Field Report

FOR MOUNTAINS AND PEOPLE

Landslides Induced by June 2017 Rainfall in Chittagong Hill Tracts, Bangladesh

Causes and Prevention

Samjwal Ratna Bajracharya

Sudan Bikash Maharjan

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The International Centre for Integrated Mountain Development (ICIMOD) is a regional development and learning centre serving the eight regional member countries of the Hindu Kush Himalayas (HKH) – Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan – based in Kathmandu, Nepal. Globalization and climate change have an increasing influence on the stability of fragile mountain ecosystems and the livelihoods of mountain people. ICIMOD aims to assist mountain people to understand these changes, adapt to them, and make the most of new opportunities, while addressing upstream and downstream issues. ICIMOD supports regional transboundary programmes through partnerships with regional partner institutions, facilitates the exchange of experiences, and serves as a regional knowledge hub. We strengthen networking among regional and global centres of excellence. Overall, we are working to develop economically and environmentally-sound mountain ecosystems to improve the living standards of mountain populations and to sustain vital ecosystem services for the billions of people living downstream – now and in the future.

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Background

The heavy rainfall of June 2017 triggered hundreds of landslides in Rangamati, Bandarban, and Khagrachari hill districts of Chittagong Hill Tracts (CHT). Landslides damaged the road sections at many places and buried some houses in the landslide debris affecting the transportation and livelihood. Immediate protection work should be carried out to stabilize the landslides before it get worse. Mr Naba Bikram Kishore Tripura, Secretary of Ministry of Chittagong Hill Tracts Affairs (MoCHTA), requested ICIMOD to investigate the landslides in the CHT to identify the cause of failure and possible prevention measures. The landslides were studied by the team of Samjwal Ratna Bajracharya and Sudan Bikash Maharjan from ICIMOD and supported by Mr Nanda Dulal Banik, Joint Secretary, MoCHTA, and Mr Arunendu Tripura, Public Relations Officer, Rangamati Hill District Council, Rangamati from 7 to 10 August 2017 in the field. During the four days of field work, the team visited more than 50 landslides and studied 31 landslides in detail.

The findings were presented in the conference "Landslides in Chittagong Hill Tracts: Causes and Prevention" by Samjwal Ratna Bajracharya as a keynote presenter in Dhaka. The conference was organized by the MoCHTA on 22 August at International Conference Centre (CIRDAP), Dhaka. The session was chaired by Mr Naba Bikram Kishore Tripura, Secretary, MoCHTA, with the chief guest Prof Dr Gowher Rizvi, Adviser to the Hon. Prime Minister, Government of Bangladesh, and special guests Ms Firoja Begum Chino (MP), Mr Ushatan Talukder (MP), and Mr Bir Bahadur Ushwe Sing (MP), Hon. State Minister, MoCHTA. Around 80 representatives of high level government organizations participated in the conference.

Introduction

Three days of unprecedented and uninterrupted rainfall on 11, 12, and 13 June 2017 triggered hundreds of landslides that damaged roads and settlements in the Rangamati, Bandarban, and Khagrachari hill districts of CHT, Bangladesh. Most of the landslides occurred at the gully head of the catchment and on steeper slope (over-hanged) landforms. Landslides on the mountain slopes are common but hundreds of landslides damaging the roads and settlements with many casualties made the event a disaster. The disaster claimed 170 lives in the districts of Bandarban, Khagrachari, Chittagong, and Cox's Bazar, including 121 lives in Rangamati hill district alone, while leaving 227 injured. In addition, the landslides that caused heavy property loss and damage include thousands of acres of orchards, agricultural lands, crops, and homesteads. Indicators show that Rangamati town area suffered the worst losses. As per information collected by the local administration, around 15,000 families including 12,450 families in Rangamati District alone have suffered losses in Rangamati sadar, Kaukhali, Kaptai, Jurachari, Bilaichari, Rajsthali, and Naniarchar upazilas. Landslides and damages are listed below (source: CHT):

- Hill slides in 145 places
- Damages at 50 sites along 20 km part of the Rangamati-Chittagong Road
- Landslides at least at 16 points in the hills either side of the Moghaichari to Manikchari Road
- Twenty-five spots where the slides caused 50 percent damage that has made the road totally unusable
- Bottleneck road formed at many points in the Rangamati and Khagrachari Road

During the field work in Rangamati from 7 to 10 August 2017, 31 selected landslides were studied in detail. Causes and mechanisms of failure were identified and protection measures to stabilize the landslides were suggested.

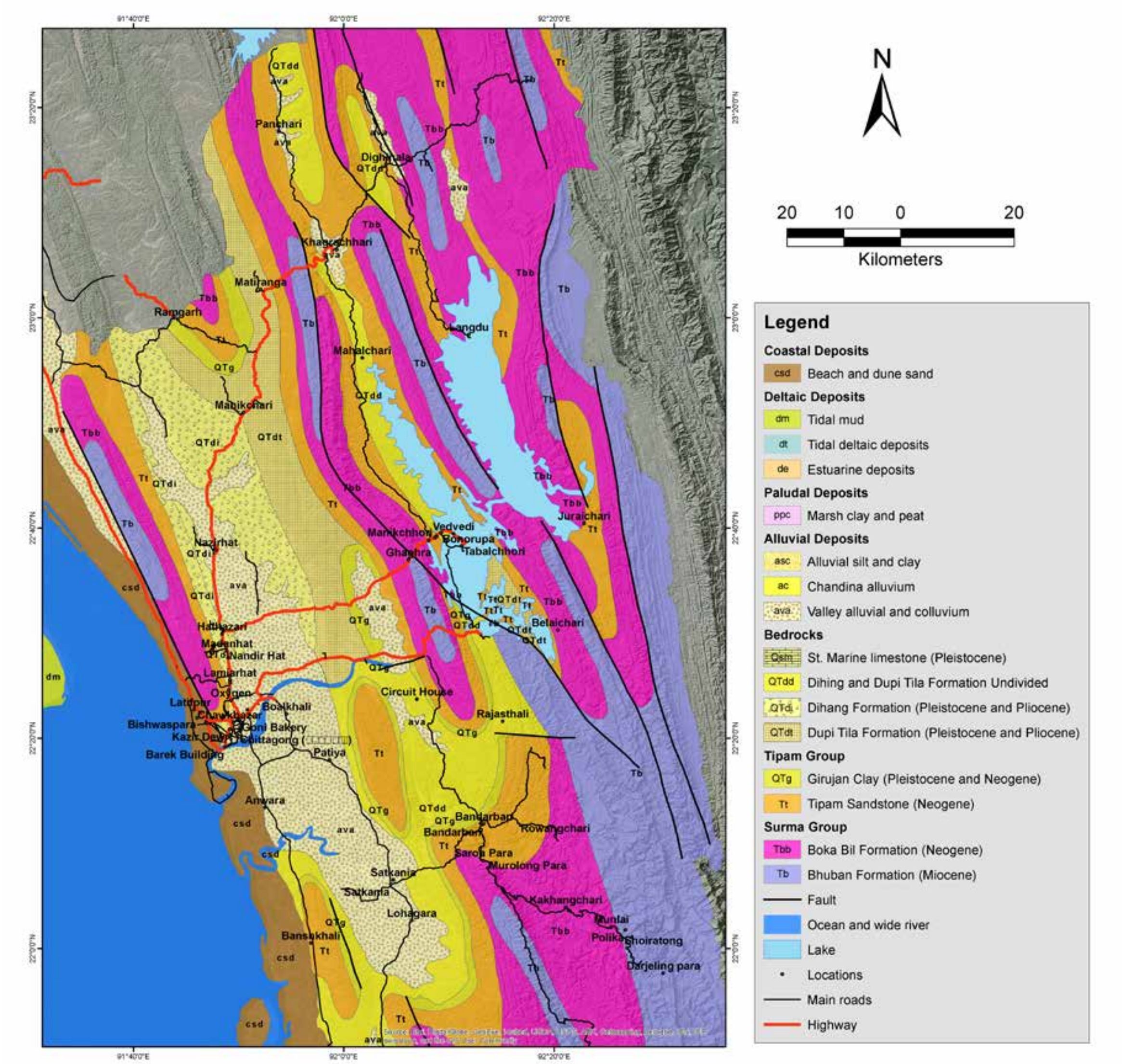
Assessments

To identify the cause and mechanism of failure, some basic information was collected and analysed prior to the field work. Based on the available information and field assessment, the types of failure and protection measures are recommended.

Geology

The investigated area is a doubly plunging asymmetrical anticline trending towards NW-SE. The eastern flank is gently dipped and the western flank is slightly steeper than the eastern flank. The region is generated due to the collision of the Indian Plate and Burmese Plate, hence the geology of this region is controlled by the presence of folds and faults with the deposition of Tertiary sediments. Based on the lithology and sedimentary sequences geological formation names are derived from type locality in Assam. Mostly the area is covered by four formations (Figure 1): Bhuban, Boka Bil, Tipam, and Dupi Tila from older to younger and Miocene to Plio-Pleistocene (Gani & Alam, 2003; Alam et al. 1990).

Figure 1: **Geological map of Rangamati area**



The major rock types in this region are only sedimentary, such as shale, silty shale, sandy shale, sandstone, and mudstone. A thick cover of soil is overlaid due to softness and less compactness of the rocks. The area is covered by mostly grey and yellowish-brown soft shale, which are characterized by

- Yellowish-brown less compact fine-grained sandstone
- Intercalation of shale and sandstone
- Yellowish clayey silt – highly porous (infiltration rate – 20 to 30 mm per hr.)
- Silty clay – moderately porous

The landscapes of the Rangamati region are of gentle slope with exception of steep slopes due to poorly consolidated sandstone and clayey silt. Besides this, the area is covered by thick (>3m) sediments osf yellowish clayey silt and silty clay that form a gently sloping landscape. Excessive rain resulted in massive surface erosion and the infiltration of rainwater to create high pore-water pressure that triggered the slides. This phenomenon is exacerbated by additional runoff along the road that drained to the gullies.

Rainfall in Rangamati

Rainfall measurements at Weather Station, Rangamati

The rainfall data collected from IWRM Rangamati Weather Station shows continuous and heavy rainfall occurred during 12, 13, and 14 June 2017. The rainfall measured at the Rangamati Station in three days was:

- 343 mm on 12 June 2017
- 374 mm on 13 June 2017
- 228 mm on 14 June 2017

Total rainfall in three days was 945 mm.

Estimation of rainfall from Global Precipitation Measurement (GPM) mission

Integrated Multi-satellitE Retrievals for GPM (IMERG) is a multi-satellite, global precipitation estimate that is associated with the Global Precipitation Measurement (GPM) mission, an international collaboration between NASA and the Japan Aerospace Exploration Agency (JAXA). The GPM core satellite launched on 27 February 2014 (Huffman et al. 2014). Within a few hours of the satellite observations being collected, the Precipitation Processing System (PPS) creates "real time" IMERG, which is supplemented by the higher-quality "research" IMERG that PPS creates several months after the observations are collected (Kelly 2017). The 30 minutes accumulation near-real time Early IMERG data of June 2017 were downloaded through ftp://jsimpson.pps.eosdis.nasa.gov/data/imerg/gis/early/ by developing automated Python script. The spatial resolution of the data is 0.1° and the Rangamati District covers 40 pixels of the data (Figure 2). The statistics of the 30 minutes accumulated precipitation of Rangamati District was calculated. Maximum, minimum, and average precipitation of Rangamati District is shown in Figure 3. The data shows that there was continuous peak precipitation for three days and the sum total of maximum 30 minute accumulated precipitation was 1,005 mm for the district.

Any area which receives "too little or too much water" is faced with disaster.. The Rangamati area received too much water within the short period of time which triggered many landslides.

Figure 2: **DHI Precipitation Data Viewer, Rangamati area, 12 June 2017, 6 am**
(Source: http://waterdata.dhigroup.com/precipitation).

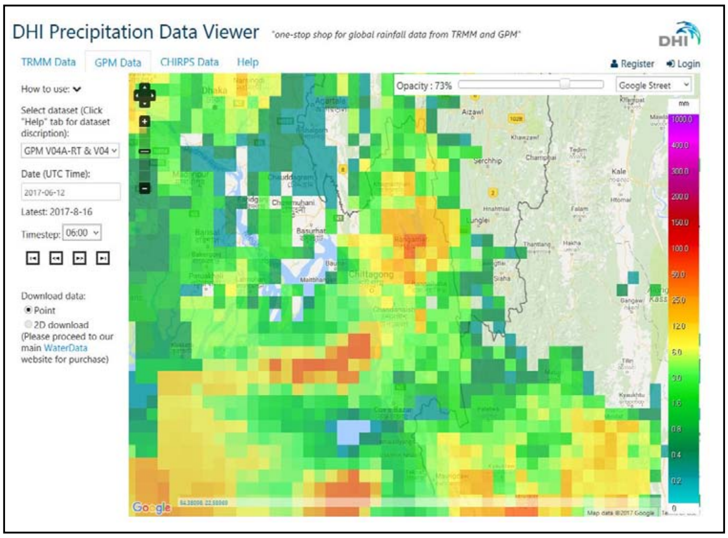
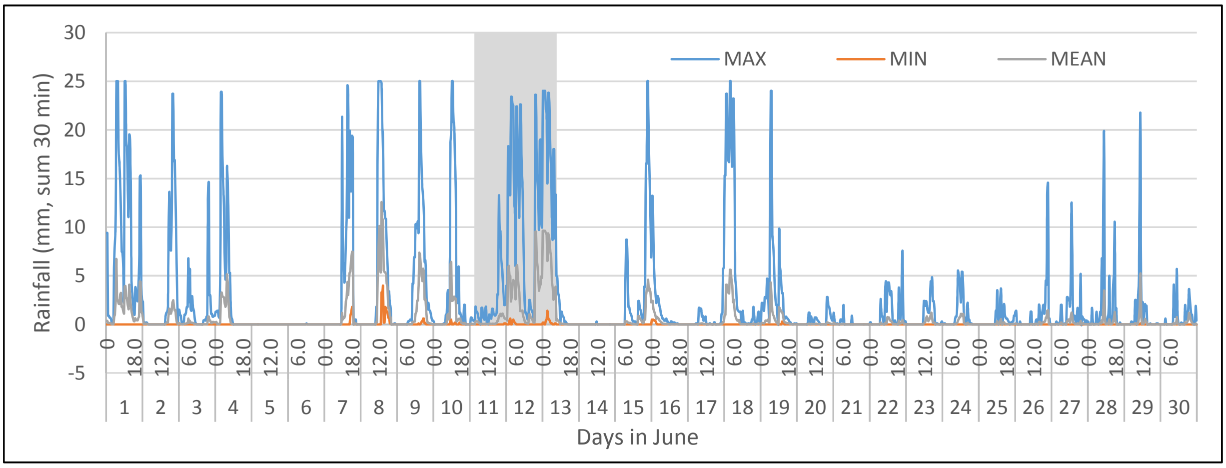


Figure 3: **Maximum, minimum, and average of 30 minutes accumulated precipitation of June 2017 based on Early IMERG data from GPM at Rangamati** (shaded bar shows the three day continuous precipitation of 11–13 June 2017)

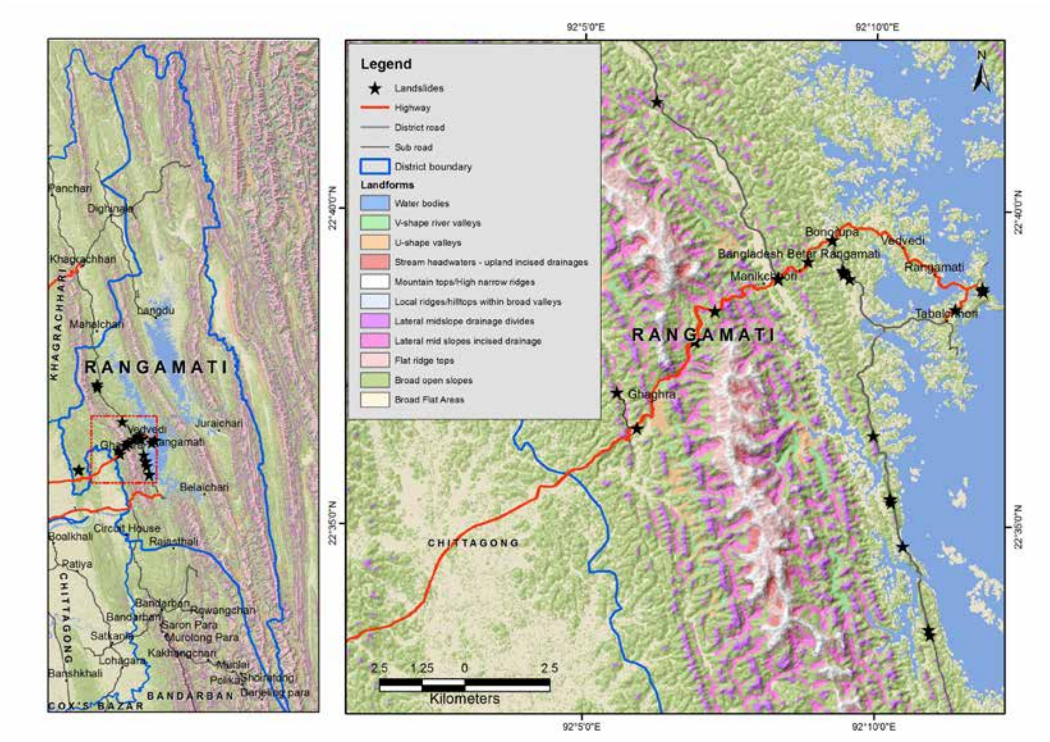


Landforms and location of investigated landslides

Topographic attributes are the most important factor in controlling the initiation and distribution of landslides triggered by rainfall. Landform classification is reducing terrain complexity into a limited number of easily discernible functional units (Burrough et al. 2000; Seif 2014). It includes interface features of land and subaqueous terrain features such as U-shaped valleys, headwaters, mountain ridges, drainages, open spaces, incised river valleys, and so forth. Some of these units are most prone to landslides. The Topographic Position Index (TPI) is the basis of the landform classification system and is simply the difference between a cell elevation value and the average elevation of the neighbourhood around that cell. Positive values mean the cell is higher than its surroundings while negative values mean it is lower (Jenness 2010). Combining TPI values at small and large scales allows a variety of nested landforms to be distinguished. TPI values can easily be classified into slope position classes based on how extreme they are and by the slope at each point.

The new Shuttle Radar Topography Mission (SRTM) digital elevation model (DEM) of 30 m (or 1 arc-seconds) resolution, released on September 2014 covering the full resolution of the world's landforms (NASA JPL 2014), was used to generate the TPI and landform classification. The DEM was void filled and resampled into 5 m resolution. The small- and large-scale TPI were generated based on void filled and resampled DEM using annulus neighbourhood mean calculation at 2000 m and 300 m radius. Then both large- and small-scale TPI grids were standardized to mean = 0 and stdev = 1 and a combination of these standardized TPI grids with slope grid generated from the same DEM were used to classify 10 different landforms in the area (Figure 4).

Figure 4: **Landforms and distribution of studied landslides**



Types of failure and damages

Road networks and settlements in this region are located along the mountain ridges and slopes. The area is composed of soft rocks with sediments 3 to 5 m thick. While the sediments are wet and saturated, surface water can easily erode and transport the sediments. Continued rain saturated the sediment and surface flow eroded the gully heavily. Ultimately, the over-hanged sediments were sliding down in the form of debris slide and debris flow depending on the water content. Most of the failures are found at the headwaters and at the road side slope. Landslides are also observed along the road side due to lack of proper road side drainage, leakage in existing drainage, and under-capacity drainage. Other failures are due to blockage of drainage, toe cutting of slopes, and oversaturated sediments. More than 30 selected landslides were studied and classified based on the field observation as follows

- Hill slope failure
- Catchment head or headwater failure
- Saddle (ridge) side failure
- Roadside slope failure
  A. No drainage
  B. Weird road side drainage
  C. Water supply leakage
  D. Under-capacity drainage
- Drainage blockage outburst
- Toe cutting
- Reactivated landslide and subsidence

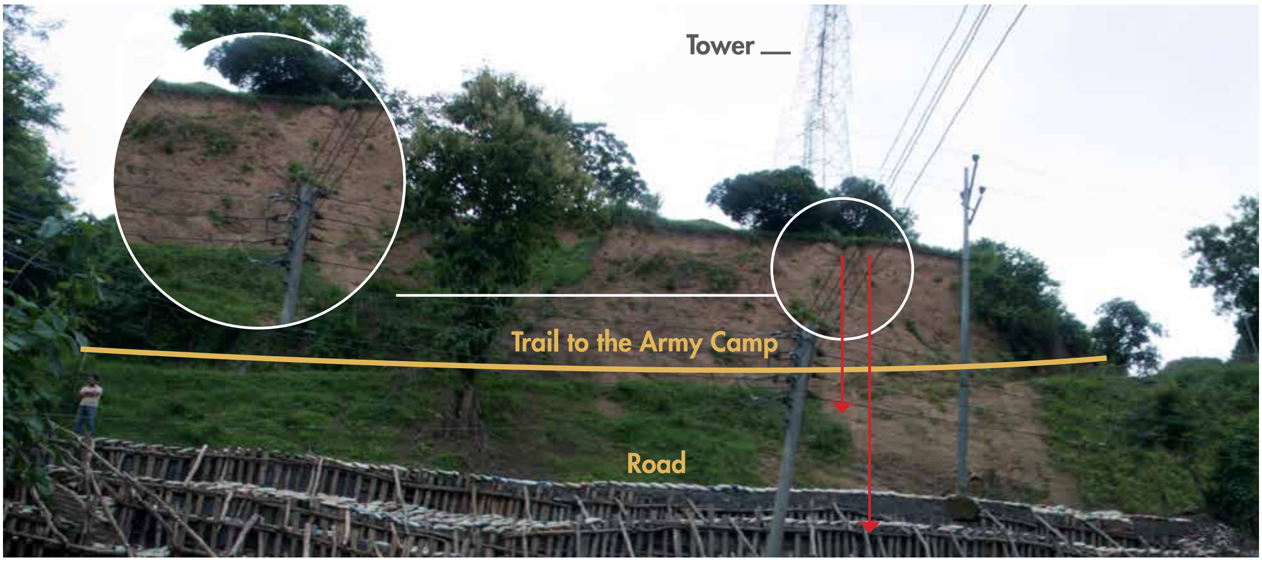
Cause of Failure and Prevention

Three days of continuous rain saturated the sediments on the surface and subsurface. Sediments on the slope were overloaded with additional pore water pressure. The overflowed surface runoff eroded the saturated sediment with deep gullies, which triggered the slide as well as debris flow depending on the saturation and availability of water. Almost all the slides are on sediments and classified into different types of failure. Cause of failure and prevention are given for the studied landslides.

1	Hill Slope Failure
A	**Hill slope failure at Manikchari — Figure 5 and Figure 6** Location: 22° 38′ 56″ N, 92° 8′ 19″ E (30 m toward Rangamati from the Khagrachari-Rangamati Road junction) Debris slide at the southern slope near to the telecommunication tower. Trail to the army camp and main road blocked by the debris. Almost 45 m of the road section washed out and disconnected Rangamati city from Chittagoan for 15 days.
	Geology: The area is covered by 3 to 5 m thick yellowish-brown silty clay over the yellowish-brown less compacted fine-grained sandstone on top and underlain by intercalation of the shale and sandstone layers. The bottom layers are mostly shale towards the junction of the road to Chhitagoan and Khagrachari. Less than half a meter thick fine sandstone bed consisting of mud balls is also observed in between. The rock is exposed only at the base of the slope at road cut section. The attitude of shale bed is N16W/28E.
	Cause of failure
	Due to saturation and surface erosion of sediment on the slope, the sediments near the tower slid down and deposited on the trail to the army camp and further on the main road (Figure 6). The debris deposit on the road blocked the rainwater surface flow, which was flowing along the road. The flow was diverted at the side slope of the road due to the blockage. The debris-loaded surface runoff eroded and washed out the side slope of the road and damaged the houses on the down slope.

Figure 5: **Plan view of hill slope failure at Manikchari Army Camp area**

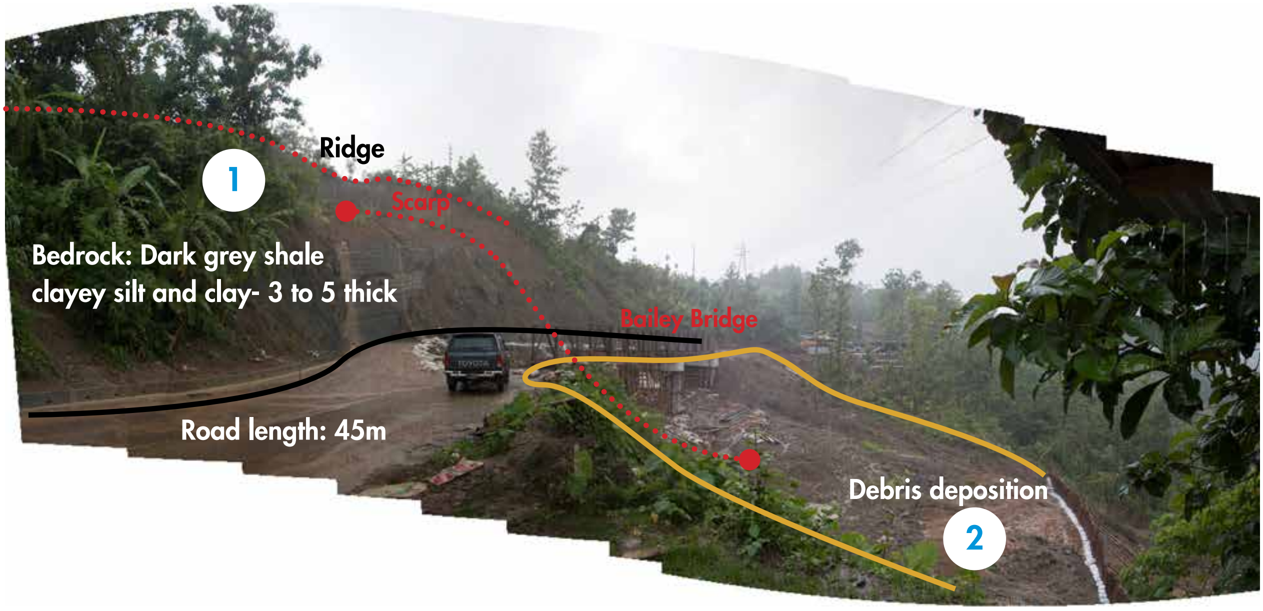
Figure 6: **Hill slope failure at Manikchari Army Camp**



	Prevention
	• Tower is safe but needs minor protection work to protect erosion on both side slopes of tower. • Road needs to be supported by concrete structure for heavy vehicles.
B	**Sapchari-Salbagan bailey bridge site** Location: 22° 38′ 24″ N, 92° 7′ 15″ E at Sapchari-Salbagan bailey bridge site (Chhitagoan-Rangamati Road) Deep erosion, debris slide, and debris flow resulting in almost 30 m wide and 6 m deep scarp at the crown. The exposed shale rock was shattered. The sediment has been transported through the road and finally road section washed out forming a deep gully. A Bailey bridge is under construction over the deep gully.
	Geology: The area is composed of dark grey, shattered shale covered by thick yellowish-brown silty clay.
	Cause of failure
	Concave type of landform from the ridge to the down gully indicates that the area is the gully head of a watershed. The area is easily eroded and transported as the sediments were saturated due to the continuous rain. The over-hanged sediments are also slipped down.

Figure 7**: Hill slope failure at Sapchari-Salbagan Bailey bridge site**

Figure 8: **Hill slope failure and debris deposition at Sapchari-Salbagan Bailey bridge site**



	Prevention
	Debris deposited at the bench near to the slide scarp (location 1 of Figure 7 and Figure 8) need to clear or protect from further transportation. Debris deposited at the lower part of the slide should be stabilized by planting trees, shrubs, and grasses (location 2 of Figure 8).

2	Catchment Head or Headwater Failure
	Location: 22° 36′ 32″ N, 92° 5′ 55″ E at Ghagra Bazar (50 m south of Rangamati-Kaptai Road junction) Gully head or catchment head failure. Some houses buried and damaged by the debris at the base of the slope.
	Geology: The area is underlain by the intercalation of shale and brownish sandstone with sediments of about 3 to 5 m thick on the surface. The length of the gully slope is about 20 to 25 m. At the head is some flat land with some houses (Figure 9). The accumulated surface water drained through that gully.

Figure 9: **Catchment gully head failure at Ghagra Bazar (50 m south of road junction of Rangamati-Kaptai Road)**

Cause of failure

The area is a concave type of landform with open and unpaved drainage at the slope. The surface water accumulated at the house area flowing down to the slope. Additional rainwater surface runoff eroded and transported the sediments down gully in the form of debris slide and flow.

Prevention

- Drain surface water properly from confined channel
- Need to construct paved gully
- Protection work at gully head
- Erosion control from vegetation measure
- Tree plantation at the bottom of the slope to protect the slide

3 Saddle (Ridge) Side Failure

Location: 22° 39′ 4″ N, 92° 9′ 26″ E at Monoghar-Rangapani Road (Figure 10)

Side slope of the ridge road failure forming 15 and 20 ft scarps at locations 1 and 2, respectively, in Figure 10. Erosion and debris slide extending to the catchment or gully head narrowing the ridge road.

Figure 10: **Plan view of saddle side slope failure at Monoghor-Rangapani at Ghagra bazar**

Cause of failure

The Monoghor-Rangapani Road at Ghagra bazar is a ridge road functioning as a water divide of the catchments. Furthermore this section is a saddle type. The rainwater surface runoff flows along the road and drains somewhere at the side of the saddle down to the gully. The landforms are forming alternatively concave and convex at both sides of the road. The concave landforms indicate the existing gully, and convex landforms form the water divide. The surface runoff drained from the concave slope (locations 1, 2, and 3 in Figure 10). The concave surface already weakened due to saturation and overload of debris. The runoff of unprecedented heavy rainwater and accumulated surface rainwater at the ridge easily eroded and transported the sediment as debris flow and slide, which damaged both sides of the road at location 1 and the front side of the road at location 2 of Figure 10 and Figure 11. The rainwater completely drained to only one side of the road eroded even the base of the road (location 2 in Figure 10 and Figure 11). Side and protection walls of the road collapsed. The existence of many gullies at the headwater indicated that there was continuous runoff even after the collapse.

Figure 11**: Saddle side slope failure at Monoghor-Rangapani at Ghagra Bazar**

Prevention

- Sound foundation of side wall and filling of road base
- Road side drainage management
- Erosion protection in the gully

4 Road Side Slope Failure

The road section at Bashar is a narrow ridge road. The side slope at the ridge was protected by using wooden stakes and sand bags on the sediment. Edge of the road section including all the slope protection measures collapsed due to debris slide. Gully erosion and debris slide had extended up to the ridge.

A No drainage

Location: 22° 47′ 30″ N, 92° 01′ 51″ E at Bashar (Rangamati-Khagrachhari Road) (Figure 12)

Cause of failure

The Rangamati-Khagrachhar Road section at Bashar is a ridge road, where the section is like a saddle. Rainwater surface runoff from both sides of the road drained to a junction and flowed down to the side slope of the catchment head (gully head). Rainwater and additional surface water were drained from a point resulting in heavy erosion, and forming the gully. The roadside slope sediment, including the wooden stakes with sand bags which were used for slope protection, were washed away as well. Gully erosion continued after the slide.

Figure 12: **Saddle road side slope failure at Basar** (Rangamati-Khagrachhari Road)

	Prevention
	• Need to manage road side drainage down to the gully. • Protection structure should be on the basement rock and fill.
B	**Weird road side drainage**
	Location: 22° 38′ 44″ N, 92° 11′ 51″ E at Risermok (Desbangla 1 km chainage) (Figure 13)
	Edge of the road section including protection wall and road side drainage collapsed due to debris slide.
	Cause of failure
	Road side drainage is used to drain the accumulated water at the road safely. The road at Risermok is laid over the sediments. The sediments are soft and easy to erode by the surface runoff water. To protect the erosion side drainage is used to control the surface runoff erosion. However the constructed road side drainage was not properly maintained in this section. Malfunction of road side drainage washed out the sediment damaging the side slope of the road. The side drainage is drained to a gully but the gully was also not paved which resulted in gully erosion and debris slide.

Figure 13: **Road side slope failure due to leakage of road side drainage at Risermok** (Desbangla 1 km chainage)

	Prevention
	• Road side drainage management • Erosion control and protection work in the gully
C	**Water supply leakage**
	Location: 22° 38′ 26″ N, 92° 11′ 22″ E at Tabalchhori (at road junction to Risermok and Rangamati, near Ananda Vihar) (Figure 14)
	Edge of the road section including drinking water supply pipes collapsed which narrowed the road width.
	Cause of failure
	Most of the road sections in Rangamati are paved on the sediments of silty clay or sandy clay, which are soft in nature. Continuous leakage of subsurface pipe water supply drains internally forms an internal gully. The void sometimes forms as a pothole on the road surface or subsidence of road section. The area will be easy to erode by additional surface runoff during the heavy rain.

Figure 14: **Road side slope failure due to water supply leakage**

Prevention

- Water supply leakage management
- Road side drainage
- Gully protection work

D Under-capacity drainage

Location: 22° 38′ 46″ N, 92° 11′ 49″ E at Risermok (100 m south from Shaheed Minar) (Figure 15)

Edge of the road collapsed narrowing the road width and forming bottleneck road.

Cause of failure

Side drainage at the road is to drain the water of the road to protect from the erosion. However the side drainage constructed at the road side was under capacity for the unprecedented heavy rain of 2017. The surface water drained through the drainage as well as from the side slope of the road, which is eroded and damaged the slope. But the damage was not so great compared to other areas.

Figure 15: **Road side slope failure due to under-capacity road side drainage at Risermok**

Prevention

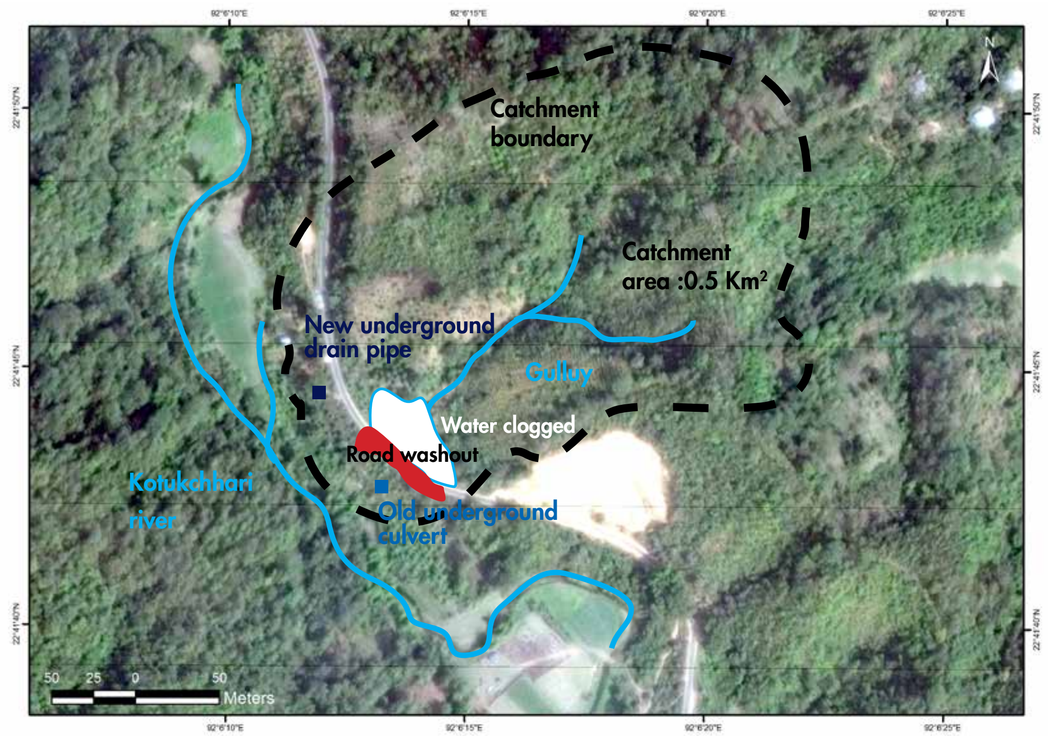
- Need full capacity of road side drainage
- Need to construct road side drainage

5 Drainage Blockage Outburst

Location: 22° 41′ 44″ N, 92° 06′ 13″ E at Montola Kijing (Rangamati-Khagrachhari Road) (Figure 16 and Figure 17)

About 30 m length with 11 m high Rangamati-Khagrachhari Road at Montola Kijing washed out completely. The road section had under reconstruction.

Figure 16: **Plan view of drainage blockage outburst at Montola Kijing** (Rangamati-Khagrachhari Road)



Cause of failure

A culvert of 1m x 1m under the road was maintained to drain the water of 0.5 km² catchment area. Debris slides with tree trunks at three places in the catchment accumulated at the culvert and choked the drain, forming a pond at the culvert. After three days the pond outburst at 8 a.m. on 15 June 2017 and 30 m length with 11 m high road washed out completely.

Figure 17: **Drainage blockage outburst at Montola Kijing (Rangamati-Khagrachhari Road** (Note: New outlet made of about 60 cm diameter is not large enough in case trees and debris block the culvert.)

Prevention

- Need full-capacity culvert
- Clear the blockage regularly particularly before monsoon

6 Toe Cutting

Location: 22° 37′ 56″ N, 92° 06′ 54″ E at tributary of Ghagra River, Rangmati Road section (Figure 18)

Debris slide at the left bank of the tributary of Ghagra River. No damage to settlement and infrastructure.

Cause of failure

Streams that flow at the base of mountain slopes continuously erode the base, resulting in lateral erosion (toe cutting). In this instance, heavy rainfall increased the discharge and erosional capacity of the stream and in addition the sediment on the slope is saturated and overloaded due to continuous heavy rain. Debris slide and flow has occurred at the mountain slope due to the combined result.

Figure 18: **Debris slide due to toe cutting of the mountain slope**

Prevention

- The slide does not affect the road and settlement at this area, so there is no need to protect the landslide.

7 Reactivated Landslide and Subsidence

A Banabhante (Rangamati-Kaptai Dam Road)

Location: 22° 34′ 41″ N, 92° 10′ 29″ E at Banabhante (Rangamati-Kaptai Dam Road) (Figure 19)

Subsidence of road section at Banabhante. The surface has dropped down by almost 5 m.

Cause of failure

The area is covered mostly by clay material with dense vegetation. The base of the hill slope is saturated due to continuous contact with the lake water. The continuous rain saturated the surface and subsurface layer, which became overburdened and overloaded. Finally the sediment had subsidence, debris slide and flow with some rotational movement. The existing road level had dropped down almost by 5 m.

Prevention

- Management of subsurface drainage
- Add protection structure to the road
- Road needs to be supported by concrete structure for heavy vehicles

Figure 19: **Subsidence and debris flow at Banabhante** (Rangamati-Kaptai Dam Road)

B	Baradam (Rangamati-Kaptai Dam Road)
	Location: 22° 35′ 26″ N, 92° 10′ 15″ E at Baradam (Rangamati-Kaptai Dam Road) (Figure 20)
	Ridge road section of about 50 m subsided by about 1 m. The road is subsiding, which is represented by the existence of tension cracks at many places in the road.
	Cause of failure
	The Rangamati-Kaptai Dam Road section at Baradam is a ridge road and also a saddle type. The accumulation of rainwater concentrate in the middle of the saddle is a result of an overflows from one side of the slope. The base of the road is soft sediment and became saturated as a result of heavy and continuous rain. Road section of about 50 m subsided by about 1 m. Existence of tension cracks on the road indicates the subsidence process is ongoing.

Figure 20: **Subsidence of road at Baradam** (Rangamati-Kaptai Dam Road)

	Prevention
	• Surface and subsurface drainage management • Side slope protection

Findings

Due to continuous and heavy rain the top soil is saturated as well as eroded. By the erosion of the gully head the scar has been shifted upward in the form of landslide. The roads and settlements at the gully head and base are affected by the erosion and landslide.

- Landslides triggered by excessive rain
- Additional triggering by continuous ear-piercing thunder
- Soft sediment on the slope
- Gully erosion extending towards the watershed (headwater)
- Additional water from road side flow to the saddle
- Poor road side drainage management
- Under capacity of road side drainage for excessive rain
- Lack of paved road side drainage system near the gully

Prevention Measures

The slides were numerous, but the scale of the slides was small. Nearly all the slides occurred on debris due to surface erosion and pore water pressure. Future prevention calls for improved management of rainwater to protect the slope from failure. Small-scale landslides can be controlled or prevented with low cost and environment-friendly bioengineering methods.

- Road side drainage should be paved completely down to the nearest gully
- Protect surface and gully erosion
- Foundation of structure on the slope should penetrate through the basement rocks
- Slides are mostly small in scale (less than 15 m in length)
- Small-scale landslide can be controlled by bioengineering methods
- Implementation of bioengineering protection work stabilizes the slope in 2–3 years

Recommendations

Almost all the landslides affecting the road and settlements are smaller in scale. The slip area is less than 15 m in length which can be controlled by bioengineering methods — using living plants for engineering purposes — in combination with small-scale civil engineering structures (gabion wall, check dam, prop wall, toe wall, catch drain, jute net, etc.) to protect the slope. Vegetation is carefully selected for the functions it can serve in stabilizing the slopes. The civil engineering structure will have a certain life span but the vegetative structure has a continuous life and so the site needs monitoring and maintenance.

Bioengineering is the low cost and environment-friendly technology to protect the slope.

- Prepare a base map of the project area using available high resolution satellite images or unmanned aerial vehicles (UAV)
- Conduct detail mapping of landslides with cause and mechanism of failure
- Identify protection measures and prepare detail plan
- Budget for protection measures of each landslide
- Implement bioengineering protection work
- Stabilize slopes within 2–3 years

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