	12	2010	Nalapara in Ambagan area in the port city	Chittagong	digging into the hill			1	2	The Daily Star,

2.4. Suggestions on the Applicable Threshold Definitions for Cox's Bazaar and Teknaf

Most of the threshold values defined in Table-7 considers hourly rainfall values. Rainfall data for the definition of rainfall thresholds for the initiation of landslides defined in Table-8 consider historical daily rainfall data. Hourly rainfall data for Cox's Bazaar and Teknaf are not available for any such analysis. Therefore, some other norms are also considered which consider only the daily rainfall.

Corominas and Moya (1999) found that the following thresholds exist for the upper basin of the Llobregat River, Eastern Pyrenees area in Spain. Without antecedent rainfall, high intensity and short duration rains triggered debris flows and shallow slides developed in colluvium and weathered rocks. A rainfall threshold of around 190 mm in 24 h initiated failures whereas more than 300 mm in 24-48 h were needed to cause widespread shallow landsliding. With antecedent rain, moderate intensity precipitation of at least 40 mm in 24 h reactivated mudslides and both rotational and translational slides affecting clayey and silty-clayey formations. In this case, several weeks and 200 mm of precipitation were needed to cause landslide reactivation. A similar approach is reported by Brand et al. (1988) for Hong Kong, who found that if the 24 hour antecedent rainfall exceeded 200 mm then the rainfall threshold for a large landslide event was 70 mm hr-1.

Bandara (2008) discussed the threshold limits prepared after studying number of landslides in Sri Lanka with the correlation of the landslide occurrence and the daily rainfall of the incidence day or day before. According to the studies following generalized threshold limits were decided for the whole landslide prone areas of Sri Lanka.

Type one -
Alert Warning – Rainfall exceed 75mm within 24 hours and continue
Type two -
Warning for getting ready for evacuation – Rainfall exceed 100 mm within 24 hours and continue
Type three –
Evacuation warning – Rainfall exceed 150mm within 24 hours or 75mm within an hour period and continue

Historical rainfall data related to landslide events are summarized as shown in Table-9 for a clear definition for Cox's Bazaar and Teknaf.

Table 9: Rainfall data for several landslides occurred in Cox's Bazaar and Teknaf in the recent history; here "0" refers to the day of landslides

		No of days prior to landslide (Values in Bold)								
		Rainfall in mm								
Location	Date	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**	**+1**
Teknaf	3/7/2008	71	106	158	98	61	33	367	53	73
Cox's Bazaar	3/7/2008	25	49	88	187	152	94	134	45	89
Cox's Bazaar	15/6/2003	17	21	110	66	13	42	8	77	84
Cox's Bazaar	30/7/2003	7	11	85	31	46	72	162	93	61
Teknaf upazila headquarters, Ukhia upazila	3/7/2008	71	106	158	98	61	33	367	53	73
valley in Dumperang of Teknaf Sadar	3/7/2008	71	106	158	98	61	33	367	53	73
Kalyanpara in Teknaf	6/7/2008	98	61	33	367	53	73	89	209	144
upazila of Cox's Bazar,Mahajanpara in Cox's Bazar	6/7/2008	187	152	94	134	45	89	64	132	35
Teknaf	15/6/2010	0	0	3	2	58	40	68	481	91
Cox's Bazar	15/6/2010	0	0	41	2	15	75	78	132	186

Following graph shown in Figure 9 can be prepared considering the last 24 and 48 hrs rainfall (including the day of disaster and the previous day).

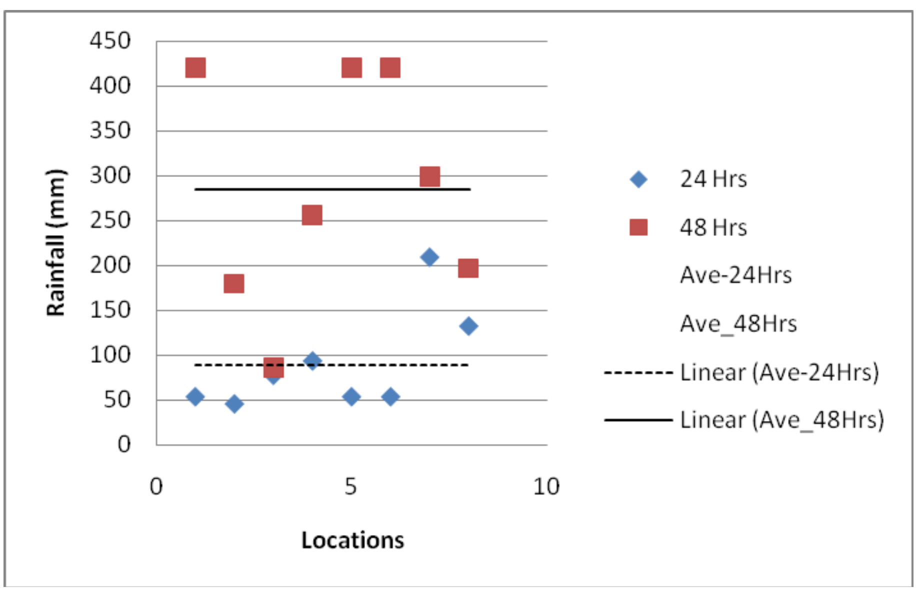


Figure 9: 24 Hrs and 48 Hrs rainfall data before landslides in Cox's Bazaar and Teknaf

This gives around 130mm during 24 hrs rainfall or 300mm rainfall during 48 hrs rainfall could cause a landslide in Cox's Bazaar and Teknaf. However, globally the last night rain causes landslides to occur in the early morning. Then, the day before could also be considered as 24 hrs rainfall and in that case, rainfall would be 170mm/24 hrs. This value exactly fits with Corominas and Moya (1999) values defined for Spain and Brand et al. (1988) values for Hong Kong. Further, it also has some close relationship with Bandara (2008) findings in Sri Lanka for an evacuation warning. However, if hourly rainfall could be found, it would be a supporting data for a better prediction.

Further, when the two locations such as Teknaf and Cox's Bazaar taken separately, the following results could be estimated.

Data from Teknaf gives around 170mm during 24 hrs rainfall or 420mm rainfall during 48 hrs rainfall could cause a landslide. However, the day before could also be considered as 24 hrs rainfall and in that case, rainfall would be 250mm/24 hrs.

Data from Cox's Bazaar gives around 96mm during 24 hrs rainfall or 185mm rainfall during 48 hrs rainfall could cause a landslide. However, the day before could also be considered as 24 hrs rainfall and in that case, rainfall would be 90mm/24 hrs.

The same data was analyzed the way Nawagamuwa et al (2011) has proposed and the Figure 10 and 11 show the relationship considering the cumulative rainfall values from 7days till the landslide for Cox's Bazaar and Teknaf respectively.

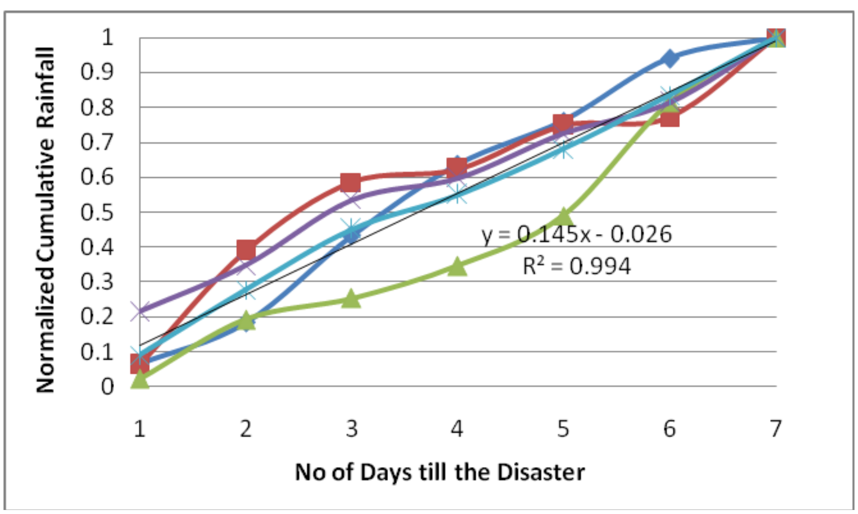


Figure 10: Normalized cumulative rainfall data for Cox's Bazaar

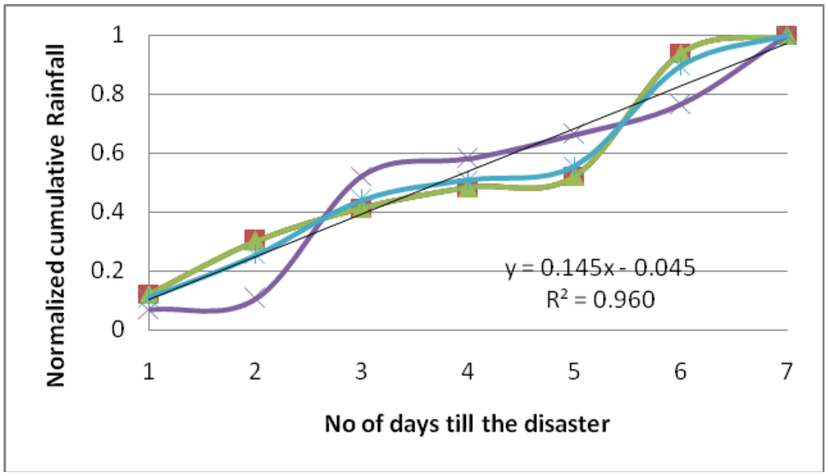


Figure 11: Normalized cumulative rainfall data for Teknaf

Methodology to use this proposed method by Nawagamuwa et al (2011) is as follows. Lets consider the relationship found for Cox's Bazaar. This gives a relationship between (Cumulative rainfall/cumulative rainfall on the day of disaster) and no of days (from 6 days prior to the disaster)

Y=0.1454X-0.0264

$$\left(\frac{Cumulative\_Rainfall}{Cumulative\_Rainfall\_disasterday}\right) = 0.1454(days) - 0.0264$$

To develop this equation, 6 days proir to the disaster has been considered. If the cumulative rainfall 4days prior to the disaster then, no of days = 3.

Lets use the landslide data of Cox's Bazaar (even on 6th July 2008)

*cumulative rainfall 4days prior to the disaster = 380

no of days = 3

$$\left(\frac{380}{Cumulative\_Rainfall\_disasterday}\right) = 0.1454(3) - 0.0264$$

Predicted cumulative rainfall on the day of disaster =927

Actual cumulative rainfall on the day of disaster =710

now, this can be further tested.

*cumulative rainfall 3days prior to the disaster = 425

no of days = 4

$$\left(\frac{425}{Cumulative\_Rainfall\_disasterday}\right) = 0.1454(4) - 0.0264$$

Predicted cumulative rainfall on the day of disaster =765

Actual cumulative rainfall on the day of disaster =710

Threshold value is getting closer.

*cumulative rainfall 2days prior to the disaster = 514

no of days = 5

$$\left(\frac{514}{Cumulative\_Rainfall\_disasterday}\right) = 0.1454(5) - 0.0264$$

Predicted cumulative rainfall on the day of disaster =734

Actual cumulative rainfall on the day of disaster =710

Threshold value is almost the same as the actual rainfall. This means, 2 days prior to the disaster, threshold value could be predicted with more accuracy. Two other locations were also considered for the analysis, such as Rangamati and Chittagong. Table 10 gives rainfall data of Rangamati for few landslides.

Table 10: Rainfall data for several landslides occurred in Rangamati in the recent history; here "0" refers to the day of landslide

		No of days prior to landslide Rainfall (mm)								
Location	Date	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**	**+1**
Jhagar beel area of Rangamati district.	30/05/1990	0	0	0	14	3	9	14	0	11
Charaipada of Bandarban	12/7/1997	17	0	4	13	0	39	1	5	25
Bandarban	11/8/1999	4	7	8	0	5	16	80	3	84
Rangamati	11/6/2007	25	52	4	16	0	21	7	26	146
Shankha river at Bandarban,	9/5/2009	7	18	27	0	0	0	0	0	0
Harinmara of Lama in Bandarban	31/07/2009	0	3	65	192	58	34	3	596	8

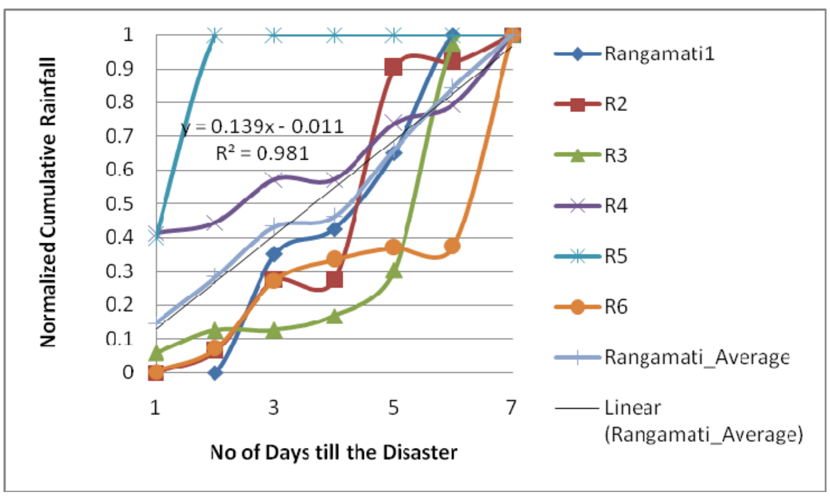


Figure 12: Normalized cumulative rainfall data for Rangamati Similar analysis was done for Chittagong too.

Table 11: Rainfall data for several landslides occurred in Chittagong in the recent history; here "0" refers to the day of landslide

		No of days prior to landslide								
Location	Date	7	6	5	4	3	2	1	0	1
Gopaipur, Chittagong	13/8/1999	29	5	9	28	86	0	123	110	206
Chittaputti area, Chittagong	15/08/1999	9	28	86	0	123	110	206	57	53
Chittagong University campus	24/06/2000	1	3	1	28	6	0	29	22	234
Noabadi, Akhaura	5/5/2003	0	17	0	0	0	8	55	0	1
Shantinagar area adjacent to the Bangladesh Cooperative Housing Society in Bayezid Bostami thana in the port city	31/10/2005	8	0	0	0	0	0	1	1	18
Satkania upazila, Chittagong	8/7/2006	0	0	40	32	1	7	63	132	45
Chittagong	11/6/2007	0	3	23	22	4	42	3	88	425
Nabinagar in Chittagong	10/9/2007	1	0	0	7	35	84	160	40	50
Matijharna in Chittagong	18/08/2008	11	106	0	8	31	2	38	104	129
Motijharna of Lalkhan Bazar in the port city	23/08/2008	2	38	104	129	11	2	2	4	2

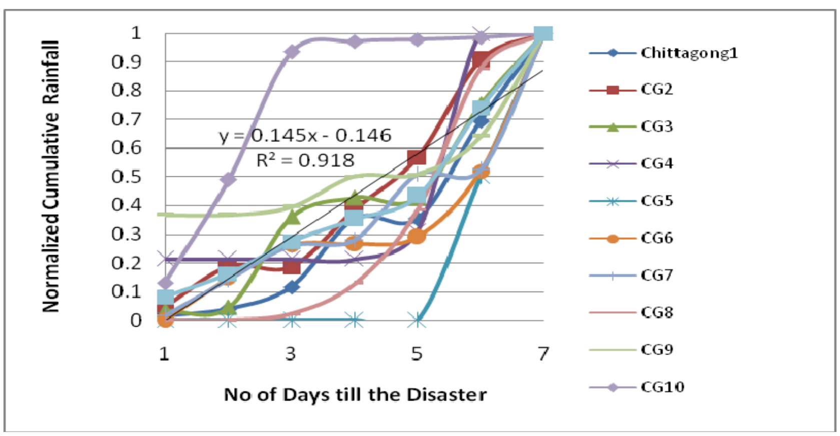


Table 12: Normalized cumulative rainfall data for Chittagong

Data of these Rangamati and Chittagong areas do not provide conclusive thresholds as Cox's Bazaar and Teknaf. However, 200mm rainfall within last 48 hrs could be considered for this area.

2.5. Concluding Remarks

Rainfall data since 1950s and landslide records were collected to formulate rainfall threshold values for this area. Following conclusions and recommendations could be made considering the rainfall and landslide data available in these two locations having referred to number of references on this topic.

Cox's Bazaar and Teknaf show that around 130mm during 24 hrs rainfall or 300mm rainfall during 48 hrs rainfall could cause a landslide in Cox's Bazaar and Teknaf. However, globally the last night rain causes landslides to occur in the early morning. Then, the day before could also be considered as 24 hrs rainfall and in that case, rainfall would be 170mm/24 hrs. This value exactly fits with Corominas and Moya (1999) values defined for Spain and Brand et al. (1988) values for Hong Kong. Further, it also has some close relationship with Bandara (2008) findings for Sri Lanka an evacuation warning. However, if hourly rainfall could be found, it would be a supporting data for a better prediction.

Further, when the two locations such as Teknaf and Cox's Bazaar taken separately, the following results could be estimated.

Data from Teknaf gives around 170mm during 24 hrs rainfall or 420mm rainfall during 48 hrs rainfall could cause a landslide. However, the day before could also be considered as 24 hrs rainfall and in that case, rainfall would be 250mm/24 hrs.

Data from Cox's Bazaar gives around 96mm during 24 hrs rainfall or 185mm rainfall during 48 hrs rainfall could cause a landslide. However, the day before could also be considered as 24 hrs rainfall and in that case, rainfall would be 90mm/24 hrs.

ADPC team has formulated the threshold values mentioned in this report using the available data which needs improvement as more data becomes available. Whenever a landslide happens in the concerned area, it is a must to collect this information and update the proposed thresholds.

ADPC team is in the process of setting up the Community Based system for early warning in two pilot communities. The precipitation threshold values recommended to be used as follows;

*Warning limit for Alert - 75 mm in Teknaf and 50mm rainfall for 24 hours for Cox's Bazaar – Increase vigilance and observe appearance of any symptoms of slope destabilization on critical slopes. If such symptoms can be observed immediately move out from the critical slope area. Otherwise use this limit for having vigilance. Note – If Cox's bazaar gets generally higher rainfall in this range, then every rainy day is an alert day. On the other hand, since Cox's Bazaar is so urbanized, this range rainfall could cause heavy damages due to landslides. If we take average daily rainfall in Cox's Bazaar since 1950, it is around 9.8363 mm per day. Maximum daily rainfall occurs in June and July and it is also around 30-40 mm per day. So having a rainfall more than 50 mm could be considered as an alert situation. *Warning limit for getting ready for evacuation to safer location from high risk locations- 100 mm in Teknaf and 75mm rainfall for 24 hours for Cox's Bazaar– Get ready for evacuation, under short notice

*Warning for Evacuation) - 150 mm in Teknaf and 90mm rainfall for 24 hours for Cox's Bazaar – Warning for evacuation to safer places.

The critical locations where these warnings should be imposed will be identified through landslide hazard mapping in Cox's Bazaar and Teknaf.

Note - Sometimes, previous night rain can also be continuing till the disaster happens. Then, we may see a very small value next day, but landslide too occurs. This has happened in Teknaf. Considering these facts, as the range is too high from 100 to 200, we can go for 150mm for additional safety.

Hourly rainfall data is very important these days as heavy intense short term rainfalls are causing no of landslides all over the world. Once hourly rainfall data will be available such data also needed to be factored in to above EW limits. In future, data interval for recording should be on hourly basis. Local Met Department should be advised to collect data using hourly precipitation. As it is not the practice of Met Department of Bangladesh to release such data, it is recommended if the focal agency could discuss and agree on releasing hourly data at least during monsoon periods for this kind of nationally important disastrous situations.

It should be noted that the main set back in defining the geology related specific thresholds is the availability of rainfall data. Because the rainfall data for Teknaf and Cox's Bazaar represents the two regions and site specific sets of data is not available. Even if we use different geology to prepare thresholds, finally we have the same rainfall data. Therefore it should be encouraged the community participation in collecting rainfall data for further improvements of these proposed thresholds.

It is strongly recommended that at least two automatic rain gauges have to be made available at respective target municipalities. ADPC has already made a request to NGI for the same under RECLAIM project but it may be better if similar request can be made by Geological Survey of Bangladesh too. It is good if the automatic rain gauges could be set up soon before the commencement of the next monsoon rains.

It is essential a Nodal Agency or responsible agency can be identified for EW for landslides. The same agency should continue data processing and updating the accuracy of threshold limits in the future.

Chapter-3

Establishment of Early Warning Devices

Executive Summery

Geographically, 38.7% of fatal landslide events, and 34.5% of landslide deaths, occurred in South Asia. In terms of occurrence of landslide fatalities by nation, Bangladesh stands the most affected country including China, Indonesia, India, Nepal and Vietnam. Apart from regular events, in 2007 in Bangladesh, heavy rainfall caused a landslide at the commercial city Chittagong in Bangladesh killing 86 people and 100 other people injured.

ADPC in collaboration with Comprehensive Disaster Management Program (CDMP) has been implementing project to address the risks of landslides in Cox's Bazar and Teknaf. This effort corroborates to bring the science, society and institutions together to deal with the landslides risks. The primary objective of this project is to to introduce community-based early warning system as a pilot basis in Bangladesh for managing landslide hazard.

Since the project inception, various activities were conducted both at the city and community level. Preliminary visits to community prone to landslides, early warning audit in six different key areas such as communication and coordination, warning reception, local hazard monitoring, local warning dissemination, preparedness and administrative compliance, city level workshops to develop consensus on most vulnerable locations and communities to landslides, rapport building with vulnerable communities, PDMC and other city officials, training and orientation program for volunteers and community based facilitators, community risk assessment and early warning and monitoring system development.

In continuation of the community based early warning system, Downscale the early warning information products at local level, Alignment of hazard monitoring and risk profiling into early warning system, Development of decision support system at the city level, Collection and processing of rain gauge data at the municipality level, Installation of Rain Gauge at the Community level and display system and simulation and mock drills would be facilitated.

3. Establishment of early warning devices

3.1. Introduction

In 2007 a total of 395 fatal landslide events were recorded, inducing a total of 3017 deaths worldwide. This is considerably lower than the average over the period 2003-2006, which is 4399 excluding losses associated with the 2005 Kashmir earthquake, or 10976 if estimated landslide deaths from this event are included. Nonetheless the total of over 3000 deaths continues to demonstrate that previous estimated of human losses from landslides have massively underestimated the true costs. Geographically, 38.7% of fatal landslide events, and 34.5% of landslide deaths, occurred in South Asia. In terms of occurrence of landslide fatalities by nation, Bangladesh stands the most affected country including China, Indonesia, India, Nepal and Vietnam. Apart from regular events, in 2007 in Bangladesh, heavy rainfall caused a landslide at the commercial city Chittagong in Bangladesh killing 86 people and 100 other people injured. The landslide phenomenon and settlement in those areas have been constantly debated in various domains including political groups, NGOs, government agencies and media as well. Due to lack of awareness to understand the nature of pre-event symptoms to take action before the event occur, has compounded the problem manifold. In most of the case, landslide occurs in the event of flash-floods or earthquakes. This makes the case of landslide as secondary hazard while focus turned to the floods and earthquakes. In a way, landslide has largely been ignored and subsided from the disaster risk reduction strategy to incorporate as a main hazard.

ADPC in collaboration with Comprehensive Disaster Management Program (CDMP) has been implementing project to address the risks of landslides in Cox's Bazar and Teknaf. This effort corroborates to bring the science, society and institutions together to deal with the landslides risks. Community in both the cities are facing landslide risks on daily basis which are somehow indicate the extensive hill cutting and lack of awareness on landslide. To address these two issues, a community based early warning system has been proposed to set up to increase awareness among community to monitor landslide events as well as reduce hill cutting activities.

3.2. Project Objectives

The primary objective of this project is to model the slopes in Cox's Bazaar and Teknaf municipal areas susceptible/potential to failure triggered by heavy rainfall and to introduce community-based early warning system as a pilot basis in Bangladesh for managing landslide hazard.

The secondary objective is to use the project experience as a model for landslide disaster risk reduction in two hazard prone cities in Bangladesh and assist stakeholder institutions to formulate a long term landslide hazard mitigation strategy for Bangladesh

3.3. Process of Community based Landslide Early Warning System

- **Preliminary visit to Cox's Bazar and Teknaf**- At the initial stage of project, a team of experts of ADPC including senior, intermediate and junior technical staff made visit to both the cities. The objective of this visit was to introduce and share the purpose of the project to the municipality and the primary stakeholder; the vulnerable community. Transect walk and direct observation methodology were used to observe the landslide locations and affected habitation and their pattern. Project related information were shared at both level; community and municipality. Since community is the primary stakeholder of this project, it was essential to understand the landslide risk perspective. Community based focal persons were also identified who will take a lead role in facilitating the CBEWS[1].

- **Early Warning Audit**- Hazard ready toolkit is primarily an audit or investigation on early warning system development to understand the strengths and weaknesses of the existing information dissemination process from national to community level. It provides an opportunity to enquire six different key areas of early warning systems such as **communication and coordination**, **warning reception**, **local hazard monitoring**, **local warning dissemination**, **preparedness** and **administrative compliance**. This helps in bridging the gaps among these key components of early warning system as well as exploring opportunities to make the early warning dissemination process simpler and effective.

As the **four key elements** of early warning focus on **risk knowledge**, **monitoring and warning service**, **dissemination and communication** and **response capability**, the hazard ready toolkit has align these perspectives as well as to touch upon the cross

[1] CBEWS- Community based Early Warning System

cutting issues such as governance and institutions arrangement, multi-hazard approach, ownership of local communities, gender perspectives and cultural diversity. The hazard ready toolkit primary highlights the set of roles played by various agencies such as communities, local governments, national governments, regional institutions and organizations, international bodies, non-governmental organizations, the private sector, the science and academic institutions. The early warning audit was conducted both at the community and municipality level. Though the municipal authorities in both the cities pay adequate attention in responding to the landslide events mostly, but landslide monitoring and preparedness is key concern for community and authorities. Due to high priorities given to cyclone, storm surge and floods, landslide always considered to a secondary hazard induced by incessant rain, cyclone and storm surge and so as monitoring and early warning at all levels from national to community.

- **City level meetings and workshops-** City level workshops were organized and project related objectives, activities and outcomes were shared. In the chairmanship of Mayor, the workshops were presided by elected councilors, PDMC[2] members, local met office and Red Crescent representative. In the workshop, the most vulnerable communities within the city were identified by the participants to implement the community based activities on landslide risk reduction. During the workshop, the consensus was development that, municipality would take lead role in the implementation of the project. It was also discussed that the elected commissioner would be a change agent in this project and mobilizes community on landslide risk reduction.

- **Identification of most vulnerable communities-** During the workshop, representatives from different agencies identified the vulnerable locations and communities to implement the project. Past events on landslide were also the major consideration for selecting community. During the initial visits to Cox's Bazar and Teknaf, all the probable vulnerable communities were identified based on Municipality recommendations. After that, all vulnerable communities sat together to identify most vulnerable communities among them. Following are the criteria that have been implied during the discussion with community, ward councilors, and pouroshava representatives;
    - Past events of landslides;
    - Loss of lives and property;

[2] PDMC- Pouroshava Disaster Management Committee

- Population density;
- Women, children, persons with disabilities and elderly.

There was common consensus on identified communities prone to landslides for both cities. Below mentioned are the identified communities in both Cox's Bazar and Teknaf:

Teknaf		**Cox's Bazar**	
Location	**Risk**[3]	Location	**Risk**[4]
Puran Pallan Para	High	Mohajer Para	High
Urumchara, Puran Pallan Para	High	S.M. Jadi Pahar	High
Fakirer Mura, Puran Pallan Para	High		

Source: Field Survey

- **Rapport building with vulnerable communities-** With the identification of the vulnerable communities, volunteers and community facilitators were identified in each selected communities. These volunteers and community facilitators would act as a change agent for landslide risk reduction.

- **Orientation and Training Program for Volunteers and Community facilitators-** With the identification of the community based facilitators and volunteers', training on early warning system was organized to orient. In this training, the focus was to discuss about the CDMP Landslide and the basics of early warning components such as risk knowledge, monitoring and warning, dissemination and communication and response capability. The training also covered the process of community based disaster risk reduction (CBDRR) and how to mobilize vulnerable community.

- **Stakeholders Analysis**- In determining the target beneficiary groups, it is crucial to conduct a stakeholder analysis and identify which group among the vulnerable is the most vulnerable. This analysis therefore focused on vulnerable groups living in the landslide locations.

[3] Risk category has been assigned based on the previous incidents as well vulnerable locations based on critical slopes.
[4] Risk category has been assigned based on the previous incidents as well vulnerable locations based on critical slopes.

Table 13: Primary Stakeholder Analysis[5]

Group	Issues	Needs	Vulnerability
	Cox' Bazar and Teknaf		
Men/youth	During the focus group discussions with men/youth, it was found that there is lack of understanding of the risk that landslide carries. Participants responded that, they are aware of the consequences of landslide but it is difficult for them to understand which particular location would high vulnerability to landslide. In the group discussion it was also found that, participants did not have understanding about CRITICAL SLOPE. Due to this lack of awareness, lot of constructions are taking place on CRITICAL SLOPE, however this can be avoided to a great extent to identify the locations which can be used to construct houses.	• Create awareness on landslide risks. • Training and orientation about the CRITICAL SLOPE and Landslide OBSERVATION. • Training on Construction of House on SLOPES.	**Medium**
Women/children	During the focus group discussion with women, it was found that the understanding on landslide risk among women is more or less same with men/youth. Some of the participants did recognize that most of the time women stay at home as men go out for livelihood. In this case women become more vulnerable than men. This also depends on the time of landslide event (day/night)	• Create awareness on landslide risks. • Training and orientation on Landslide OBSERVATION • Provide lead role in Landslide Early Warning System	**High**
Persons with different abilities	In specific group discussions with persons with different abilities, it was found that, in the community, they are the most vulnerable group. The reasons that participants brought up during the discussions were; very limited participation in any of the community or public meetings, limited interactions with the ongoing community based activities. As most of the time, persons with different abilities stay at home close by places due to the household restrictions.	• Same as above	**High**
Elderly	During the group discussion with elderly it was found that, in terms of understanding the nature and symptoms of landslides, group of elderly people have vast knowledge. Water oozing, cracks, hill cutting were some of the symptoms that participants discussed. But due to lack of participation in community based activities, elderly people do not take interest to facilitate the Landslide Risk Reduction process and due to cultural barrier, elderly people are less mobile than men/youth or women.	• Same as above	**High**

[5] There are two kinds of stakeholders; Primary and Secondary. The above matrix gives information on Primary Stakeholders because of the direct impact of the disasters.

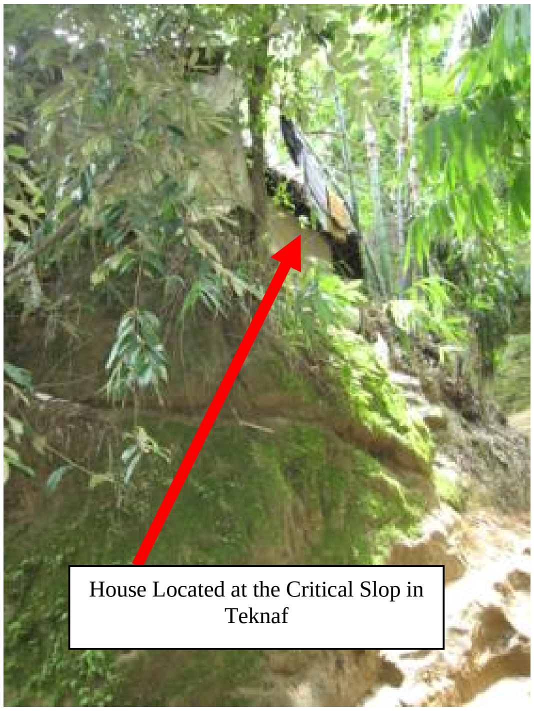
Table 14: Secondary Stakeholder Analysis

Group	Issues	Needs
Bangladesh Meteorological (BMD) Department	• The BMD provides rain fall forecast and warnings. The existing problem is with the limited understanding to interpret the rainfall data and predict landslide event or warning.	• BMD can downscale the rainfall related information at the city level and local met office can assist municipality to develop LOG BOOK to OBSERVE or MONITOR the THRESHOLD VALUES for LANDSLIDES
City level Met Office	• The linkage between city level met office and PDMC is weak in terms of utilizing information generated by the BMD from national to local office.	• The local met office can play a key role in mechanizing the information from BMD at national level to the city level linked with PDMC.
PDMC	• PDMC members are mostly elected members representing the different wards and normally they do not get involved in this early warning activity at all.	• PDMC is an asset for the city which has linked to the community, given the opportunity to mobilize community on EWS, PDMC would be able to do so.
NGOs	• NGOs have intensive outreach in Cox's Bazar and Teknaf but have little interventions on CBEWS.	• With the assistance of NGOs, the outreach can be maximized in different community settings.

- **Community Risk Assessment (CRA) -** After conducting the training, the next step was to facilitate community risk assessment. Under this activity, risk mapping, early warning action planning and implementation were facilitated through the identified volunteers and community based facilitator. Risk and resource maps were developed for each of the community and ward level. The purpose of the risk and resource map are as follows:

  - Community will be able to understand about critical slope in landslide locations.
  - Community will be able to identify vulnerable houses and people over the space.
  - Community will be able to identify the symptoms of landslides.
  - The risk and resource map has also identified the evacuation route within the community in the event of landslides.

- **Review and validation of Community Risk Assessment (CRA) process –** after accomplishment of CRA process, a review and validation activities were conducted in both the cities at the community level. In the review and validation process, each identified community reviewed the risk and resource maps and identified the gaps. Following were the information updated during the validation process at the community level where volunteers, ward councilors, teachers, and representatives from vulnerable houses
  - Some of the risk and resource maps did not have the community level demographic information.
  - During the mapping process, risks were categorized into three; high, medium and low risks. During the discussion with community it was found that, some of the houses were exactly located on the critical slopes and some at the foothill. Based on the discussion with community, houses located at the critical slopes have been identified as VERY HIGH RISK and houses at foothill as HIGH RISK.
  - Some of the risks and resource maps did not have legend mentioned.
  - Houses of important resource persons such as volunteers ward councilors and teachers were not located on the map.
  - Development of evacuation map



House Located at the Critical Slop in Teknaf

House Located at the Foothill in Teknaf

Risk and Resource Map Validation in Cox's Bazar

Risk and Resource Map Validation in Teknaf

- **Development of Communication Strategy-** After the completion of risk and resource map validation, a communication strategy is being developed at the community level. The communication strategy deals with the communication and dissemination procedure before and during the landslide event. Following are the standard steps that have been adopted to develop the communication strategy:

- **Demarcation of Clusters within the identified community**- The identified community has been grouped as cluster to design the communication and dissemination strategy at the community level. How the information would be disseminated to each of the vulnerable location.
- **Identification of Cluster level volunteers within community**- the demarcation of clusters within community then identified the cluster volunteers. Each cluster volunteer would have list of key resource persons to mobilize households in that particular cluster as well as to other cluster volunteers to provide landslide early warning information.
- **Communication Process**- The communication process was also discussed with each community on HOW each cluster will communicate internally and externally with regards to landslide early warning system.
- **Internal, within cluster and external communication process**- Each cluster has discussed and defined the communication process. Cluster volunteers will have internal communication with regards to early warning information collection and dissemination. On the other hand, cluster volunteers would also communicate with other cluster counterpart as a part of community mobilization before and during the landslide event. At the same time, these cluster volunteers would also communicate with external agencies such as Pouroshava, Red Crescent, NGOs and other response agencies.

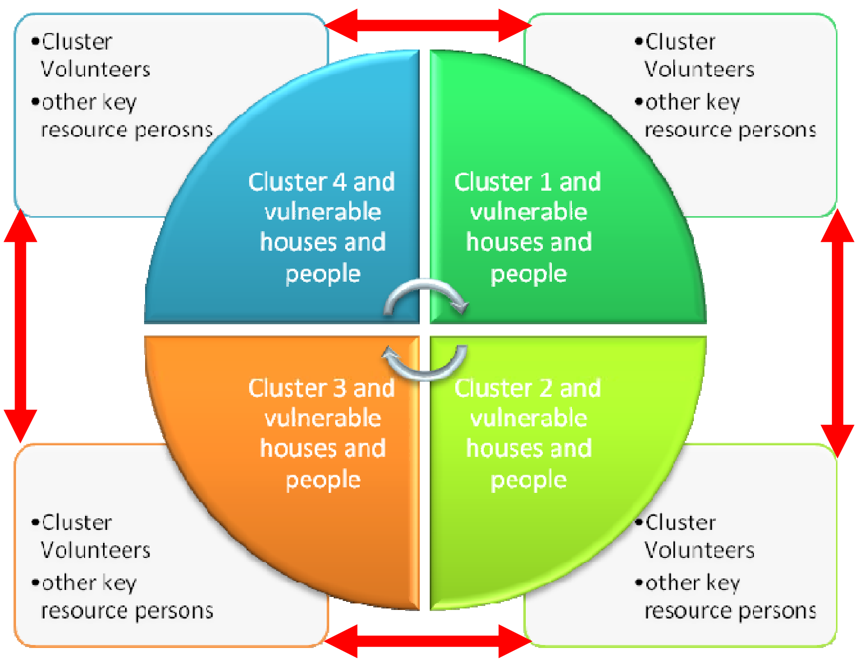


Figure 13: Communication Strategy on Landslide Risk Information Dissemination

In Cox's Bazar, each community has four clusters and in Teknaf, there are 3 clusters. The demarcation of clusters is based on as follows:

- **In Cox's Bazar**- The criteria of four clusters within the community is based on the geographic location and area. The geographical area in selected community is big and it is difficult for volunteers to manage. It was decided by the volunteers that, there should be four clusters in S.M. Jati Pahar and Mohajeer Para so that communicate the early warning effectively and community can be mobilized easily.

- **In Teknaf**-The criteria here is based on location of volunteers. There are three clusters in selected community where cluster volunteers are located in three different locations.

- **Development of Standard Operating Procedure (SOP) at community level-** The standard operating procedure was also developed during validation of CRA process. Key mobilizers within each cluster and stakeholders for SOP were also developed. The purpose of SOP is to have a SIMPLE GUIDELINE at the community level so that specific roles and responsibilities can be performed. The develop SOP is at the consultation stage and would be finalized during the simulation. It is also better to give this guideline a local name rather than SOP which is more technical. What should be the name of this guideline will also be discussed with community. Following is the format that have been developed for SOP and written by community themselves:

Change Agents of Early Warning System	Responsibilities	
	Before	**During**
Cluster Volunteers	• Facilitate the risk and resource map development and installation of Early Warning Display Board • Monitoring Very High Vulnerable Houses and regular contact and Put Color code to the most vulnerable houses • Maintenance of Early Warning Equipment. • Collect data from Rain Gauge and interpret • Disseminate early warning information to Vulnerable Houses in Clusters • Facilitate Simulation/Drill on regular basis	• Communicate with Ward Councilors and response agencies • Facilitate Evacuation for other possible landslide areas • Inform other cluster volunteers to be vigilant
Ward Councilors	• Mobilize community to develop and update Risk and Resource Map • Disseminate early warning information to various key persons in the community, school teacher, religious leader and Pouroshava authorities. • Facilitate Simulation/Drill on regular basis	• Coordinate with Response agencies. • Facilitate evacuation process for other possible landslide areas. • Keep in touch with other cluster volunteers and external agencies
Religious Leaders	• Mobilize community to develop and update risk and resource map • Regular public announcement about Landslide protection and vigilance • Facilitate Simulation/Drill on regular basis	• Coordinate with Response agencies. • Facilitate evacuation process for other possible landslide areas.

		• Keep in touch with other cluster volunteers and external agencies
Teachers	• Discuss on Hill Cutting and its consequences with children • Participate in the development of risk and resource map along with children • Orient children to discuss about landslide with their parents and siblings • Participate in Simulation/Drill on regular basis with children	• Coordinate with Response agencies. • Facilitate evacuation process for other possible landslide areas. • Keep in touch with other cluster volunteers and external agencies
Red Crescent	• Discuss on Hill Cutting and its consequences with houses located in very high risk areas • Facilitate the risk and resource map development and installation of Early Warning Display Board. • Facilitate Public Awareness on regular basis • Facilitate Simulation/Drill on regular basis	• Communicate with Ward Councilors and response agencies. • Facilitate Evacuation for other possible landslide areas • Inform other cluster volunteers to be vigilant
Social Worker	• Discuss on Hill Cutting and its consequences with houses located in very high risk areas • Facilitate Public Awareness on regular basis • Facilitate Simulation/Drill on regular basis	• Facilitate Evacuation for other possible landslide areas
Youth Club	• Discuss on Hill cutting and its consequences with houses located in very high risk areas. • Facilitate the risk and resource map development. • Facilitate Public Awareness on regular basis • Facilitate Simulation/Drill on regular basis	• Facilitate Evacuation for other possible landslide areas
School Children	• Discuss with Peer Group, parents and siblings about landslides • Participate in the development of risk and resource maps • Participate in Public Awareness Campaign on Landslides • Participate in Simulation/Drill	
Women	• Discuss on Hill cutting and its consequences with houses located in very high risk areas. • Facilitate the risk and resource map development. • Facilitate Public Awareness on regular basis • Facilitate Simulation/Drill on regular basis	• Facilitate Evacuation for other possible landslide areas
Persons with Disabilities	• Discuss with household members about landslides • Participate in the development of risk and resource maps • Participate in Public Awareness Campaign on Landslides • Participate in Simulation/Drill	• Facilitate Evacuation for other possible landslide areas

Source-Community Consultation

- **Early warning and monitoring system development-** after conducting the community risk assessment, early warning and monitoring system has been developed. Numerous areas of possible interventions were identified through this activity. Encouragingly, most of the identified possible interventions have already been incorporated into the Project design. In this section, the important thing now is to analyze *how* to best implement these interventions. Analysis on local institutions mechanism and community-level social dynamics are very important in this regard, as they help identify existing mechanisms/institutions the Project can take advantage of to ensure smooth implementation and sustainability of the project impacts. Following mechanism has been discussed with municipality and community to act upon to establish early warning and monitoring system development:

  - ***Downscale the early warning information products at local level-*** At the national level in Bangladesh BMD have been engaged intensively to develop variety of information products on rainfall data and forecasts. These products required to be analyzed in the local context so that the essence of the generated information remains the same but the interpretation changes from ***Macro-Meso-Micro levels***. In other words, the developed early warning information at the national level requires guidance to be translated at the city and community level for different users.

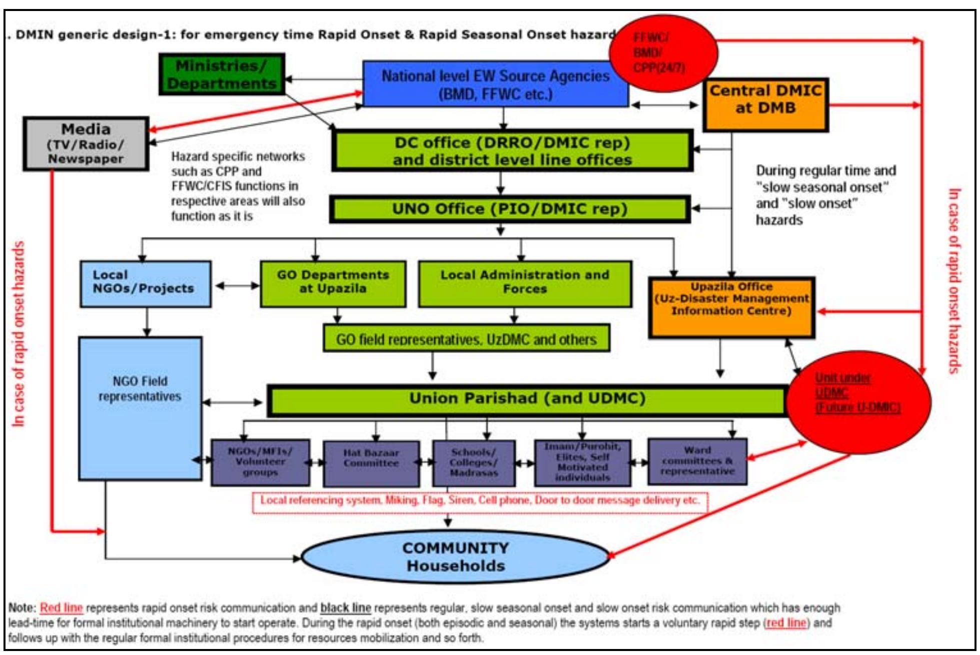


Figure 14: *DMIN generic design*

  - ***Alignment of hazard monitoring and risk profiling into early warning system-*** The most important aspect in early warning system is to monitor the hazard and understand how and where it will have the severe impact within the location. In the current scenario, hazard monitoring is being done by the government agencies at various levels such as meteorological department and local met office etc. To complement the existing efforts, the risk profiling can be brought into the picture to develop the scenarios in case of hazard turns into disaster. This will also help monitoring institutions, government agencies, designated response agencies,

- volunteers, non-government organizations to make their response smart and effective in times emergency.

- ***Development of decision support system at the city level-***At present the city has very limited capacity to develop decision support system. Most of the time, decision support system utilization or analysis takes place at the national level which invariably takes time to reach to micro level. To minimize the information transmission cost as well as increase the reaction time, there is a need to develop the capacity of the city level officials to engage in developing decision support system. If city is prone to landslide hazard with high vulnerabilities, in this case the DSS would assist city to prepare and respond to landslides. Most of the work at the city level with regards to disaster risk reduction takes place without the use of risk maps and resource inventory, risk profile, vulnerability maps and inundation maps and these information are the requirements of city level disaster management authorities. The diagram shows the disaster management information network (DMIN) which has covered both slow and rapid onset hazard. Using the existing resources and system, the DSS can easily be developed at the city level.

- ***Collection and processing of rain gauge data at the municipality level-*** The information collected at the community level would be send to municipality. Municipality would also have a display system to record the rainfall data on day to day basis. Municipality would closely work with local meteorological department to observe and interpret the rain gauge data and will act accordingly.

- ***Installation of Rain Gauge at the Community level and display system-*** Since the scientific study has been done to develop the threshold values using rainfall data and soil quality, rain gauges have been installed in various strategic locations in the community vulnerable to landslides. Volunteers and community based facilitators have been trained to collect the rain fall data through the rain gauge. These rain gauges have three different color codes as shown below:

Color code	**Level**	**Threshold Values**	**Actions**
	Evacuate		
	Ready		
	Alert		

The information collected by volunteers and facilitators at each of the rain gauge would be displayed at the community level using a display board. The display board would be located in a strategic place within the community.

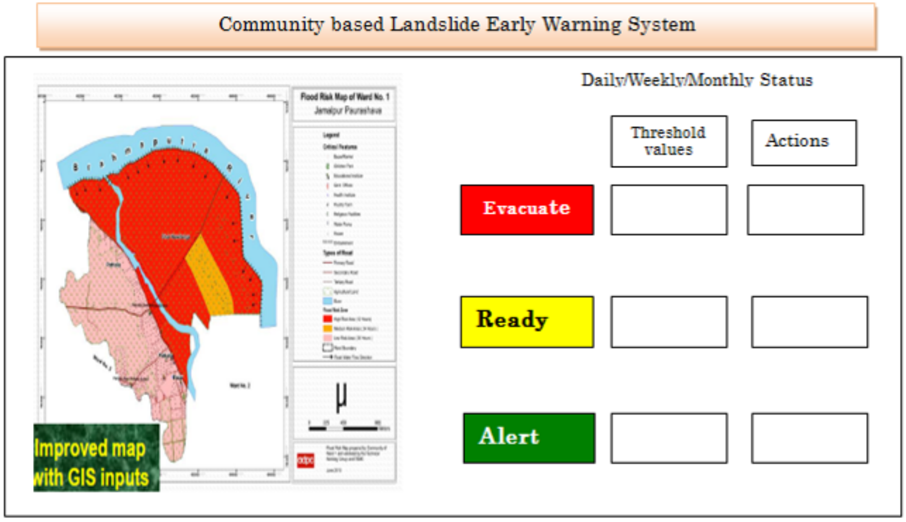


Figure 15: Community based early warning system

Based on community consultation, regarding the display board where community by themselves has decided the best possible structure for the information to be displayed. The location to install the display board has also been finalized. The developed risk and resource map would be computerized and printed and installed with early warning system as shown above.

3.4. Next Step

Bangladesh has developed the information products related to early warning at the national level. These information products require to be translated to the city as well as at the community level by understanding what information products are required by the community and in what language or communication medium. The effort here is to bring science, institutions and society together to minimize or reduce the impact of disaster. The current intervention is to strengthen the **DMIN** would be an additional advantage for developing a community based early warning system (CBEWS). Below mentioned activity detail are the next step to realize the community based early warning system on Landslides in Cox's Bazar and Tekanf:

1. Installation of Rain gauges at the community level.
2. Training of Cluster Volunteers on Community Based Early Warning System
3. Installation of Risk Information DISPLAY BOARD including risk and resource maps, evacuation map and early warning on Landslides.
4. Development of Decision Support System (DSS) at the City level.
5. Simulation and Mock Drills

Plate 6 : Field Activities related to CBEWS

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Annexure-A

Description on the landslide events collected from newspaper & other sources

Annex-B

List of the inventory on landslide events in Teknaf and Cox's Bazar