UNIT 3 FLOODS AND LANDSLIDES

Structure

3.0 INTRODUCTION

This unit introduces you to the natural phenomena of floods, droughts and landslides. These are natural processes and affect human life and property. They can be due to natural or anthropogenic factors. Torrential rains, flash floods and landslides have killed many people. They also have ravaged farms, pasture and damaged buildings. These hazards have forced people to migrate. The science of forecasting and prediction of the hazards is to be understood. Landslides cause hazards that are accidental and dynamic. They occur in mountainous regions and on slopes. Climate controls the form of the precipitation and snowmelt. These changes include the frequency, intensity, magnitude, and seasonality including the occurrence of cyclones. They are the significant external drivers for these hazardous events. Land use changes, field drainage, changes in forest covers can multiply runoff and floods. Further, a decrease in vegetation enhances landslide activity. Take an example of Southern Europe, where there is a reported increase in shallow landslides. This is due to soil erosion and the abandonment of the lands in the terraced slopes. In this unit, you will also learn about the hydrological cycle, the different causes of

floods and the types of floods. Further, you will be able to distinguish floods and droughts, along with the different stages of drought. The unit will finally deal with landslides, its causes and effects.

3.1 OBJECTIVES

After reading this unit, you should be able to:

- describe the nature of floods;
- understand the different types of droughts; and
- analyze the causes and effects of landslides.

3.2 FLOODS

Dear Learners, let us now learn about floods in the following paragraphs.

3.2.1 Overview of Floods

Water is in constant motion in the earth in various forms powered by the solar energy. This cycle is called hydrological cycle. Even small additional amounts of precipitation more than the average amounts can result in streams to run out of its confines. This leads to flooding. Rivers are sources of water for consumption. It is of utility to agriculture, and industry. Transportation routes, energy, and means of waste disposal are some other services. Also, the topography of the stream valleys is relatively flat, suitable for constructions. Throughout the history of human civilizations, cities have grown along streams. Human populations that live along and near the streams by default face the risk of floods as the flow of water in streams is not constant. When large amounts of water enter into the streams, it can cause flooding. Some of the causes for flooding can be that during heavy rainfall the rivers overflow its bank or when the ocean waves come onshore. Flooding can also occur when rapid snow melt occurs or due to dam/ levees failures. Flooding can range from a few inches of water to covering a house rooftop. Floods that occur in a very short time are called flash floods. A flood occurs when the stream overflows its bank. This submerges surrounding areas. Flood plain is that area which is flat or nearly flat land adjacent to a stream or river. It experiences occasional or periodic flooding. (Figure 3.1, 3.2) This consists of floodway (stream channel and adjacent areas that carry flood flows) and the flood fringe (areas covered by the flood which do not experience a strong current).

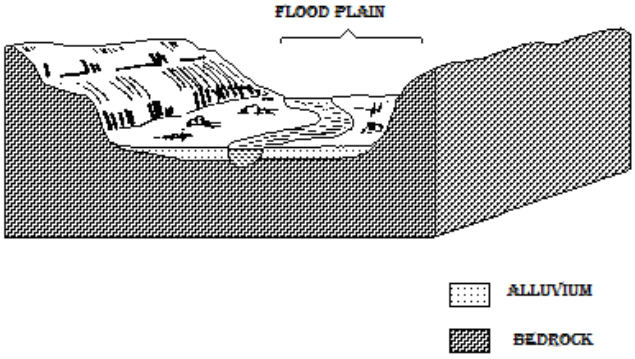

Fig.3.1: Flood Plain

Source: Baskar S and Baskar R, 2009. Natural Disasters.

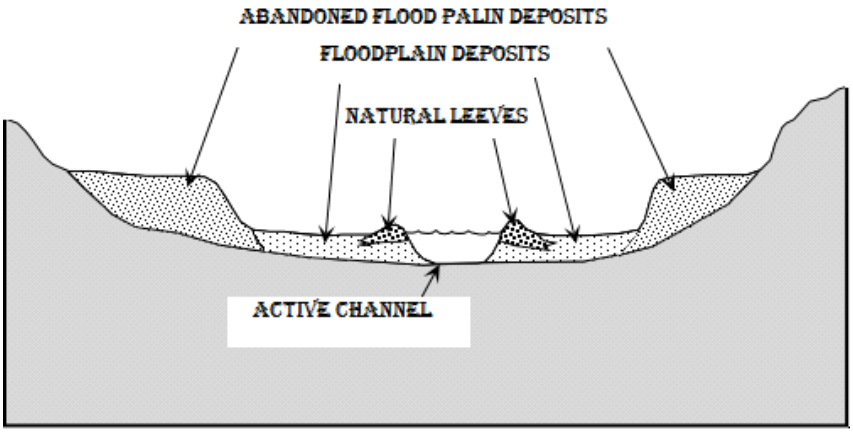

Fig. 3.2 Cross Section of a Flood Plain

Source: Baskar S and Baskar R, 2009. Natural Disasters.

Floods have caused several hazards, more damaging especially in the less developed and developing countries. High population densities, absence of land use planning, and reduced flood control measures, lack of early warning systems are cited as some of the reasons. One classic example of a country that is most vulnerable to flood disasters is Bangladesh. Floods and tropical cyclones have caused approximately 200,000 deaths in 1991.

In the developed countries, on a relative scale the flood hazard causing loss of life is lesser. This is due to the existence of proper flood control structures, land use planning that do not allow the habitation of vulnerable areas, and also emergency preparedness. Additionally, advanced engineering techniques such as levees, bunds, reservoirs, and weirs are also used to prevent and reduce the impact of flooding. Sea walls and artificial beach nourishment have been constructed to prevent coastal flooding in several cities in Europe. For example, in the city of London a huge mechanical barrier, the Thames barrier, across the River Thames has been constructed to prevent flooding. This barrier is raised when the water level reaches a certain point. Another interesting example is Venice, which has a similar arrangement, although it is already unable to cope with very high tides. Needless to mention even in these developed countries, there are always reports of property damage and disruption of life. Despite the availability of flood control structures and proper land use planning, floods still do occur. This disrupts normal life.

Because of the topography, areas in the low-lying coastal areas and rivers are at the greatest threat from flood disasters. Heavy rain can result in increase in the water level of streams and rivers. The people living near the coastal regions also are at risk from floods.

Case Study: Kerala Floods, 2018: Calamity of a severe nature

Kerala in August, 2018 received heavy monsoon rainfall. This was about 256% more than the usual rainfall in the state. Further, approximately 65% of the dams in the state were opened. All five overflow gates of the Idukki Dam were opened simultaneously. The secondary effects of heavy rains were severe with landslides in some regions. It was the worst flood in Kerala. The Government of India classified it as a Level 3 Calamity, or "calamity of a severe nature". About one-sixth of the total

populations of the state were directly affected by the floods. The rescue and relief operations were coordinated by the National Crisis Management Committee. Some reasons for the disaster of this scale are because for the first time, 35 of its 54 dams were opened. Added to this, the sudden release of water from the Mullaperiyar Dam by the Tamil Nadu government aggravated the situation. Another factor could be due to the discharge of excess water from 80 reservoirs across the state.

Source: https://www.downtoearth.org.in/news/kerala-floods-reveal-the-horror-that-is-climate-change-61435

3.2.2 Causes of Floods

Floods have been occurring throughout geological history of the earth. It will occur as long as the water cycling occurs. Precipitation is one of the main sources for water for streams. For example, in drainage basins, the precipitation amount falling varies on a daily, yearly and centennial basis. Thus, from a geological point of view, floods are a natural outcome of stream flow in a dyanamic environment.

a) ***Precipitation*:** Weather patterns determine and control the amount and location of precipitation. This includes rainfall and snow. This can vary from area to area. Overall, the water cycle is a balanced system. Though water flowing into one part of the cycle is balanced by water flowing back to the ocean, sometimes the amount flowing in to one area is greater than the capacity of the system to hold it within natural confines. This results in a flood. Various factors along with exceptional precipitation can also lead to flooding. For example, heavy snow melts, water saturated ground, unusually high tides, and drainage modifications when combined with heavy rain can result in flooding.

b) ***Coastal Flooding:*** Coastlines get subjected to flooding as a direct result of tsunamis, hurricanes and unusually high tides. Even long term processes like subsidence and rising sea level as a result of global warming can lead to the encroachment of the sea on to the land.

c) ***Dam and Levee Failures:*** Dams can be either natural or man-made. Natural dams are created by natural processes. For example, volcanic events (lava flows and pyroclastic flows), landslides, or blockage by ice. Dams are constructed or single or multiple purposes. The utility of dams is for storing water, electrical power generation and to act as flood control structures. All dams can fail. This can cause sudden release of water into the downstream drainage. Some examples of dam and levee failures include that resulting in flooding downstream include:

- The St. Francis Dam, near Saugus, California, failed in 1929 killing 450 people.
- The Johnstown, Pennsylvania dam, built of earthen material (soil and rock) collapsed after a period of heavy rainfall in 1889. 2,200 people were killed by the flood.
- The Vaiont Dam in Italy did not fail in 1963, but the landslides that moved into the reservoir behind the dam caused water to overtop the dam killing over 3,000 people.
- During the Hurricane Katrina in New Orleans (August 2005), levee systems designed to prevent flooding failed and lead to catastrophic flooding and loss of life.

d) ***Cloudbursts:*** It is an extreme amount of precipitation in a short period of time. It can be accompanied by hail and thunder that is capable of creating flood conditions.

3.2.3 Types of Floods

Let us now learn about the different kinds of floods and the extent of floods. Floods can be rapid or slow. It could also be classified as riverine, estuarine, coastal, catastrophic or muddy floods.

a) Riverine Floods: Heavy rains from monsoons, hurricanes and tropical depressions causes riverine floods which are slow but rapid riverine flooding is caused by intense thunderstorm.

b) Estuarine Floods: Storm force winds generate sea tidal surges which can flood estuarine areas.

c) Coastal Floods: Tsunami, hurricanes and severe sea storms are known to flood coastal areas.

d) Catastrophic Floods: Catastrophic events like earthquakes, volcanic eruptions and dam failure cause these types of floods.

e) Muddy Floods: Runoffs on croplands can result in muddy floods.

Case Study: Assam floods, 2016

The Assam floods in July 2016 were caused by large rains over the state of Assam, India. The state of Assam received around 60% more rains when compared with the rainfall in July 2015. The flooding had affected about 1.8 million people. People abandoned their households and livestock and escaped with help of homemade rafts. The rainfall resulted in flooding of various rivers. The Brahmaputra River had crossed its danger mark level in the seven districts of Lakhimpur, Dhemaji, Nagaon, Jorhat, Golaghat, Morigaon and Biswanath. It also flooded the Kaziranga National Park-famous for the Rhinos. Severe flooding affected the mobile phone networks. Power transmission in many regions of the state was out of gear. Around 200,000 hectares of farming land was affected by the floods.

Check Your Progress 1

Note: a) Write your answer in about 50 words.
b) Check your progress with possible answers given at the end of the unit.

1. What are the causes of flooding?

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2. Describe the types of floods.

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3.3 ENVIRONMENTAL EFFECTS OF FLOODING

Let us see how the flooding affects the environment. Hazards associated with flooding can have primary or secondary or tertiary effects. Primary effects occur due to direct contact with water. Secondary effects occur because of the flooding event. They cause famine and health disease outbreaks. They can also cause disruptions in essential services. Tertiary effects include changes in the position of river channels.

3.3.1 Primary Effects

They occur as a result of immediate and direct contact with the flood waters. In this case, the velocities of the flood waters tend to be high. As discharge increases the velocity also increases.

a. Higher velocities can transport larger particles such as suspended particles, rocks and sediment. Further, large objects such as automobiles, houses and bridges can also be disrupted and transported.

b. Erosion can occur at very large scales due to floods. These erosion processes can undermine bridge structures, levees, and buildings. As a result these structures can collapse.

c. Water entering human built structures cause water damage. Even with minor flooding of homes, furniture, floors and walls are damaged. Automobiles are also affected by flooding.

d. When the flood waters retreat, sediment or a thick layer of stream deposited mud is deposited.

e. Flooding of farmlands causes damages to crops. Livestock, pets, and other animals are often carried away by floods.

f. Human beings can get drowned in the flood waters in extreme cases.

3.3.2 Secondary Effects

Secondary effects are those that occur as a consequence of the primary effects. Among the secondary effects of a flood are:

a. Drinking water supplies can get contaminated and there are health risks, if sewerage treatment plants are affected. This is more commonly observed in under developed countries.

b. Floodwaters can result in the accumulation of solid wastes and some pollutants. This can cause the secondary effects of health hazards.

c. Gas lines may leak and electrical service may be disrupted.

d. Transportation systems may be affected. It can result in the reduction of food supplies. Such food shortages have been reported to cause starvation in many under developed countries.

3.3.3 Tertiary Effects

Tertiary effects occur as a result of the long term changes that take place. They include the following:

a. Shifting of river channels may occur. New river new channels can form and the old channels may dry.

b. Sediment deposited as a result of flooding can totally devastate vast agricultural lands. The silt deposited by floodwaters is useful in increasing agricultural productivity.

c. Changes in of ecology of the area.

Check Your Progress 2

Note: a) Write your answer in about 50 words.
b) Check your progress with possible answers given at the end of the unit.

1. What are the primary effects of floods?

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2. What are the secondary and tertiary effects of floods?

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3.4 DROUGHTS

Unlike cyclones, tornadoes, hurricanes which tend to bring high quantities of rainfall; a drought is a period of abnormal dryness in a region. When a region experiences a noticeable deficit in water supply or rains for extended periods such as months or years, a drought occurs. A region is termed drought affected when it receives consistent below average precipitations. Intense drought can cause significant damage to the local economy. Droughts as hazards are unique in the sense that they are slow onset hazards. They may lead to secondary effects like famine. It damages the ecosystem and agriculture of the affected region.

3.4.1 Drought Consequences

It can have significant environmental, agricultural, health, socio-economic consequences. The consequences of drought vary according to vulnerability. People working on farming and agriculture migrate during drought because they do not have alternative food sources. Drought can reduce the quality of water and result in contamination. This is because the lower water flows reduce dilution of pollutants and thereby contaminate water supplies.

Do you think drought can have consequences? Let us now learn them in following paragraph.

- Decreased crop growth
- Decreased carrying capacity for livestock
- Erode the landscapes
- Dust storms
- Famine can occur as a result of low water for irrigation
- Health problems such as malnutrition and dehydration
- Habitat and ecosystem damage
- Mass migration, resulting in internal displacement
- Shortage of water for industrial users
- Disputes over natural resources, including water and food and social unrest
- Wildfires.

3.4.2 Stages of Drought

Droughts undergo three critical stages before their ultimate manifestation.

- Meteorological drought: This precedes the other kinds of drought. This occurs when there is an extended period with less than average precipitation.
- Agricultural droughts: They affect the crop production of the region. It also occurs as a result of extended periods of below average precipitation.
- Hydrological drought: This stage of drought occurs when the water reserves in aquifers, lakes and other reservoirs falls down below the statistical average.

Some Case studies: Drought in India

The Indian agriculture is dependent on the climate of India which is a favourable southwest summer monsoon. This is critical in securing water for irrigating Indian crops. In certain parts of India, the failure of the monsoons result in water shortages, resulting in below average crop yields. This is particularly true for the major drought-prone regions such as southern and eastern Maharashtra, northern Karnataka, Andhra Pradesh, Orissa, Gujarat, and Rajasthan. In the past, droughts have periodically led to major Indian famines, including the Bengal famine of 1770, in which up to one third of the population in affected areas died; the 1876–1877 famine, in which over five million people died; and the 1899 famine, in which over 4.5 million died.

Source: https://www.deccanherald.com/national/stares-drought-rains-elude-682491.html

3.5 LANDSLIDES

Down slope movement of small stones, soil and rock fragments, even if very slow should not be underestimated. These processes can ultimately result in landslide hazards. When rocks, soils, artificial fill move downward, landslides can occur. These are also known as slope forming materials. These materials can move by the following ways: falling, toppling, sliding, spreading, or flowing. Landslides or mass wasting is the down-slope movement of regolith (loose uncemented mixture of soil and rock particles that covers the Earth's surface) due to gravity. It occurs without the help of geological agents such as water, ice, or wind. Contributory factors include soil saturation from rainfall or seepage, or human activity (i.e. vegetation removal, construction of roads, railways or buildings on steep terrain). In some cases they can also be natural hazards like earthquakes, volcanoes. Down slope displacements of regolith, rock, and soil are referred to as landslides. It can also occur under the sea, it is better to term them as mass movements. Mass movements are one of the most serious hazards in areas with steep slopes. Mass-wasting is part of a continuum of erosion processes between weathering and stream transport. Mass-wasting causes regolith to move down-slope. Sooner or later the loose particles will be picked up by another geological agent. It will eventually be moved to a site of deposition such as an ocean basin or a lake bed. In order for regolith to move in a mass wasting process, it must be on a slope, since gravity will only cause motion if the material is on a slope.

3.5.1 Causes of Landslides

When the stability of the slope changes landslides occur. The change is from a stable to an unstable condition. Such changes in slope stability may be caused due to multiple factors. They can act together or alone. They can be due to natural or anthropogenic reasons.

a) Natural causes include:

- pressure of groundwater that causes slope destabilization
- little or no vertical vegetative structure,
- absence of soil nutrients/structure
- erosion of the top of a slope by rivers or ocean waves
- weakening of a slope through saturation by snowmelt, glaciers melting, or heavy rains
- earthquakes adding loads to barely-stable slopes or earthquake-caused liquefaction destabilizing slopes volcanic eruptions

b) Human induced causes include:

- vibrations from machinery or traffic
- mine and blast activities
- certain types of earthwork which changes the slope shape
- the removal of deep-rooted vegetation that binds colluvium to bedrock
- Construction, agricultural, or forestry activities which change the amount of water which infiltrates into the soil

3.5.2 Failure of Slope

Failure of slope is a significant natural hazard. Slope failure can be defined as a downward movement of a large amount of material. They can occur suddenly in one easily recognized movement. It may also occur almost imperceptibly over a long period of several years. A slope failure is classified based on its movement and the material type being moved. It damages highways, homes, and other property. These occur due to natural events like earthquakes, heavy rainfall from thunderstorms, volcanic eruptions, floods, freezing and thawing of soil. Slope failure events and their scientific analysis have confirmed that almost any modification of a slope by people increases the risk of slope movement. This is particularly true in areas already susceptible to natural hazards.

1. Factors Leading to Slope Failures:

Regions situated in the mountainous terrains, hills and coastlines are prone to slope failures. Tectonically active regions are prone to slope failures. Earthquakes and volcanic activity in most cases accompany slope failures. Sinkholes are a common geological feature in karst landscapes, where water has dissolved underlying bedrock, typically limestone or gypsum. It causes subsidence and slope failures. Slope failures can occur in any season. But, they can be triggered by extreme weather events such as rain,

snow, or freezing and thawing of soil water. Slopes can become unstable when streams erode their banks or surf action undercuts a slope (Figure.3.3).

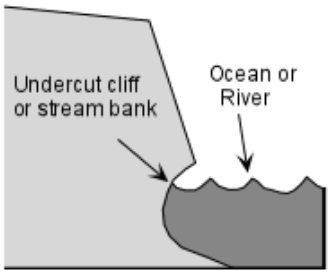

Fig. 3.3: Undercutting

Slope failures can occur nearly everywhere slopes exist. This can be triggered by weather conditions, geologic events, human modification of the landscape, or most commonly, some interaction of all of the above (Figure 3.4).

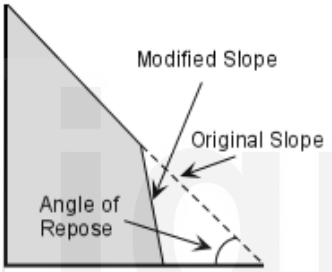

Fig. 3.4: Unstable Slopes due to Slope Modification

3.5.3 Factors that Affect Mass Movement

- ***Rate of Land Movement:*** This can be exceptionally slow, only a few centimetres per year (which can damage roads, buildings, pipelines, etc). This can also be sudden total collapse or avalanche of perhaps millions of tonnes of debris, with the potential to crush vehicles, buildings and people, or to sweep away roads, power and telephone lines.
- ***Degree of Land Movement:*** The distance travelled by landslide debris can also vary by many degrees. This may range from a few centimetres to many kilometres. It can occur when large mudflows follow river valleys.

Two types of forces combine in any type of mass movement: Driving forces that promote movement and resisting forces that deter movement. The material on the slope breaks loose and moves down slope whenever the driving forces are greater than the resisting forces.

1. Driving Forces:

i) Gravity: Steeper the slope, the greater is the tendency of materials to move down slope. Gravity is the primary driving force. It can be influenced by human activity. When a portion of a slope moves downward as a result of either, natural conditions or human activity, this process is known as slope failure.

ii) **Rock Structure:** Rock structure can be an important driving force. Rocks are far from being completely solid and most have pore spaces. These pore spaces allow water and air to infiltrate. Rocks can break along natural fractures and joints in the rock caused by stress. In all highway and building construction, engineering geologists conduct studies to determine the stability of the slopes when building highways, railways, canals, and any type of construction site. Plate tectonic movements may cause rock layers to become tilted. The slope can become unstable if they're tilted in the same direction as the slope itself.

iii) **Water:** Water is an important driving force. Its role is complex as it acts as resisting force in certain circumstances. Water increases the weight of slope material by filling previously empty pores and fractures. This promotes mass movement. For example, a sandy slope can have up to 35% pore space. After a prolonged period of rain, the pores may be completely filled, increasing the weight of the sediment. This will increase the probability for movement by gravity. Water can decreases the strength of the rock or sediment by reducing cohesion among the particles. For example, water circulating in limestone can dissolve the calcium carbonate particles, reducing cohesion of the rock. Water can also infiltrate pore space, then freeze (frost heaving), breaking the rock apart. Water can create shrink-swell clays, which are a common hazard in the construction of building foundations. In clay-rich sediments, clay-sized particles attract and absorb water molecules, causing the sediment to swell to many times its original volume. The best known of these clays is bentonite. Between rains, these clay-rich sediments can shrink and contract, forming large surface cracks that can damage any structures built on top. Finally, clays can be turned to liquid in a process called liquefaction. Quick clay is formed by this process, and can occur when saltwater ions, which normally help to hold the sediment together, are flushed out and replaced with freshwater. Solid clay-rich sediment transforms to very unstable quick clay.

2. Resisting Forces

Water can also act as a resisting force to mass movement in certain cases. In sediment pore spaces that are not completely filled, the thin film of water actually makes the particles stick together due to cohesion. Water molecules that line the pore spaces tend to hold other molecules - this attraction is called surface tension, a force that holds water together.

The complex role of water can be appreciated by taking the sand castle as an example. Without water, it is impossible to build a sand castle. With just the right amount of water, one can build a sand castle because the water creates surface tension that holds particles together. When the sand castle becomes saturated with high tide, the castle breaks apart, because the pore spaces have been completely filled with water which is now a driving force.

The angle of repose is the maximum angle on a slope to which sediment particles can be piled. Some sediment can accumulate in large volumes, yet remain stable. Some factors that affect the stability of particles on a slope include:

- **Particle Size:** larger particles maintain a steeper slope than smaller particles.
- **Particle Shape:** particles with angular edges can have a steeper slope than ones with rounded edges
- **Particle Sorting:** poorly sorted particles have all sizes represented. These can have steeper slopes because the smaller particles can fill the spaces between the larger particles.
- **Particle Moisture:** particles with some water can have a steeper slope than particles with no or too much water.

Finally, particle packing will affect the ability of sediment to move down slope. Packing describes the arrangement of particles in sediment. Cubic packing occurs when grains are aligned with their centers above one another, and represents loose sediment. Rhombohedron packing occurs when the centers of the grains of sediment are located over the spaces between the grains. This type of packing occurs in sediments that have "settled" due to shaking or sorting by water movement.

Case Study: Landslides in Uttarakahand, 2010

Tectonic activities in the Himalayas contribute to hill slope instability.Anthropogenic interventions are additional factors contributing to terrain instability. This is the reason for the increasing frequency and magnitude of landslides observed since 1970. During the month of August and September 2010, Uttarakhand Himalaya witnessed large scale slope destabilization. This was evident along the roads where widening work was in progress. The landslides killed about 220 people in the entire rainy season of 2010 and 2138 houses were partially damaged due to heavy precipitation. The cause of regional-scale landslides has been attributed to exceptionally high rainfall in the region during September. In September 2010, 336% higher rainfall was received by the area when compared with the average rainfall for the month of August and September from 2000 to 2009. There are also suggestions that inadequate consideration of geology and geomorphology during the road alignment and poor, faulty engineering techniques were additional factors responsible for the recent landslides.

3.5.4 Effects of Landslides

- ***Landslides and Water:*** **One of the** main causes of landslides is the slope saturation by water. This effect can occur in the form of intense rainfall, snowmelt, changes in ground-water levels, and water-level changes along coastlines, earth dams, and the banks of lakes, reservoirs, canals, and rivers.
- ***Land Sliding and Flooding:*** They are closely connected. Both are related to precipitation, runoff, and the saturation of ground by water. These two events often occur simultaneously in the same area. Landslides can cause overtopping of reservoirs and/or reduced capacity of reservoirs to store water. In addition, debris flows and mudflows usually occur in small, steep stream channels and often are mistaken for flood. Landslides can cause flooding by forming landslide dams that block valleys and stream

channels, allowing large amounts of water to back up. This causes backwater flooding and, if the dam fails, subsequent downstream flooding. Also, solid landslide debris can "bulk" or add volume and density to otherwise normal stream flow or cause channel blockages and diversions creating flood conditions or localized erosion.

- ***Landslides and Seismic Activity:*** The occurrence of earthquakes in steep landslide-prone areas greatly increases the likelihood that landslides will occur. This is due to ground shaking alone or shaking-caused dilation of soil materials, which allows rapid infiltration of water. Widespread rock falls also are caused by loosening of rocks as a result of ground shaking. The 1964 Great Alaska Earthquake caused widespread land sliding loss due to the earthquake. Many mountainous areas that are vulnerable to landslides have also experienced at least moderate rates of earthquake occurrence in recorded times.

- ***Landslides and Volcanic Activity***: Volcanic lava can melt snow at a rapid rate, causing a deluge of rock, soil, ash, and water that accelerates rapidly on the steep slopes of volcanoes, devastating anything in its path and are some of the most devastating types. These volcanic debris flows (also known as lahars) reach great distances and can damage structures in flat areas surrounding the volcanoes. The 1980 eruption of Mount St. Helens, in Washington triggered a massive landslide on the north flank of the volcano, the largest landslide in recorded times.

- ***Landslide Effects on Buildings*:** Landslides can occur where the terrain has been altered geologically or anthropogenically and can damage buildings. As pressures on the ground increase, so does the likelihood of buildings being devastated.

- ***Landslide Effects on Plant-life:*** Landslides can affect plant-life and ecology. Any kind of plant-life in the slides way will get washed down with the slide. The steeper a slope, the more likely a slide will occur. The weaker rock and sediments are, the more prone they become to a landslide occurring. If land becomes saturated, the land may flow more easily.

Case Study: Good Landslide Risk Management Practice

This good management practice is reported in Hong Kong, China. On 18th June 1972, heavy rainfall resulted in two destructive landslides in Sau Mau Ping and Po Shan Road in Hong Kong. It killed one hundred and thirty-eight people and a high-rise building also collapsed. In 1977, a Geotechnical Engineering Office was set up. The main objective was to implement a comprehensive system to maintain slope safety. The key components of the system included: comprehensive enforcement of geotechnical standards, community participation for slope safety, systems for early warning and emergency response., They also created comprehensive databases of landslide events and implemented various risk mitigation measures. As a result of the implementation of the Slope Safety System. For about a decade, there has been no fatalities. Among the natural hazards Landslides are considered potentially manageable. There are now available a range of approaches and techniques to reduce the level of hazard. There is ample scope to reduce their impacts.

Check Your Progress 3

Note: a) Write your answer in about 50 words.
b) Check your progress with possible answers given at the end of the unit.

1. What are landslides?

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2. How does slope failure occur?

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3.6 LET US SUM UP

In this unit we have studied about the floods, its types and causes of floods. We have also understood why drought occurs. The unit also discusses how drought proceeds from the initial stage to the most severe stage and when famine can occur. We have also discussed the driving and resisting forces in the landslide occurrence. We have analyzed the causes and effects of landslides. In conclusion, the chapter gives an overview of these hazards.

3.7 KEY WORDS

Floods : Additional amounts of precipitation more than the average amounts can result in streams to run out of its confines. This results in flooding.

Landslides : Down slope movement of small stones, soil and rock fragments, even if very slow should not be underestimated. These processes can ultimately result in landslide hazards.

Droughts : A drought is an extended period (of months or years) when a region experiences a noticeable deficiency in water supply.

Hydrological cycle : Water is in constant motion in the earth in a cycle. This is called hydrological cycle.

Sinkholes : They are a common geological feature in karst landscapes, where water has dissolved underlying bedrock, typically limestone or gypsum.

3.8 REFERENCES AND SUGGESTED FURTHER READINGS

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3.9 ANSWERS TO CHECK YOUR PROGRESS

Answers to Check Your Progress 1

1. Your answer should include the following points:
   - **Precipitation**
   - **Coastal Flooding**
   - **Dam and Levee Failures**
   - Cloudbursts
2. Your answer should include the following points:
   - Riverine floods
   - Estuarine floods
   - Coastal floods
   - Catastrophic floods
   - Muddy floods

Answers to Check Your Progress 2

1. Your answer should include the following points:
   - The primary effects of floods are those due to direct contact with the flood waters. Water velocities tend to be high in floods. As discharge increases velocity increases.
   - Give examples
2. Your answer should include the following points:
   - Secondary effects are those that occur because of the primary effects
   - Tertiary effects are the long term changes that take place.
   - Give examples

Answers to Check Your Progress 3

1. Your answer should include the following points:
   - Downward movement of slope-forming materials (like rock, soil, artificial fill, or a combination) can lead to landslides. These materials can move by the following ways: falling, toppling, sliding, spreading, or flowing.

- Landslides or mass wasting is the down-slope movement of regolith (loose uncemented mixture of soil and rock particles that covers the Earth's surface) due to gravity.
- Write with case studies

2. Your answer should include the following points:
   - Failure of slope is a significant natural hazard.
   - Slope failure can be defined as a downward movement of a large amount of material.
   - These occur due to natural events like earthquakes, heavy rainfall from thunderstorms, volcanic eruptions, flooding, or even freezing and thawing of soil moisture.
   - Write some factors leading to slope failures