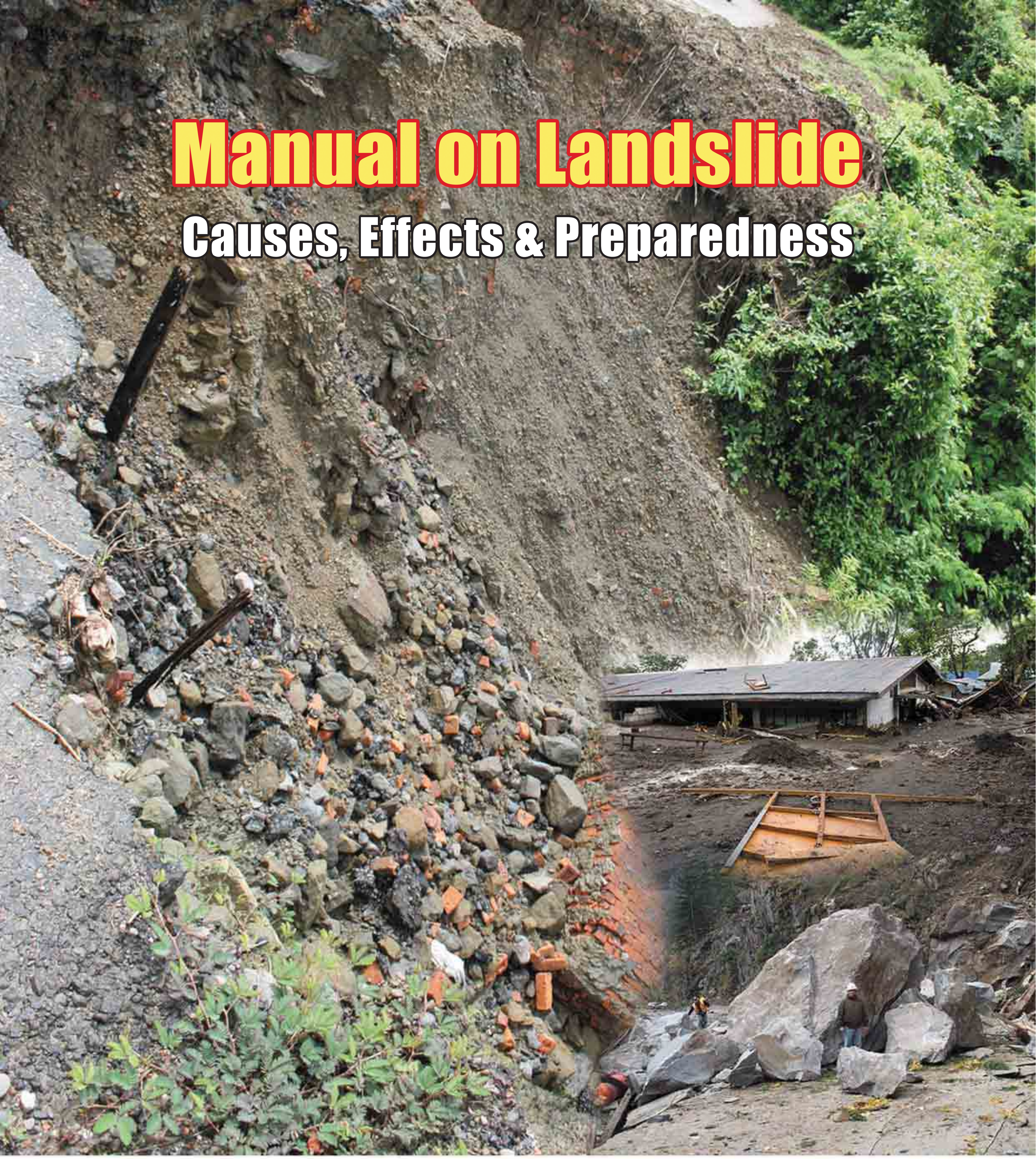
Manual on Landslide

Causes, Effects & Preparedness



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Habitat gratefully expresses its thanks to the Ministry of Social Welfare, Relief and Resettlement for its valuable comments. Our special thanks also go to the Norwegian Ministry of Foreign Affairs for its generous financial support given for the development and publication of this document.

This manual provides guidelines and information on various causes and effects of a disaster. It targeted for school teachers, students, parents, Civil Society Organizations, individuals, households, communities and practitioners in the field of Disaster Risk Reduction so that they are in a better position to prepare for and respond to future disaster.

This manual would not have come into fruition without the technical and financial support from the individuals, organizations and agencies mentioned above.

UN-Habitat/Myanmar

United Nations Human Settlement Programme

FOREWORD

According to its geographical features, Myanmar is prone to multiple hazards. Its coastal regions are exposed to cyclones, storm surges and tsunamis while major parts of the country are at risk from earthquake and fires. The Cyclone Nargis which hit Myanmar in May 2008 has been so far the worst natural disaster in history of Myanmar.

In any disaster situations most lives and properties are lost due to lack of proper awareness and knowledge on preparedness and effective response in a systematic manner. The Cyclone Nargis has reiterated the fact that lack of awareness of the people living in the disaster risk prone areas cause more human casualties.

Thus, there is a strong need of development of manuals, IEC materials and guidelines on providing basic information on various types of disasters affecting the country. The information disseminated through these public education materials will enhance the awareness at all levels. There is a strong need of wider knowledge dissemination among school children, communities, local civil society organizations and other practitioners in the field of disaster risk reduction.

This manual is being developed through various intensive consultative processes and inputs from subject and sector specialists. A wider consultation was also organized in order to share and get inputs from various line departments, UN Agencies, International NGOs and Local NGOs including professional organizations working in the field of disaster risk reduction.

I hope this information package in the form of manual will guide and give desired information on various causes and effects of disasters, and preparedness and response measures at individual, household and community level. At the time when the entire people are striving to build disaster resilient and safer Myanmar, this manual plays a key role to support this task.

U Soe Aung
Director General
Relief and Resettlement Department

Don't Wait for Disaster

No country can afford to ignore the lessons of the earthquakes in Chile and Haiti. We cannot stop such disasters from happening. But we can dramatically reduce their impact, if the right disaster risk reduction measures are taken in advance.

A week ago I visited Chile's earthquake zone and saw how countless lives were saved because Chile's leaders had learned the lessons of the past and heeded the warnings of crises to come. Because stringent earthquake building codes were enforced, much worse casualties were prevented. Training and equipping first responders ahead of time meant help was there within minutes of the tremor. Embracing the spirit that governments have a responsibility for future challenges as well as current ones did more to prevent human casualties than any relief effort could.

Deaths were in the hundreds in Chile, despite the magnitude of the earthquake, at 8.8 on the Richter Scale, the fifth largest since records began. In Haiti, a less intense earthquake caused hundreds of thousands of deaths. Haiti had non-existent or un-enforced building codes, and very poor preparedness.

The lessons are universally applicable. No country is immune from disaster, be it earthquakes or floods, storms or heat waves. More and more intense natural disasters are affecting all five continents, we believe as a result of climate change. Many of the world's poorest people live in high-risk densely populated cities in flood or earthquake zones, or both.

The culture of disaster risk reduction must spread. I am encouraged that we already have a head start in this regard. The Hyogo Framework for Action, a 10-year plan to make the world safer from disasters triggered by natural hazards, was adopted by 168 governments in 2005.Hyogo gives national authorities a blueprint to assess and reduce risks through planning, training, and better public education. For example, making sure that school, hospitals, and other key public infrastructure meet certain safety standards.

There has been progress. Bangladesh lost more than **500,000** people during Cyclone Bhola in 1970. It subsequently built 2,500 cyclone shelters on elevated concrete platforms and trained more than 32,000 volunteers to help in evacuations. When Cyclone Sidr struck in 2007 with an enormous sea surge, the death toll was less than **4,000**. Cyclone Nargis, a similar event in unprepared Myanmar in May 2008, cost **140,000** lives. Cuba weathered four hurricanes in 2008. It sustained $9 billion of physical damage but very few lives were lost.

The evidence is overwhelming. Yet the lessons of these disasters are forgotten with depressing speed. We know prevention actually saves governments money in the long run. When China spent $3.15 billion on reducing the impact of floods between 1960 and 2000, it averted losses estimated at about $12 billion. Similar savings have been recorded in Brazil, India, Vietnam and elsewhere.

Everyone has a role to play.

Governments, central and local, have to do what it takes to make communities able to cope with both continuing challenges and sudden shocks. The Chile and Haiti earthquakes showed us once again why action ***before*** disasters makes all the difference. To prevent natural hazards turning into disasters, we must all act sooner and act smarter.

Excerpts from the speech of Ban Ki-moon,
Secretary-General of the United Nations

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Chapter 1

Introduction to Landslide

1.1. What is Landslide?

Landslide means "Down-slope movement of soil, rock and debris or earth under the influence of gravity, and also the land form that results." It occurs when part of a natural slope is unable to support its own weight. Therefore, soil material on a slipping surface underneath such as clay seams, clay layers, bedrocks, etc., can become heavy with rain water and slide down due to its increased weight.

Three distinct physical events occur during a landslide: the initial slope failure, the subsequent transport, and the final deposition of the slide materials. The movement of falling, sliding and flowing rate may range from very slow to rapid. The mass of moving material can destroy property along its path of movement and cause death to people and livestock.

As landslides are natural hazards of ground failure type, many different types of movement, materials and triggering events such as heavy rain, floods, vibration of earthquakes and blasting, volcanic eruptions, and human activities may be involved.

1.2 Causes of Landslides

The main causes of landslides can be divided into two types:

(i) Natural causes and

(ii) Man-made causes

1.2.1 Natural causes

There are several natural factors that can cause slope failure. They are:

(a) Geological conditions

(b) Erosion Processes

(c) Hydrogeological characteristics

(d) Earthquake vibrations

(e) Volcanic eruptions

(f) Blasting vibrations

(g) External factors

1.2.1.1 Geological conditions

Dip of bedding planes, clay seams, joint set (dip direction) or weak rock layers are nearly the same as those of the slope causing planar sliding. Weathering of rock-mass, weathering process creates the permeable materials and these permeable materials can cause the increasing of pore water pressure. Soluble rocks with solution cavities in karst areas also cause subsidence. Huge boulders are sitting on the hill surface and are likely to topple or slide down.

1.2.1.2 Erosion processes

Erosion processes are caused by the continuous run-off over a slope. These causes include wave erosion of slope toe, glacial erosion of slope toe, and subterranean erosion. Uncontrolled flow of rain water on slope surfaces washes out soil and boulders, which threaten the people who are living along the base of the hilly regions.

1.2.1.3 Hydrogeological characteristics

Groundwater table rises up temporarily in the monsoon. It washes out the cementing material from soil and rock masses. Perched water table builds up very fast in the monsoon on impervious surfaces, e.g. clay seams, clay layers, bedrocks etc. Seepage from choked catch drains may raise pore-water pressure along the slip surfaces. This saturation destroys capillary tension in soils and reduces its cohesion because of increasing moisture content. Pressure of aquifers, such as sand layers or sandstone layers can cause very high pore-water pressure on overlying layers in slopes in sedimentary deposits.

1.2.1.4 Earthquakes vibration

Earthquake shaking has triggered landslides in many different topographic and geologic settings. Rock falls, soil slides and rockslides from steep slopes involving relatively thin or shallow disaggregated soils or rock, or both have been the most abundant types of landslides triggered by historical earthquakes.

1.2.1.5 Volcanic eruptions

Deposition of loose volcanic ash on hillsides commonly is followed by accelerated erosion and frequent mud or debris flow triggered by intense rainfall.

1.2.1.6 Blasting vibration

The vibration of uncontrolled blasting can also be a triggering event in landslide prone areas.

1.2.1.7 External factors

External factors, such as storms and torrential rain, impact groundwater regimes. Storms also produce intense rainfall for periods as short as several hours or have a more moderate intensity lasting several days and have triggered abundant landslides. Deposition of snow will raise the groundwater table which leads to the decrease of soil strength and increases the weight of associated material. Rapid melting of snow adds water to soil mass on slopes.

1.2.2 Man-made causes

The following human activities may cause significant change in slope surface and groundwater regions and cause the instability of slopes.

(a) Excavation of slope and its toe, leading to slope instability,

(b) Large-scale indiscriminate deforestation due to mass production of timber, causing rapid slope erosion,

(c) Large-scale indiscriminate blasting and quarrying, leading to slide slope forming materials due to vibration,

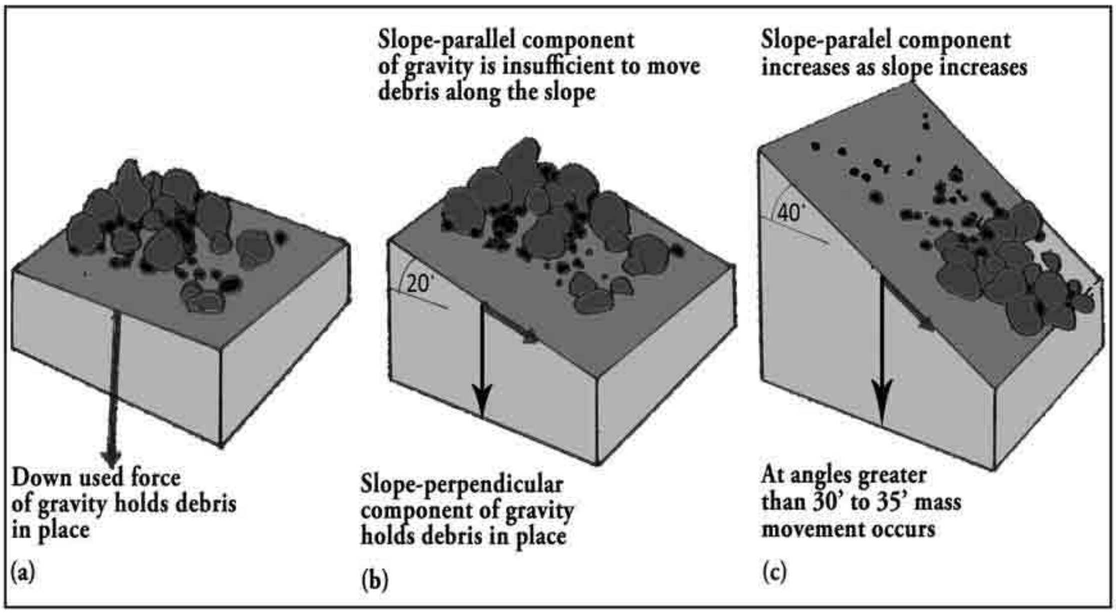
(d) Large-scale construction involving long hours and heavy structures on an entire hill, done without proper engineering inputs, and impact assessments

(e) Construction of dams, reservoirs or canals without specialists' advice, and

(f) Burning down of vegetation for cultivation.

1.3 Driving Force of Landslides

The principal driving force for any landslide is the gravitational force and the tendency to move of this mass will be proportional to the hill slope angle. The resisting forces preventing the mass from sliding down the slope are inversely proportional to the same hill slope angle and proportional to the friction angle of the material. As seen in Figure 1-1, the stability of the material resting on a slope will be reduced with an increased slope angle. In addition, the resisting forces can be significantly reduced in case of rain or earthquake vibrations.



Source: www.engineering4theworld.org/LAP

Figure 1.1 Showing instability of slope due to increasing slope angle.

1.4 Types of Landslide

All Landslide processes take place on slopes and river banks. The classification of slope movements depends on the basis of (a) nature of the movement, (b) the rate of movement and (c) the type of materials.

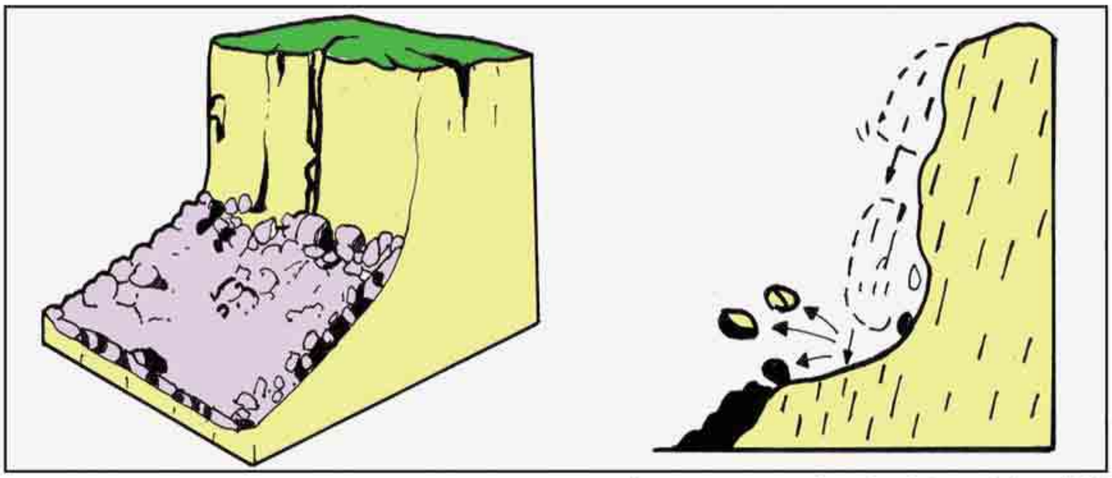
The various movements are falls (rock falls; debris falls and soil falls), topples (rock topple, debris topple and earth topple), slides of rocks, debris and soil (rotational slides and transitional slides), spread (rock, debris and earth), flow (rock) debris and earth and complex (combination of two or more principles of movement).

1.4.1 Falls

Falls are all sudden, vertical movement of earth material from an overhanging cliff.

(a) Rock fall

Rock fall starts with the detachment of rock from a steep slope along a surface on which little or no shear displacement takes place. The material then descends mainly through the air by falling, bouncing, or rolling. Movement can be very rapid to extremely rapid. Rock falls are very common and in most cases they are easily identifiable as seen in Figure 1.2 and Figure 1.3.



Source: www.engineering4theworld.org/LAP

Figure 1.2 Sketches of a Typical Rock Fall Sites

Source: www.engineering4theworld.org/LAP

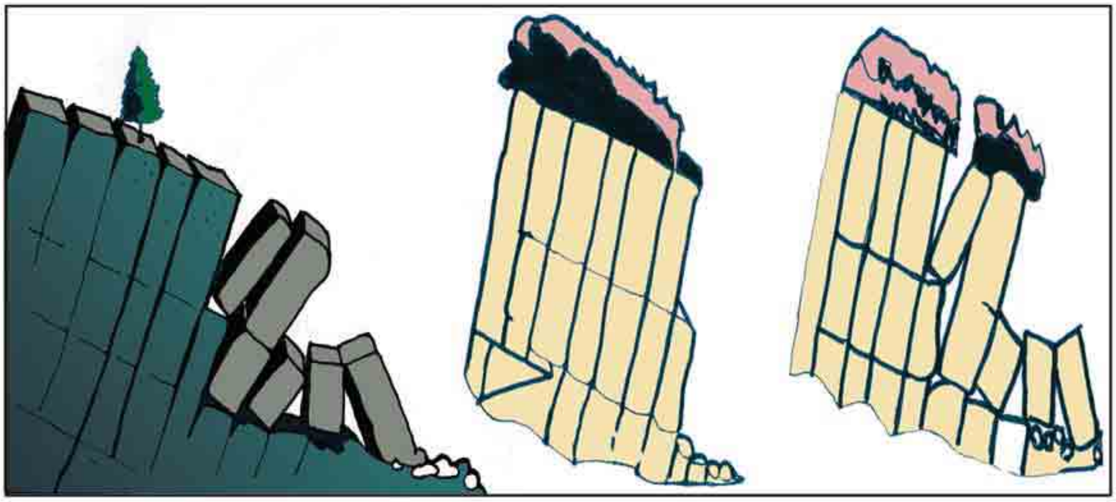
Figure 1.3 Photograph Showing Typical Rock Fall

(b) Debris fall

Similar to rock fall, but it consists of a mixture of rock and weathered regolith as well as vegetation.

1.4.2 Topples

A topple is a block of rock that tills or rotates forward on a pivot or hinge and then separates from the main mass falling on the slope and subsequently bouncing or rolling down the slope. In particular, the continuous columns of rock separated by well developed steeply dipping discontinuities break as they bend forward (Figure 1.4)



Source: www.engineering4theworld.org/LAP

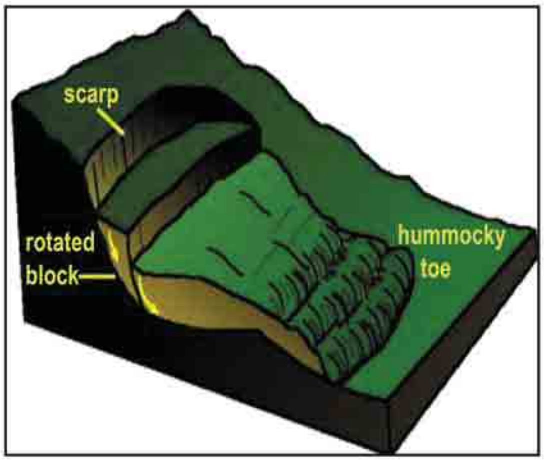
Figure 1.4 Processes of Rock Toppling

1.4.3 Slides

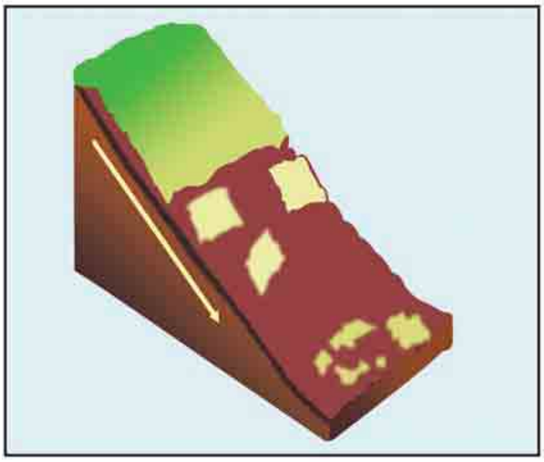
The term "slides" refers to the mass movement with a slide material from the more stable underlying materials. The two major types of slides are rotational and transitional slides.

(a) Rotational slides (slump)

Rotational slides occur on slopes of homogeneous clay or shale and soil slopes. These slides move along a surface of rupture that is curved and concave. If the surface of rupture is circular the displaced mass may move along the surface with little internal deformation. Generally, their axes are parallel to the contour of the slope [Figure 1.5(a)]



(a)



(b)

Source: www.engineering4theworld.org/LAP

Figure 1.5 (a) Rotational Failure with Multiple Planes
(b) Transitional Failure

(b) Transitional slides

Transitional failures occur when the failure surface is approximately flat or slightly undulated and the soil mass moves parallel to the surface of the terrain [Figure 1.5 (b)]. Transitional slides generally are relatively shallower than rotational slides. As transitional sliding progresses, the displaced mass may break up and start flowing, becoming a debris flow rather than a slide.

1.4.4 Spreads

They are caused by liquefaction-sudden movements on water-bearing seams of sand or silt overlain by homogeneous clays or loaded by fills. Lateral spreading occurs when the soil mass spreads laterally and this spreading comes with tensional cracks in the soil mass as seen in Figure 1.6.

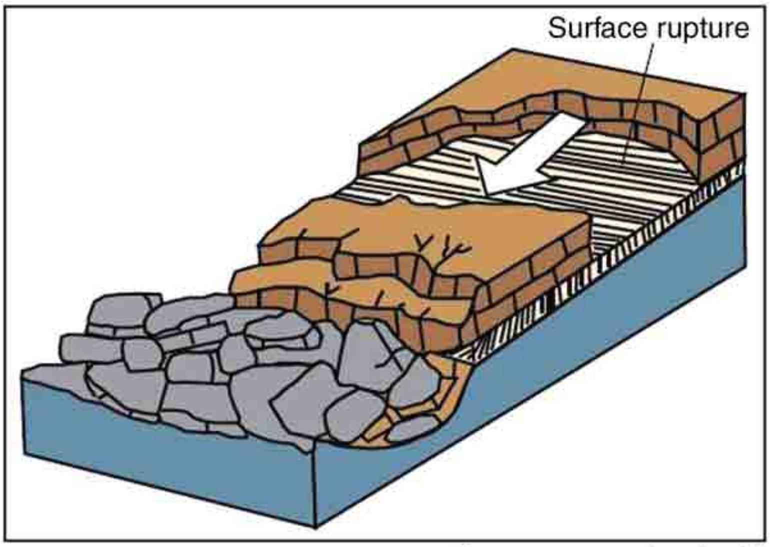


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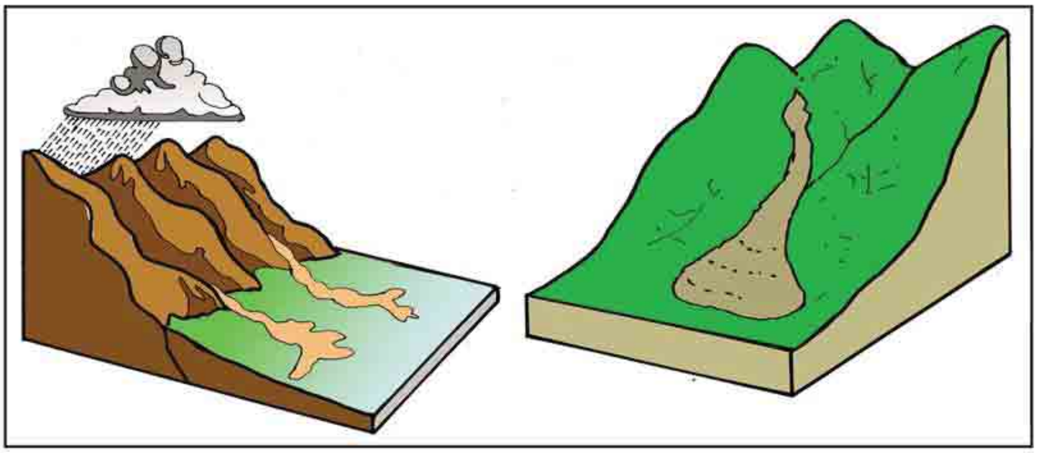
Figure 1.6 Sketch of Lateral Spreading

1.4.5 Flows

The term "flow" means "descending mass moving down-slope as a viscous fluid". These flows include debris flows, earth flows and mud flows.

(a) Debris flow

Debris flow is a form of rapid mass movement involving loose soil, rocks and organic materials along with entrapped air and water that form the slurry that flows down a slope. They usually start on steep hillsides as soil slumps or slides that liquefy and accelerate to a speed as great as 35 miles (56 km) per hour. Multiple debris flows that start high in canyons commonly funnel into channels. There, they merge, gain volume, and travel long distances from their source. (Figures 1.7 and 1.8).

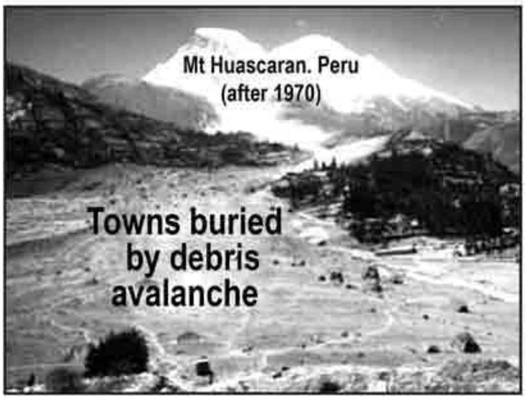


(Fig 1.7) (Fig 1.8)

Source: www.engineering4theworld.org/LAP

Figure 1.7 & 1.8 Two Views of Debris Flow Environments

Debris flows also begin in swales (depressions at the top of small gullies) on steep slopes (Figure 1-9), making areas downslope from swales particularly hazardous. The case of Mt. Huascaran in Peru, 1970 (Figures 1.9 and 1.10), which caused over 20,000 casualties, is a dramatic example of the destructive power of such events.



(Fig 1.9)

(Fig 1.10)

Source: www.engineering4theworld.org/LAP

Figure 1.9 & 1.10 Photograph Showing Towns Buried by Debris Avalanches

(b) Earth Flows

In an earth-flow, debris moves down-slope as a viscous fluid; the process can be slow or rapid. Most earth-flows involve both slop and flow.

(c) Mud flows

Mud flow is a slurry of debris and water. Mud flows are types of earth-flow consisting of material containing about 50% sand, silt and clay-sized particles that are well saturated and flow rapidly.

(d) Lahars

Lahars (Figure 1-11) are mudflows or debris flows composed mostly of volcanic materials on the flanks of a volcano. These flows of mud, rock, and water can rush down valleys and stream channels at speeds of 20 to 40 miles per hour (32 to 64 km per hour) and can travel more than 50 miles (80 km). Some lahars

Source: www.engineering4theworld.org/LAP

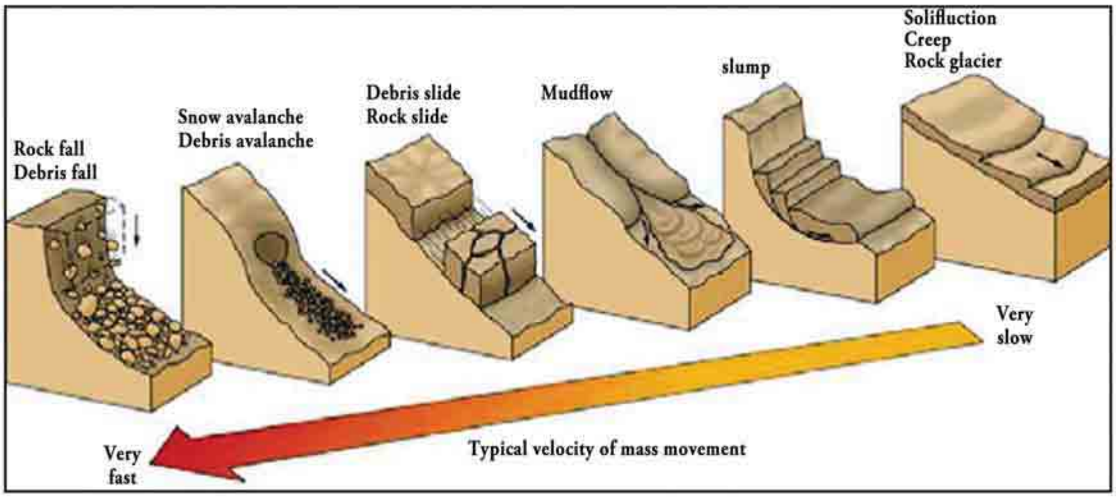
Figure 1.11 Active Volcano with Lahars in the Front

contain so much rock debris (60 to 90 percent by weight) that they look like fast-moving rivers of wet concrete. Close to their source, these flows are powerful enough to rip up and carry trees, houses, and huge boulders miles downstream. Further downstream they entomb everything on their path in mud.

Historically, lahars have been one of the deadliest volcano hazards. They can occur both during an eruption and when a volcano is quiet. The water that creates lahars can come from melting snow and ice (especially water from a glacier melted by a pyroclastic flow or surge), intense rainfall, or the breakout of a summit crater lake. Large lahars are a potential hazard to many communities downstream from glacier-clad volcanoes.

1.5 Landslide Speed

The speed at which the different types of landslide occur varies greatly. From Figure 1.12, it can be observed that the failure speed of rock falls is much higher than the one observed in slumps or soil creeping. The speed of a landslide will make it more or less avoidable and therefore, more or less risky.



Source: www.engineering4theworld.org/LAP

Figure 1.12 Relative Failure Speed for Different Types of Landslides

1.6 Landslide impacts

1.6.1 Direct impacts

Physical damages	- anything on top of or in the path of a landslide will suffer damage. Debris may block roads, supply lines (telecommunication, electricity, water, etc.), and water-ways.
Casualties	- Death and injury to people and animals.
Indirect losses	- Loss of productivity of agricultural and forest land, reduced property values, erosion, flooding in downstream area, etc.

1.6.2 Indirect Impacts

The following is an example of how a man-made structure, a dam, can have an impact on the environment.

The safety of a dam can be severely affected by land slides in the upstream area or on the slopes bordering the reservoir. Possible impacts include:

(a) Flood surges caused by movements of large masses of soil into the reservoir. The wave formed by those failures can overtop the dam causing downstream flooding and possibly failures to the dam.

(b) Increased sedimentation in the reservoir, resulting in loss of water storage can increased likelihood that the dam will be overtopped during periods of excessive runoff.

1.6.3 Landslides and Flooding

Landslides and flooding are closely associated because both are related to intense rainfall, runoff and ground saturation. Debris flow can cause flooding by blocking valleys and stream channels, forcing large amount of water to back-up. This causes backwater flooding in the upstream area and if the blockage gives away, it results in flooding downstream. In turn, flooding can cause landslides, due to rapidly moving floodwaters, which often undercut slopes or abutments. Once support is removed from the base of saturated slopes, land sliding often takes place.

1.7 Where do Landslides Usually Occur?

(a) Slope stability map

Large, deep-seated slides tend to be a reactivation of existing landslide complexes. Slope stability maps can provide an excellent indication of unstable areas. A competent geological analysis can usually provide an estimate of stability of problem areas on a site. It cannot reliably provide a probability of failure or an exact map of the area to be affected.

(b) On steep slopes

Steep slopes are typically found along shorelines where centuries of wave or river currents have eroded the toe of the slope. Most steep slopes experience sliding.

(c) On benches

Relatively level benches on an otherwise steep slope often indicate areas of past slope movement.

(d) Where drainage is causing a problem

Landslides are often triggered by the failure of drainage systems. Large amounts of water flowing from driveways, roof areas, roads and other impermeable surfaces can cause slides.

(e) Where certain geologic conditions exist

Landslides occur where certain combinations of soils are present. When layers of sand and gravel lie above less permeable silt and clay layers, groundwater can subsequently accumulate and zones of weakness can develop.

1.8 Elements at Risk

The most common elements at risk are settlements built on steep slopes, at the toe and on the mouth of streams emerging from mountain valleys. Buildings constructed without appropriate foundations for a given soil and in sloppy areas are also at risk. Roads, communication lines and buried utilities are also vulnerable.

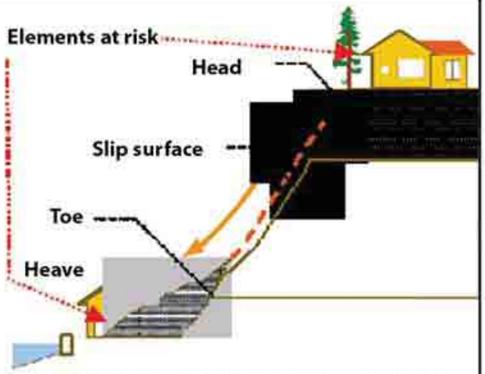


Figure 1.13 Sketch Showing Elements at Risk

1.9 Case History of Destructive Landslides in Asia

The number of events from 1980 to 2008 and their impacts are summarized below. Details of the landslides are listed country-wise in Table 1.1.

No. of events	——	366
No. of people killed	——	20,008
Average people killed per year	——	690
No. of people affected	——	7,031,523
Average people affected per year	——	242,466
Economic damage (US$)	——	6,059,838
Economic damage per year (US$)	——	208,960

Table 1.1 Events of Landslides and their Impacts from 1980-2008 in Asia

Location	Data	No. of Affected			Death Toll	Triggering processes	Los s ($)
		Village and tracts	House-holds	Families			
Bhutan	7.23.10	a bridge	-	-	3	heavy rain	-
China	8.8.10	-	-	-	100 (2000 miss ing)	mudslide	-
China	10.3.10	-	-	-	26	-	-
China	2007	-	-	-	17	Typhoon	
China	5.9.05	-	-	-	24	-	-
China	2008		1000	-	22 (45 missing)	with mud flow	-
China	12.4.04	-	-	-	23	-	-
China	6.5.04			-	21	-	-
India	26-5-05	-	hundreds	-	10	heavy rain	-
Indonesia	23-2-10	a village	-	-	70	heavy rain	-
Indonesia	2009	-	20	-	14	heavy rain	-
Indonesia	2008	-	-	-	24	heavy rain	-
Indonesia	2007	-	hundreds	-	63	torrential rain	-
Indonesia	24-12-06	-	-	-	100	heavy rain	-
Indonesia	1-4-03	-	-	-	26	heavy rain	-
Indonesia	17-10-05	12 villages	284	-	-	heavy rain	-
Indonesia	18-10-06	6 villages	400-500	-	5	heavy rain	-
Indonesia	4-1-06	-	-	-	27	heavy rain	-
Philippines	2008	-	-	-	9	heavy rain	-
Philippines	2007	-	-	-	5	heavy rain	
Philippines	14-2-06	-	-	-	11	heavy rain	
Philippines	19-12-03	-	-	-	200	heavy rain	
Pakistan	4-1-10	-	-	-	10	heavy rain	
Pakistan	8-7-07	-	-	-	22	heavy rain	
Pakistan	24-7-06	-	-	-	12	heavy rain	

Pakistan	2007	-	-	-	40	heavy rain	
Myanmar (Kachin State	4-7-09	-	-	-	-	heavy rain	
Myanmar (Taninthaye)	14-9-05	-	-	-	30	heavy rain	
Malaysia	6-12-08	-	-	-	-	heavy rain	-
Nepal	2007	a village	-	-	21	heavy rain	-
Nepal	14-7-06		Several houses	-	15	heavy rain	-
Yemen	28-12-05	a village	31	-	-	heavy rain	-
Tajikistan	1-3-03	-	33	-	-	heavy rain	-

Source: USGS http://landslides.usgs.gov/learningeducation/majorls
http://www.glidenumber.net/glide/public/result/report.jsp
DPA
OCHA
http://www.kuenselonline.com/modules.php?name=News&file=article&sid=16168

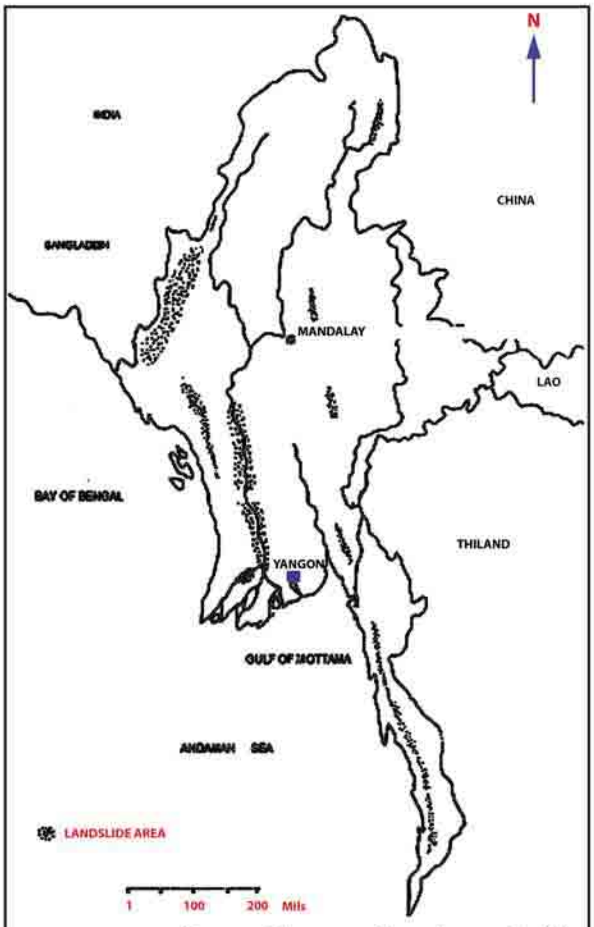
Chapter 2

Landslides in Myanmar

Myanmar has experienced many types of geologic hazards including earthquakes, landslides and subsidence in *Karst* areas. Among these, earthquakes and landslides are major hazards affecting the country. Geomorphologically, Myanmar has two mountainous areas: namely the Western Ranges and the Eastern Highland. These provinces are inherently unstable areas of the country. The steep slopes, unstable geologic conditions, and heavy monsoon rains combine to make the areas one of the most hazard-prone areas in Myanmar.

2.1 Landslide Prone Areas in Myanmar

Tectonically and geo-morphologically, Myanmar can be subdivided into three provinces: namely, the Western Fold Belt (WFB) in the west, the Central Lowland (CL) in the middle, and the Shan-Tanintharyi Block in the east. Therefore, geologically, Myanmar has two mountainous areas: namely, the Western Ranges and the Eastern Highland (Maung Thein, 1993). These provinces are inherently unstable areas of the country. They have steep slopes, unstable geology, and intense monsoon rains. These features make the mountainous areas one of the most hazard-prone regions in Myanmar. Besides, the major river of Myanmar, the Ayeyarwady, flows from north to south along the central lowland. Because of flooding and erosion, landslides occur along the banks of the river and its tributaries. The hazard areas are shown in Figure 2.1.



Source: Myanmar Geosciences Society

Figure 2.1 Landslide Prone Areas in Myanmar

2.1.1 Landslide Hazards in Shan-Tanintharyi Block

This province is composed of the oldest rock units in Myanmar, such as gneiss, schist, phyllite, greywacke, metasedimentary rocks, limestone and dolomite. Due to the long term differential erosion and weathering, the weathered features such as scarps, steep slope and *Karst* topography are observed. Moreover some igneous rocks which intruded among these units are also observed. These phenomena make the area more complicated. Because of the steep slope, highly weathered nature and heavy rain along the eastern part of this province, it experienced many types of landslides. Landslide and *Karst* photos are shown in Figures 2.2 and 2.3.

Photo@ U Kyaw Tun

Figure 2.2 Circular Failures Near Mogok

Photo@ U Kyaw Tun

Figure 2.3 *Karst* feature near Pwekauk Chaung in Eastern High Land

2.1. 2 Landslide Hazards in Western Fold Belt (Sothern Continuation of Himalayan Fold Belt)

In this province, landslide hazards commonly occur both along the eastern and western flanks of the ranges, Kale-Tiddim-Falam road and Kale-Kalewa-Tamu

Photo@ U Kyaw Tun

Figure 2.4 Multi-landslide Occurred in Western Ranges

Photo@ U Kyaw Tun

Figure 2.5 Road Slide due to Heavy Rain(Kalewa-Kale Road)

road. The most common types occurring in this province are (i) circular failure (ii) plane failure (iii) wedge failure and (iv) toppling failure. This area consists of Rakhine Yoma, Chin and Naga Ranges. Most of the rock types found in these ranges are thick layered flysch rocks, metamorphic rocks, metasedimentary rocks and ultrabasic rocks. The layers of the rocks are tightly folded and dipping in an easterly direction. Large over-thrusts with inclined fault plane are exposed as north to south direction. The main causes of landslides in this province are abnormally high pore-water pressure which rises during the rain storms, cutting down of natural vegetation, under-cutting erosion, and digging of slope toe. Photographs of landslide from this belt are shown in Figures 2.4 and 2.5.

2.1.3 Landslide Hazards along Banks of Ayeyarwady River

Landslide features are usually found along the banks of lower Ayeyarwady River and its tributaries. The landslide hazard is related with the seasonal rise and fall of river water-level. In rainy season, the water level of the Ayeyarwady River is high, and large amounts of water may enter the banks, producing bank storage

Photo@ U Kyaw Tun

Figure 2.6 Serious Landslide Occurred along the Ayeyarwady River

Photo@ U Kyaw Tun

Figure 2.7 Serious Bank Erosion Occurred along the Ayeyarwady River

phenomena. When the water level suddenly drops in the hot season, the stored water in the bank is left unsupported. This process can produce an abnormal pore-water pressure which reduces the resisting forces. Simultaneously, the weight of the stored water increases the driving forces, and therefore under cutting of the banks can occur. Finally, bank failure tends to occur along the river after the flooded water has receded. Thus, the landslide hazards have occurred along the banks (Figures 2.6 and 2.7).

2.1.4 Landslide Hazards in Yangon Area

As Yangon area is situated at the southern extremity of a long narrow spur of the Bago Yoma, the most notable feature of the topography is the central ridge known as Shwedagon-Mingladon anticlinal ridge. Therefore, the central part of the area is higher than its limbs. Most types of the landslide occurred in this areas are creeps, earth flow and slumps or block slides. Soil creeps are noted at Shwe-Taung-Kyar, Botahtaung and Hninsigon Bobwa Yeiktha. Earth flow types of landslides are observed at Dhamazedi Road. Slumps or block slides are noted at Inya Myaing, University Avenue Road, and Cantonment, west of Yangon Zoological Garden.

2.2 Historical Landslides in Myanmar

Some historical landslides in Asia, their triggering processes and impacts have been listed earlier in Table 1.1 (page 13). The events of landslide that occurred in Myanmar are listed below in chronological order:

1. On 23rd May 1912, serious landslides happened due to Maymyo Earthquake. There were no casualties and no loss of property.
2. Landslides, ground cracks, and sand blows occurred at Tagaung, Htigyaint, Kawlin and Thabeikkyin trigged by earthquakes in Tagaung on the 12th of September 1946 and on the 5th of January 1991 respectively.
3. In 1999, a landslide occurred along the western slope of the Tanintharyi Ranges due to torrential rain. Some villages were buried.
4. In 2001, a subsidence occurred in Nansang due to heavy rains. A circular graven appeared measuring about 50 feet in diameter..
5. On the 22nd of September 2003, landslides, ground cracks and liquefaction occurred in the Taungdwingyi area due to an earthquake, which caused some casualties and damage.
6. There was a large-scale landslide (and earth movement) that happened near Kalemyo, Sagaing Division of Myanmar, in September 2004 during the rainy season. About 30 kilometre-stretch of the main road, including bridges, were destroyed.
7. The Kyunsu Landslide occurred on 17 August 2005 in Kyunsu Township, Tanintharyi Division, destroying four houses.
8. The Pulaw Landslide occurred on 14 September 2005 in Pulaw Township, Tanintharyi Division, killing 12 people and injuring 21 others. Two houses were destroyed.
9. The Htantalang Landslide occurred on 17 September 2005 in Htantalan Township, destroying two houses and affecting 8 people from two households.

10. The Mogok Landslide occurred on 14 October 2005 in Mogok Township, Mandalay Division. Losses amounted to about one million kyat.

11. The 2008 Mogok Landslide occurred on 16 August 2008 in Bawbadan Village, Mogok Township, killing six people. It also destroyed a house and affected 6 people from a household.

12. The Thandaunggyi Landslide occurred on 5 September 2008 in Thantaunggyi Township, Kayin State, killing three people and affecting 15 other persons from four households. It also destroyed two houses. Losses amounted to about 6.2 million kyat.

13. The Lashio Landslide occurred on 8 September 2008 in Lashio Township, Northern Shan State, killing 3 people.

14. Landslides occurred in Buthidaung and Maungdaw in northern Rakhine State due to heavy rains in June 2010.

Source: Kyaw Htun (2009)

Chapter 3

Mitigation and Preparedness Measures

3.1 Landslide Risk Reduction Measures

3.1.1 Mitigation Methods

There are a variety of mitigation methods to deal with landslides, depending on the degree of the landslide hazard as well as legal, social, environmental, geotechnical and economic factors. These options include "Avoidance," "Do Nothing," "Maintenance," and "Selective Stabilization" approaches. However, there is usually no standard rule-of-thumb solution because formulation of mitigation measures is often unique for each site and requires proper technical evaluation of causative factors. Mitigation options can be categorized based on the way each measure improves stability. There are three main categories to improve stability: (a) avoidance, (b) reduction of driving forces, and (c) increasing resistance.

(a) Avoidance

This category can include "no-build" designations in the area surrounding the landslide, relocation of planned facilities, and bridging over landslide areas. "No-build" designations help to reduce risks to jurisdictions, property owners and the public. The objective is to construct new facilities in locations where no landslide risks exist or have been adequately stabilized. Roads and utilities can be routed across landslides on bridges with sufficiently long spans to avoid contact with any portion of the slide mass and adjacent marginal areas.

In the construction of railway, motor roads and other engineering structures, the avoidance method is suitable for landslide prevention. If there is no way to avoid a potential slide and if prevention treatment will not assure stability, it is sometimes necessary to construct a bridge across the unstable area. For instance, the bridging method is often used in order to mitigate the risk of landslide during the construction of railroad lines.

(b) Reduction of driving forces

This category can include removal of weight from the upper portions of landslides and drainage of water and groundwater flowing into the landslides. Unloading can be accomplished by excavating the amount of slide material to sufficiently improve the margin of stability. Another means of unloading is to remove the upper part of the slide mass and replace it with lighter-weight materials to support the facility. Reduction of driving forces can also be taken to the extreme by removing the entire landslide mass and forming stable slopes in adjacent ground. Drainage of groundwater near the head of slide areas reduces driving forces by decreasing seepage forces and total weights of soil in the driving portion. The use of surface drainage systems, impermeable covers, and hydrophilic plants can help to reduce infiltration. However, bio-stabilization methods are more appropriate for erosion control rather than landslide mitigation. These methods are designed to increase the stability of landslide mass by reducing the forces that cause movement. The chief methods are:

(i) Removal of head;

(ii) Flattening of slopes;

(iii) Benching of slopes, and

(iv) Complete removal of all unstable materials.

Most of the problems involving the stability of slopes are associated with the design and construction of untraced cuts or highways, railways and canals. Cuts with greater depth and length are limited to prevent the landslide. The slope ratio of the road-cuts should be 1.5:1. In flooded area, the 2:1 and 3:1 slope ratios are recommended for side slopes.

(c) Increasing resistance

This category can also include improvement of soil shear strengths, buttressing, restraint/reinforcement, and dewatering. Shear strengths can be improved by replacing portions of the shear zone material with stronger materials, such as buttresses and shear keys. Buttresses, gravity walls and berms constructed in the toe area of a landslide can add positive weight that increases the net shear resistance, and the amount of benefit achieved would be influenced by the strength of the material in the shear zone (slip surface). Dewatering using drainage systems can reduce buoyancy and result in improved resistance along the shear zone, provided that the drainage systems can effectively reduce groundwater pressures on the shear zone. More expensive structural alternatives could be considered when there are special constraints or when the risks and consequences of failure are significant. Structural methods of adding resistive forces include retaining walls, ground anchors and shear piles. The concept of using chemical injection and grouting methods to improve shear strength has been recognized, but such methods typically do not achieve uniform or significant improvement.

3.1.2 Structural Mitigation Measures

3.1.2.1. Drainage Corrections

Drainage management has significantly improved the slope stability of medium and large landslides. The most important triggering mechanism for mass movements is water infiltrating into an overburden during heavy rains, and consequent increase in pore pressure within the overburden. Hence the natural way of preventing this situation is by reducing infiltration and allowing excess water to move down without hindrance. As such, the first and foremost mitigation measure is drainage correction. This involves maintenance of natural drainage channels, both micro and macro, in vulnerable slopes.

(i) Surface Drainage

The surface drainage control works are implemented to control the movement of landslides accompanied by infiltration of rain water and spring flows. The rill and gully erosion were largely mitigated by surface drainage management. It consists of drainage channels or ditches, prevention of leakages, cleaning natural ditches.

(ii) Sub-surface Drainage

Sub-surface drainage of a soil-rock mass can be achieved either by pumping the water up to the surface or by opening an artificial outflow to a point which is situated at a lower level than the projected level of the lowered water table. This can be done in slopes where boreholes are drilled from the lowest point of the slope in slightly upward direction deep into the slope. These boreholes have the advantages that drainage is independent from a source of energy; the water flows out by itself. This drainage consists of drainage tunnels, counter fort trenches, deep-seated counter fort drains, vertical drill holes, horizontal borehole, slope seepage drainage wells of Ferro-concrete, and drainage of linear plates.

More expensive structural alternatives could be considered when there are special constraints or when the risks and consequences of failure are significant. Structural methods of adding resistive forces include retaining walls, ground anchors and shear piles. The concept of using chemical injection and grouting methods to improve shear strength has been recognized, but such methods typically do not achieve uniform or significant improvement.

3.1.2.2. Structural Support Measures

Structural support measures improve the stability of slope by increasing stabilising component of sliding mass. Structural support measures include retaining wall, anchored structures, rock-bolts, earth anchors, and rock anchors.

(i) Retaining walls

Retaining walls can be built in order to stop land from slipping (these walls are commonly seen along roads in hill stations). They are constructed to prevent smaller sized and secondary landslides that often occur along the toe portion of the larger landslides. Retaining wall may be classified as (a) Gravity wall (b) Tie-back wall (c) Driven cantilever wall (d) Reinforced earth wall.

Retaining wall constructed from concrete cribbing, gabions (stone filled wire baskets) or piles (long concrete, steel or wooden beams driven into the ground) are designed to provide support at the base of a slope. They should be keyed in well below the base of the slope, backfilled with permeable gravel or crushed rock and provided with drain holes to reduce the chances of water pressure building up in the slope.

(ii) Buttresses

Buttresses are used in connection with embankment construction and seldom, if ever, used to restrain slopes in excavation. A modified application of the buttresses has been found effective in preventing sloughing or flowing of wet cut slopes. This method, which is really a combination of drainage and buttress, consists of placing over an excavated slope a heavy blanket of clean coarse gravel or similar previous materials.

(iii) Anchored structure

Rockbolts : Rockbolts with bar tendons are particularly useful where plane failures and wedge failures are likely to occur. The principal of rockbolts is to integrate rock plates together so as to form monolithic mosaic. The measures are basically preventive in nature and minimize future failures of rock.

Earth /rock anchor : The mechanism of load transfer from anchors relies on bands at the soil-grout interface and tendon grout interface, rather than soil-soil frictional resistance. The length of earth/rock anchors in the fixed anchor zone varies depending on the degree of consolidation of soil materials and on the nature and degree of weathering bed rock.

(iv) Bioengineering

Bio-engineering helps living vegetation, either alone or in conjunction with civil engineering structures and non-living plant material, reduce shallow-seated instability and erosion on slopes. Bio-engineering measures can contribute to the following: (i) Prevention of scour erosion; (ii) Reduction of shallow planar land-sliding; (iii) Channelling of runoff to alter slope hydrology; (iv) Providing support to the base of the slope and trapping material moving downward.

Increasing vegetation cover is the cheapest and most effective way of arresting landslides. This helps to bind the top layer of the soil with layers below, while preventing excessive run-off and soil erosion.

(v) Geotextiles

Geotextiles and related materials are permeable sheets or strips of materials, which are used in association with soils. They are usually made from petroleum products such as polyester, polyethylene and polypropylene. Geotextiles have a range of physical properties, mechanical properties, hydraulic properties and durability properties.

Geotextiles provide additional technology for low cost slope stabilization and reinforcement. Multiple layers of geotexiles placed in during construction or reconstruction will reinforce the soil and help increase slope stability. Soil reinforcement allows for the safe construction of steep slopes, typically on the order of one horizontal to one vertical. Even vertical structures can be safely constructed. The most important benefits are: (i) reducing amount of fill material and the cost; (ii) it is easy to place gentle slope with reinforced steep slope; (iii) increasing the factor of safety of marginally stable slope; (iv) resisting construction damage imposed by compaction equipment.

(vi) River Training Measures

The stabilization measures required to prevent landslides resulting from river flooding are river bank protection and drainage and structural and bioengineering measures. The aim is to safeguard the banks rather than the river itself. River bank protection work includes either revetment or spur, or a combination of both.

3.1.3 Non-structural Mitigation Measures

3.1.3.1. Landslide Hazard Zonation Map

Application of reliable landslide hazard and vulnerability zonation technology to identify landslide risk is necessary from country to community level in the Asia Pacific region. Adequate land-use planning to avoid landslide disasters should be promoted by this technology. Landslide hazard mapping will locate areas prone to slope failures. This will allow identification of avoidance-areas for building settlements. These maps will serve as a tool for mitigation planning.

Myanmar Geosciences Society (MGS) has developed a first draft macro level landslide hazard map taking into consideration the gradient of the slope, hydrologic characteristics of the slope, presence of troublesome earth materials, process of erosion, geological condition and other potential triggering events (Figure 3.1). This initiative should be promoted to develop a detailed landslide hazard zonation map for the whole country and micro level maps with situation-specific choice of mapping scale.

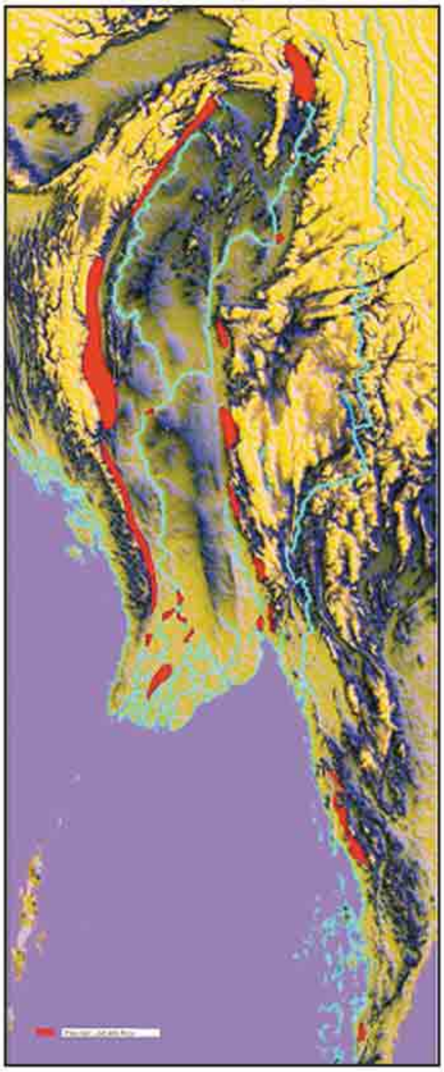


Figure 3.1 Proposed Landslide Hazard Map

3.1.3.2. Landslide risk assessment

Comprehensive risk assessment for the landslide hazard prone areas in Myanmar should be carried out. These assessments should be based on land planning policies and practices.

3.1.3.3. Proper Land Use Measures and Settlement Planning

Effective land-use regulations and building codes should also be adopted based on scientific research. Through land-use planning, discourage new construction or development in identified hazard areas or encourage implementation of appropriate remedial measures.

Regional hazard and risk assessments should be based in land planning policies and practices. This ensures that appropriate processes are in place whereby new development applications are assessed with respect to slope stability issues, and zoning for future development is directed towards areas with low or very low risk of slope instability.

Permanent settlement should be avoided in high-risk zones, site selection even in moderately safe zones, especially in plateau edge regions should be made with caution. Diversion of stream channels in upper slopes, especially above settlements, should strictly disallowed.

3.1.3.4. Landslide Risk Mitigation Plan

Based on hazard zonation on macro and micro scales, a comprehensive landslide risk mitigation plan should be developed in consultation with members of a technical committee (for example, the Myanmar Geosciences Society), government departments concerned, communities and all other stakeholders.

3.1.3.5. Other Recommendations for Landslide Mitigation Measures in Myanmar context

Landslides are a threat to infrastructure in the hilly regions of Myanmar. The slope geometry, slope height and the material composing the hilly terrain are basic components for the instability of the slope. Mapping of terrain configuration and geology should be carried out. Landslides are often associated with the ingress of both surface and subsurface water of nearby areas. Thus, hydrological and hydrogeological studies should also be conducted. The proper planning and implementation of Highway and road construction is required with the aid of engineering geologists and earth-scientists. Local communities play an important role in landslide hazard mitigation. Therefore, education on landslide hazards in rural areas should be undertaken.

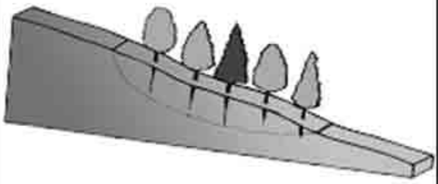
3.1.4. Landslide mitigation at community level[1]

There are some landslide mitigation activities which communities themselves can perform in their locations.

- Prepare hazard map and define the limits of danger zones so as to regulate the community activities within those zones

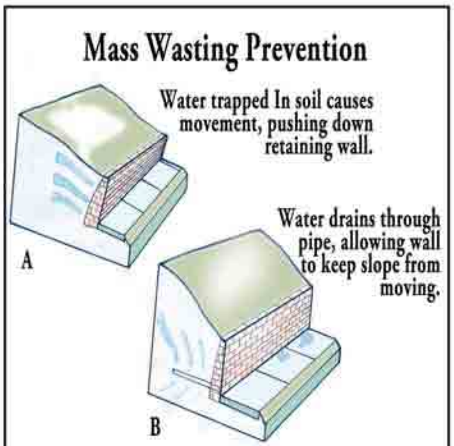
[1] Reducing the community impact of landslide, EMA

- Keep records of erosion, landslide masses and falling rocks. Never construct buildings on their debris without proper guidance. Loosened masses can subside when load is added to them.
- Try to protect the slopes. Prevent people from excavating, removing materials from the soil or cutting trees without proper advice from technical experts.
- Avoid building houses at the base of slopes that are prone to landslides.
- Replant trees where they have been removed to prevent soil erosion.
- Prevent deforestation and vegetation removal.
- Avoid weakening the slope.
- Reforestation: Root systems bind materials together and plants both prevent water percolation and take water up out of the slope. Tree roots help holding the different soil layers together and hinder landslides. (Figure 3-2)



Source: www.engineering4theworld.org/LAP
Figure 3-2: Tree roots help holding the different soil layers together and hinder landslides.

- Proper water runoff must be ensured, especially where houses and roads have disrupted the natural flow patterns. This can be achieved by providing a proper canalization network.
- Drainage: good ground drainage is essential to prevent saturation and consequent weakening. Drainage is also needed when any kind of civil work, like retaining walls, are constructed. This can be observed in Figures 3-3 A) & B).



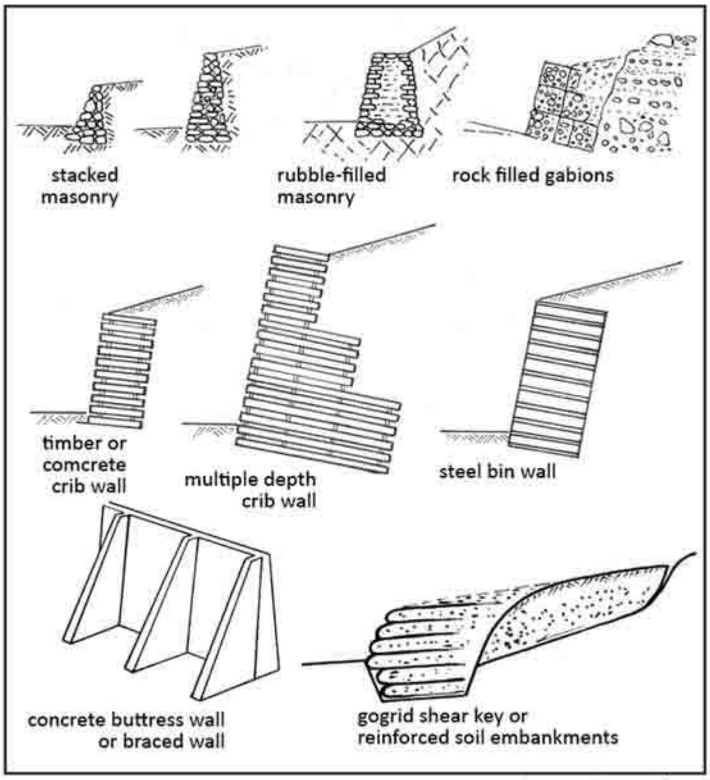
Source: www.engineering4theworld.org/LAP
Figure 3-3 (A) High pore water pressures weaken the ground and push down the retaining wall;
(B) By providing proper drainage, the pore water pressures are reduced as well as the forces on the retaining wall.

- Nets (Figure 3-4) are a common and cost effective solution. However, it is still too costly (and technically complicated) to be used in small villages or to protect private homes.

Source: www.engineering4theworld.org/LAP

Figure 3-4: Net used to prevent stone fall on a roadway

- Retaining walls efficiently reduce localized landslide hazards, like in the case where cuts into the slopes are needed to build a house or a road. However, they have to be used with caution because they might also



Source: www.engineering4theworld.org/LAP

Figure 3-5 Examples of low-cost retaining walls

increase the hazard if water in the soil is not allowed to drain properly. In Figures 3-5, a number of low-cost ways to build retaining walls are illustrated.

- In addition, gabions can also effectively replace the more expensive reinforced concrete retaining walls (Figure 3-6).

Source: www.engineering4theworld.org/LAP

Figure 3-6 Retaining wall built with gabions

3.2. Landslide Preparedness Measures

3.2.1. Landslide Preparedness Measures at the community level[2]

3.2.1.1. Community-based Organisation on Disaster Risk Reduction

It is best if the community has already formed a Community-based Organisation (CBO) on Disaster Risk Reduction (DRR). If not, community leaders should coordinate the formation of such organizations so that they comprise all relevant stakeholders of the community. Under the CBO on DRR, a number of sub-groups or teams should also be organized to address different disaster management activities such as early warning dissemination, evacuation, search and rescue, first aid, relief operation etc.

3.2.1.2. Community-based Disaster Management Plan (CBDMP)

The CBO should prepare a CBDMP with the help of local authorities, NGOs, community leaders and community members. The plan should list activities which the community members are required to perform for landslide preparedness. It should also detail the delegation of duties so that each individual is aware of his/her specific responsibilities when an emergency warning is received. Once the plan is prepared, it should be shared with the community through various means, such as announcements in the community assembly and postings on the notice board of the village or ward's Peace and Development Council, monasteries/churches, markets, etc. Everyone in the community should well understand the contents of the plan. It should be rehearsed through the use of drills and updated periodically so that it will reflect and adapt to the changing conditions of the community, climate, and natural environment.

[2] Hazards, disasters and your community_India

3.2.1.3. Education and awareness generation[3]

The most damaging landslides are often related to human interventions such as construction of roads, housing and other infrastructure in vulnerable slopes and regions. So, it is important that communities well understand the causes of landslides and how landslide risk can be reduced. Education and awareness generation among the communities is one of the community-based landslide risk mitigation activities.

3.2.1.4. Community-based landslide risk assessment

The community risk assessment is a participatory process of determining the nature, scope and magnitude of negative effects of hazards to the community and its households within an anticipated time period. It determines the likely negative effects on 'elements at risk' (people; household and community structures, facilities like schools and hospitals; livelihood and economic activities, jobs, equipment, crops, livestock etc; lifelines, access roads and bridges) and why particular households and groups are more vulnerable to specific hazards. The coping mechanisms and the resources present in the community are also identified.

Communities can play a vital role in identifying the areas where there is land instability. Compacting ground locally, slope stabilization (procedures such as terracing and tree planting may reduce damages to some extent), and avoiding construction of houses in hazardous locations are all things that the community has to do to avoid damage from possible landslides. This would also lift the burden of having to relocate already-built settlements from hazardous slopes in order to rebuild on a safe site as it is not practical to do so on a large scale.

3.2.1.5. Landslide monitoring and warning system

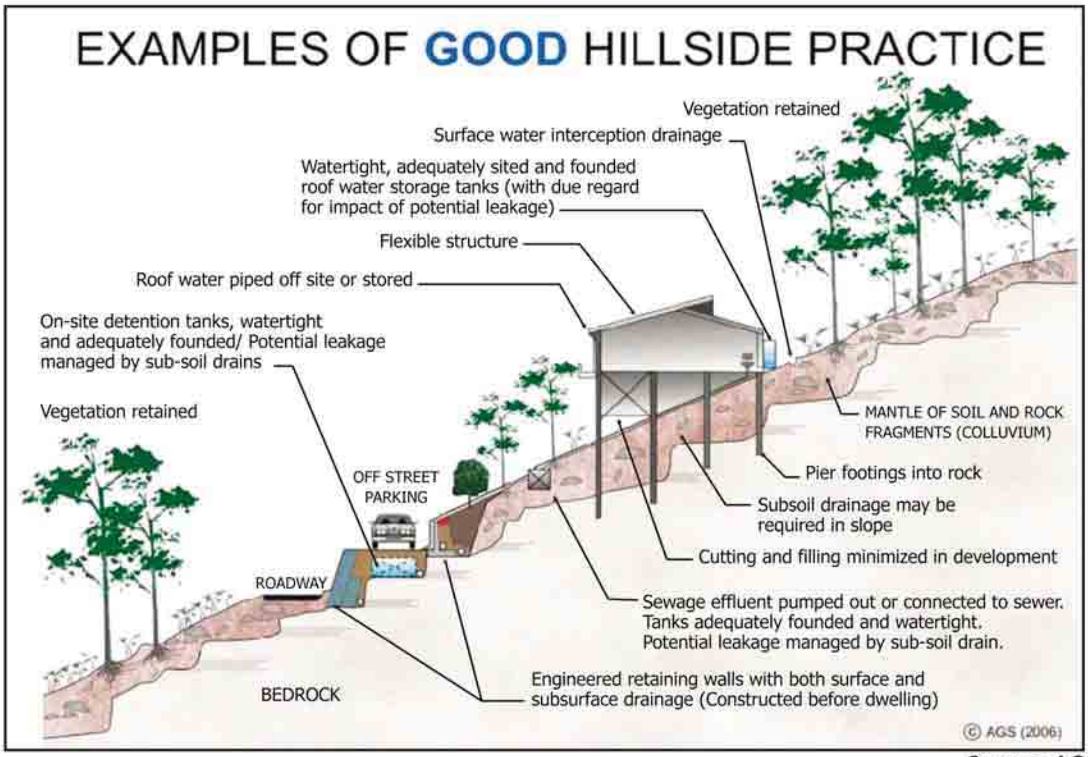
Landslide warning systems do not prevent landslides. But they can provide time to evacuate people and their possessions, and to stop trains or reroute traffic. The most cost-effective method of mitigating landslide disasters is early warning and evacuation. Hazardous areas can be visually inspected for apparent changes and small rock falls on roads and other areas can be noted for quick removal. Some warning methods include electrical systems, tilt-meters and geophones that pick up vibrations from moving rocks. Shallow wells can be monitored to signal when slopes contain a dangerous amount of water and in some regions, monitoring rainfall is useful for detecting when a threshold precipitation has been exceeded and shallow soil slips become much more probable. The relevant and effective landslide monitoring and warning system should be developed by the community in landslide prone areas of Myanmar.

[3] Reducing the community impact of landslide, EMA

3. 3 Landslide preparedness at the household level[4]

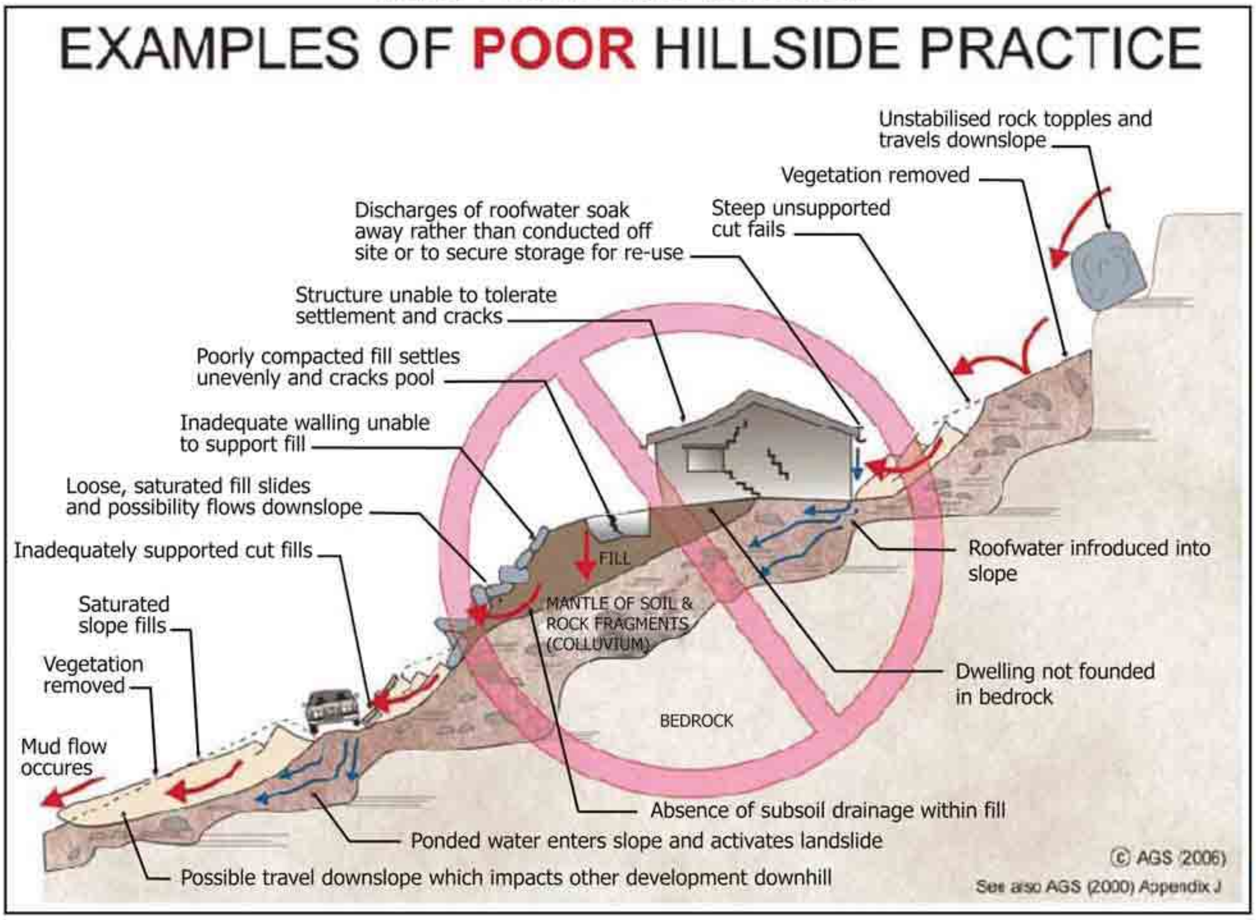
- Before purchasing a piece of land or building on your own land, try to get as much information as possible on its history of landslides. Elders of the area can give you information on past incidents.
- Choose a safe location to build your home, away from steep slopes and places where landslides have occurred in the past
- Avoid building houses at the base of slopes that are prone to landslides.
- Observe the features on the up-slope area before you start any construction. Fill areas constructed above, lacking appropriate slope retaining structures, rock debris or boulders can move into your land. Be sure of the stability of the up-slope area before you start to build on your land. If you are in doubt obtain advice from a specialist on the subject.
- Do not obstruct natural streams or drainage paths during construction. Be mindful of the other structures on the down slope. Avoid dropping rock pieces, boulders, loose earth, etc. down the slope during construction. Introduce a retaining structure to prevent movement of fill material, if you need to fill your land located on the slope.
- When constructing on a slope, use a design that suits the natural slope. This will also save on the cost of construction. Do not remove vegetation and large trees while constructing.

[4] CBDRM for local authorities



Source: AGS

Figure 3-7 Examples of good hillside practice



Source: AGS

Figure 3-8 Examples of poor hillside practice

Family Landslide Preparedness Plan

People and households residing in landslide prone locations should develop their own family landslide preparedness plan. Trying to make plans at the last minute can be upsetting and create confusion. The plan should include an evacuation arrangement and let all the family members know where to go if they have to leave. Everyone should know what to do in case all family members are not together. Do's and Don'ts during a landslide should be well known to all family members. Discussing disaster ahead of time helps reduce fear and lets everyone know how to respond during a landslide or debris flow. A stock of appropriate supply of the following should be kept handy, especially in the rainy season:

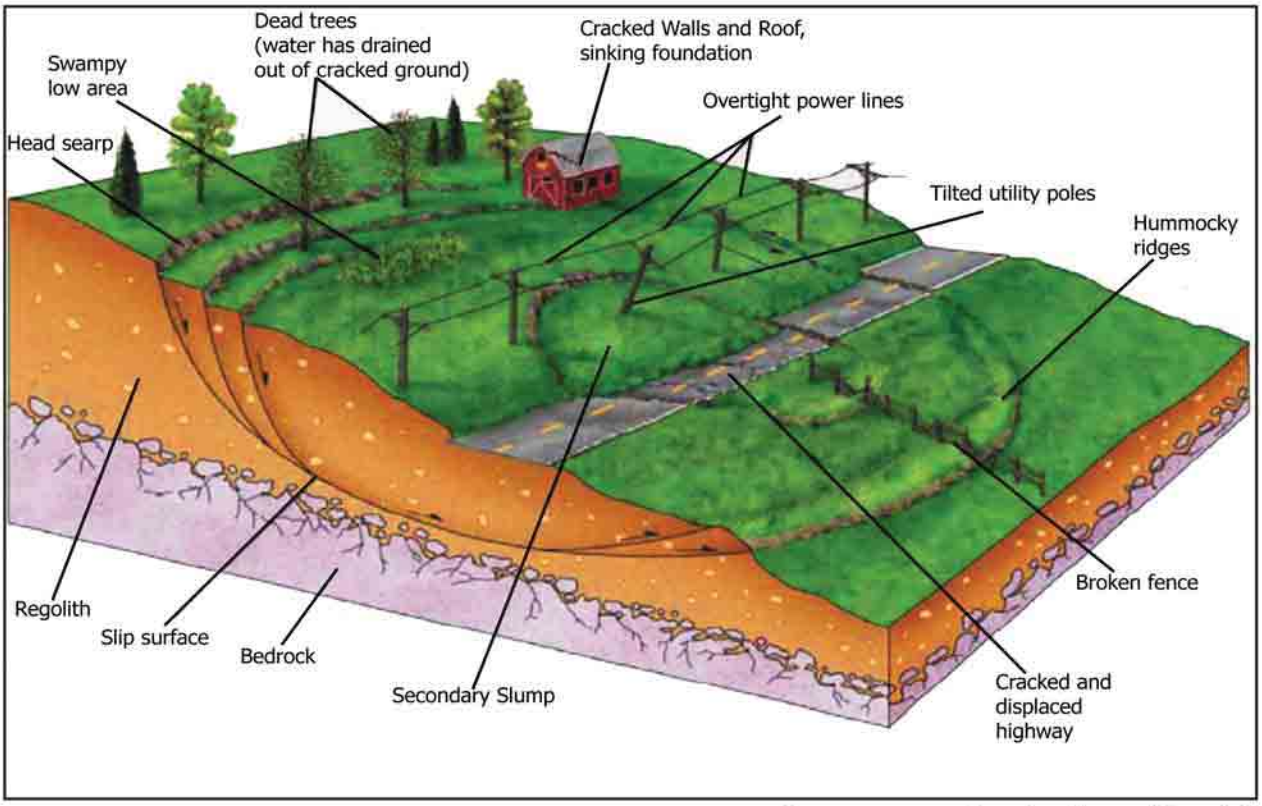
- Food and drinking water.
- First-aid kit and essential medicine.
- Flashlights with extra batteries (keep them in several locations).
- Portable radio with extra batteries.
- Warm clothes.
- Important documents and valuables.

Chapter 4

Landslide safety tips

4. 1. How to recognize Landslide Warning Signs[5]

- Changes occur in your landscape such as patterns of storm-water drainage on slopes (especially the places where runoff water converges) land movement, small slides, flows, or progressively leaning trees.
- Doors or windows stick or jam for the first time. Sticking doors and windows, visible open spaces between windows and their frames.
- New cracks appear in plaster, tile, brick, or foundations.
- Sudden appearance and rapid expansion of cracks on road pavements or ground surface.
- Outside walls, walks, or stairs begin pulling away from the building.
- Slowly developing, widening cracks appear on the ground or on paved areas such as streets or driveways.



Source: www.engineering4theworld.org/LAP

Fig 4.1 Morphologic and structral landslide endicators

[5] CBDRM for local authorities

- Water breaks through the ground surface in new locations. Sudden appearance of springs, seepage traces or patches with ground saturation in areas that have not typically been wet before.

- Movement of pavements, decks, sidewalls of structures, or bulging of retaining walls relative to the main structure.

- Sudden breakage of water supply lines and other underground installations and underground utility lines.

- Bulging ground appears at the base of a slope.

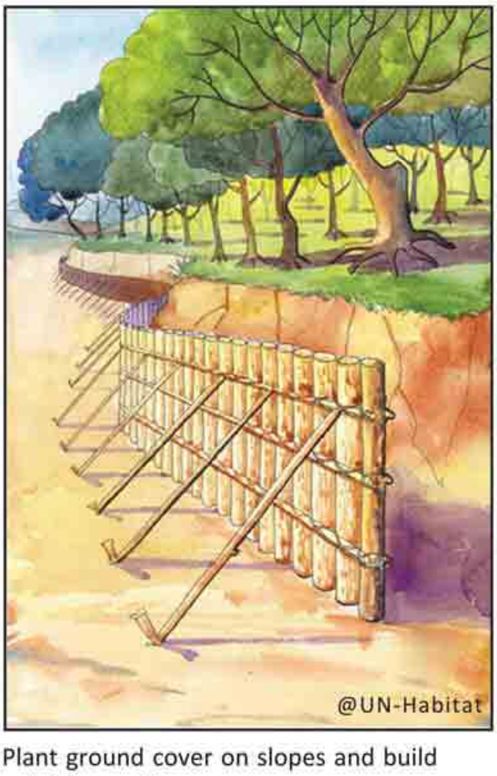
- Fences, retaining walls, utility poles, or trees tilt or move.

- Rapid increase in water levels in pools, creeks, streams, etc. in mountainous areas.

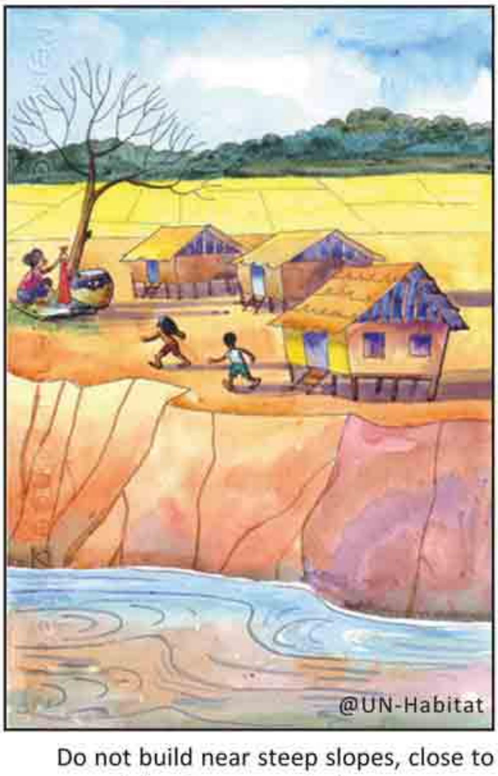
- Increased turbidity in stream water flow.

- Sudden appearance and disappearance of creeks.

- A faint rumbling sound that increases in volume becomes noticeable as the landslide nears.

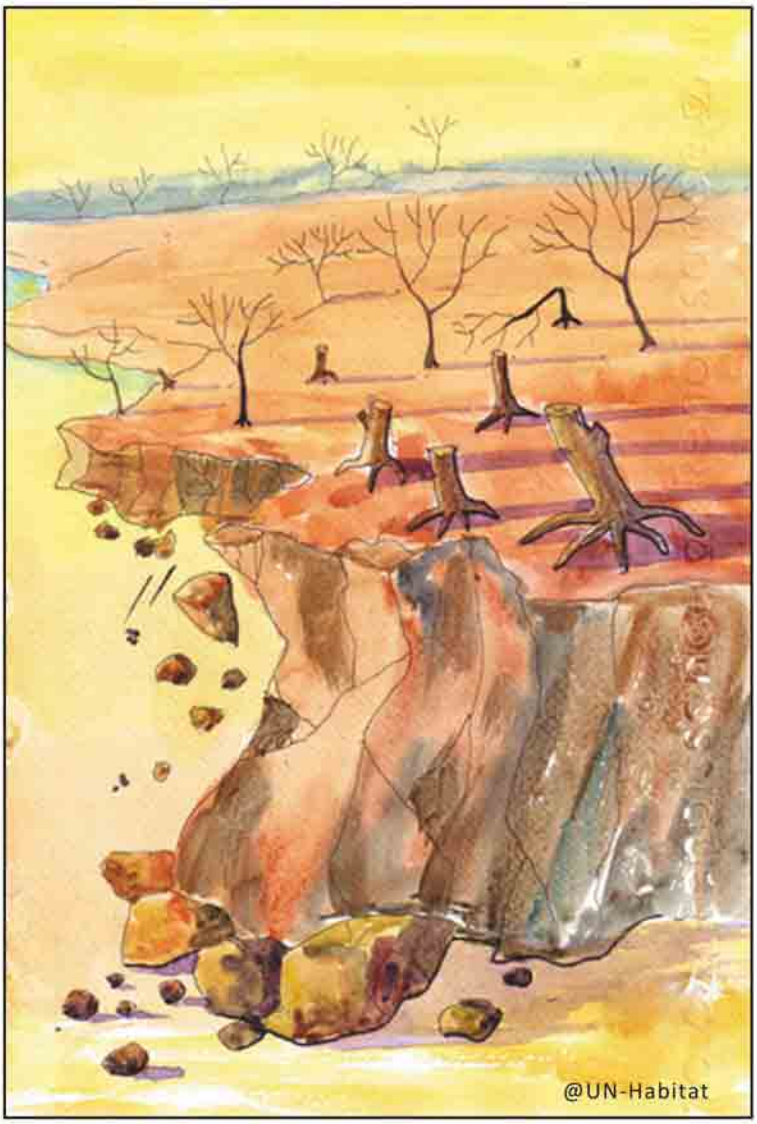


Plant ground cover on slopes and build retaining walls



Do not build near steep slopes, close to mountain edges, near drainage ways, or natural erosion valleys

- Unusual sounds, such as trees cracking or boulders knocking together, might indicate moving debris.
- Collapsed pavement, mud, fallen rocks, and other indications of possible debris flow can be seen when driving (embankments along roadsides are particularly susceptible to landslides).



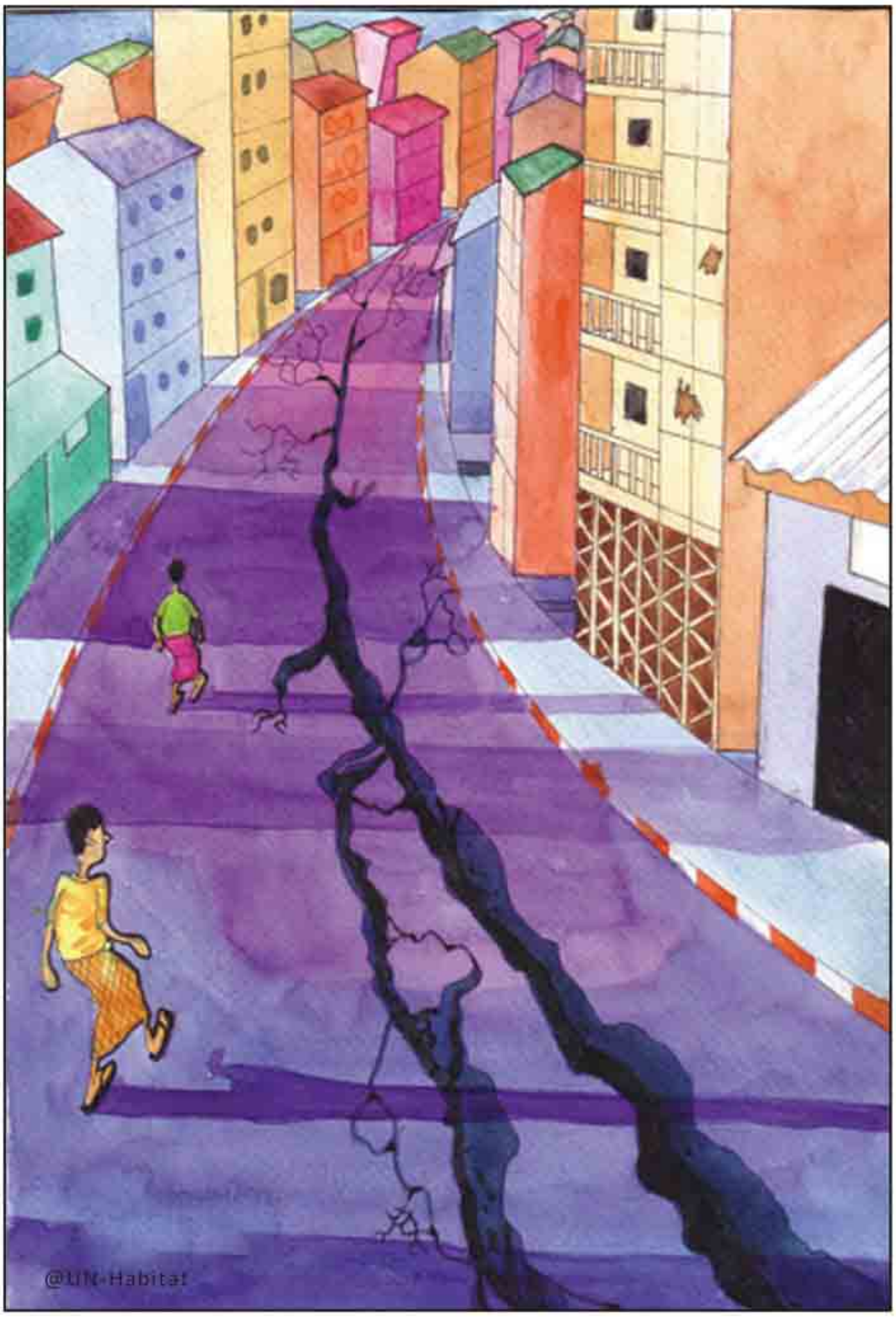
Avoid cutting trees near steep slopes, near drainage ways, close to mountain edges

4. 2. Before a Landslide or Debris Flow: General guidelines for those living in a landslide - prone area

4.2. 1. For normal time[6, 7]

- Do not build near steep slopes, close to mountain edges, near drainage ways, or natural erosion valleys.
- Minimize home hazards:
- Have flexible pipe fittings installed to avoid gas or water leaks, as flexible fittings are more resistant to breakage (only the gas company or professionals should install gas fittings).
- Plant ground cover on slopes and build retaining walls.
- In mudflow areas, build channels or deflection walls to direct the flow around buildings.
- Listen to weather forecasts on the radio, TV about heavy rains. Continuous heavy rainfall during a 24-hour period or a high-density rainfall within a period of a few hours has the potential to trigger landslides.
- Be alert if you are living in an area in which landslides occur regularly. Organize groups to inspect the slopes.
- Remain awake during nights of heavy continuous rain and be ready to move to a safer location.
- Observe the warning signs mentioned above such as appearance of cracks and their rapid expansion over the slope. They may indicate the possibility of a landslide. Inform the authorities when such warning signs are recognized.
- Listen for abnormal sounds of soil and rock movement or breaking of trees. They may be associated with landslide movements.
- Observe abnormal behavior of domestic animals such as dogs and cats. They are very sensitive to natural hazards. They might indicate the danger by making unusual sounds, unruly behavior, etc.
- Never go closer to observe cracks on the slope. If you spot cracks, inform the authorities and move out from the area.

[6] CBDRM for local authorities,[7] CBDRM for local authorities

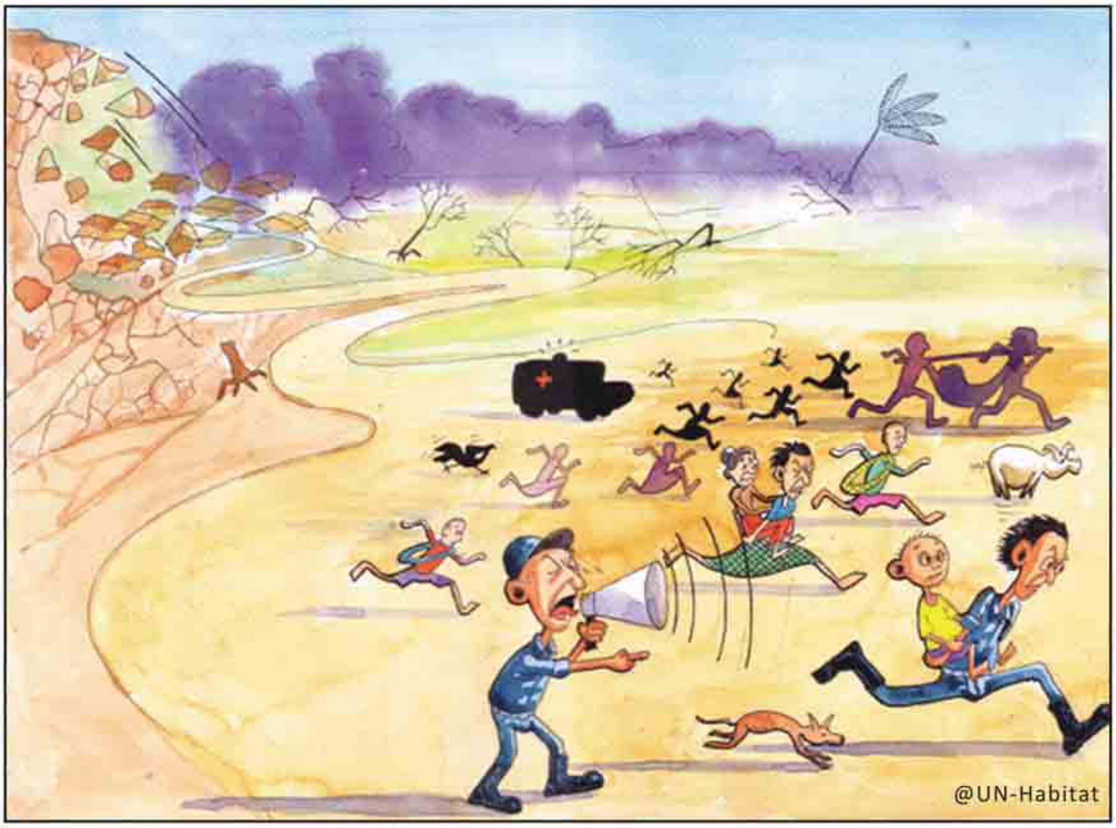


4.2. 2. Prior to a Potential Landslide[8]

- Stay alert and stay awake! Many debris-flow fatalities occur when people are sleeping. Listen to a radio for warnings of intense rainfall. Be aware that intense short bursts of rain may be particularly dangerous, especially after longer periods of heavy rainfall and damp weather.
- If you are in areas susceptible to landslides and debris flows, consider leaving if it is safe to do so.

[8] Landslide hazard training manual

- Listen for any unusual sounds that might indicate moving debris, such as trees cracking or boulders knocking together. A trickle of flowing or falling mud or debris may precede larger flows.
- Contact your local authority, village disaster preparedness committee, fire services department, or Myanmar Police Force. Local officials are the best persons who are able to assess potential danger.
- If you are near a stream or channel, be alert for any sudden increase or decrease in water flow and for a change from clear to muddy water. Such changes may indicate debris flow activity upstream, so be prepared to move quickly.



In case you need to evacuate, do so immediately. Do not try to collect your belongings. Landslides can occur suddenly.

- Especially be alert when driving. Embankments along roadsides are particularly susceptible to landslides. Watch the road for collapsed pavement, mud, fallen rocks, and other indications of possible debris flows.
- In case you need to evacuate, do so immediately. Do not try to collect your belongings. Landslides can occur suddenly.

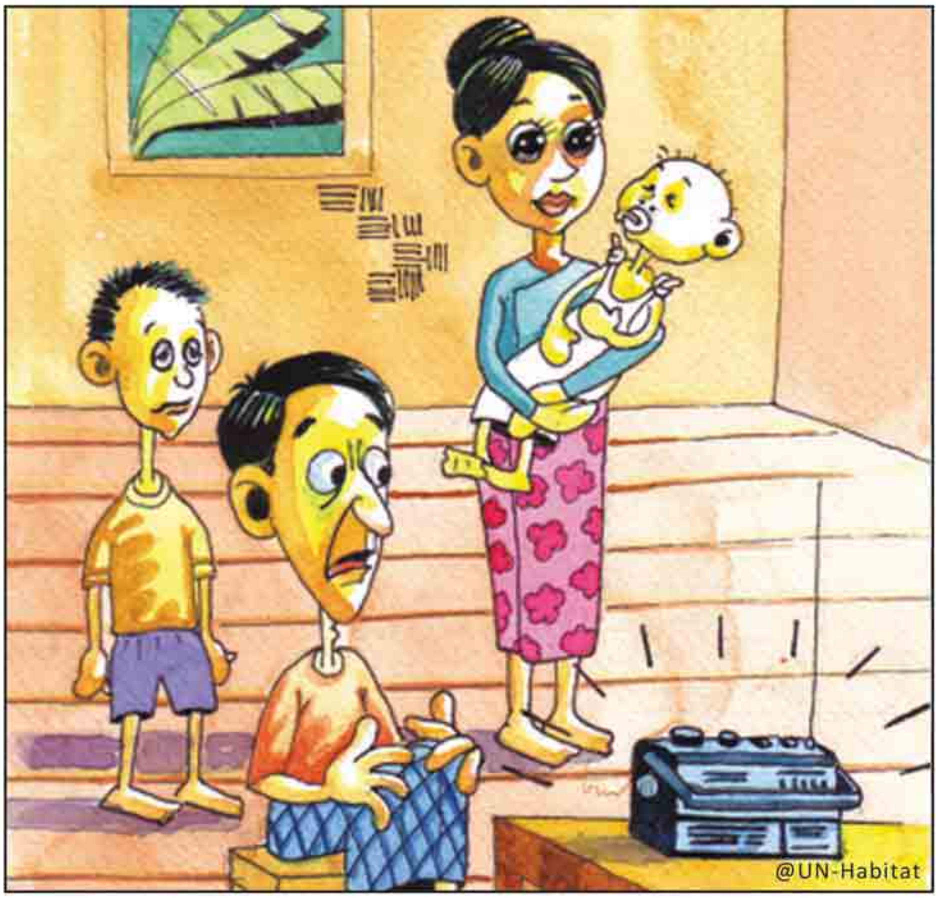
- While evacuating, do not cross possible landslide paths.
- When you see falling rocks, seek cover behind trees and other solid objects.
- There is a strong possibility that an earthquake may trigger landslide especially in areas where landslides occur regularly. Therefore, be alert when an earthquake occurs. Try to organize groups to monitor the situation
- Landslides that occur as a result of ground shaking can create a large volume of mudflow along the slope into the valley. Therefore, do not move in the direction of the valley if you are requested to evacuate. Instead, move to elevated areas.
- If a landslide occurs near your home, check the foundation and walls of your home for cracks. Search for any new cracks in the surrounding area. Look out for any warning signs of landslide movement.
- Inform affected neighbors. Your neighbors may not be aware of potential hazards. Advising them of a potential threat may help save lives.
- Help neighbors who may need assistance to evacuate.
- Evacuate. Getting out of the path of a landslide or debris flow is your best protection.

4. 3. During a Landslide

- Quickly move out of the path of the landslide or debris flow. Moving away from the path of the flow to a stable area will reduce your risk.
- If escape is not possible, curl into a tight ball and protect your head. A tight ball will provide the best protection for your body.

4. 4. After a Landslide

- Stay away from the slide area. There may be danger of additional slides.
- Check for injured and trapped persons near the slide, without entering the direct slide area. Direct rescuers to their locations.
- Help a neighbor who may require special assistance - infants, elderly people, and people with disabilities. Elderly people and people with disabilities may require additional assistance.
- People who are disabled/sick or who have large families may need additional assistance in emergency situations.



- Listen to local radio or television stations for the latest emergency information.
- Watch for flooding, which may occur after a landslide or debris flow. Floods sometimes follow landslides and debris flows because they may both be started by the same event.
- Look for and report broken utility lines to appropriate authorities. Reporting potential hazards will get the utilities turned off as quickly as possible, preventing further hazard and injury.
- Check the building foundation, chimney, and surrounding land for damage. Damage to foundations, chimneys, or surrounding land may help you assess the safety of the area.
- Replant damaged ground as soon as possible since erosion caused by loss of ground cover can lead to flash flooding.
- Seek the advice of a geotechnical expert for evaluating landslide hazards or designing corrective techniques to reduce landslide risk. A professional will be able to advise you of the best ways to prevent or reduce landslide risk, without creating further hazard.

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MANUAL ON LANDSLIDE

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Developed by UN-HABITAT. Myanmar

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