3.4 The human impact

Stability of slopes

Rates of mass movement can be altered by human activities, such as building or excavation, drainage or agriculture. Mass movements can be accelerated by destabilising slopes. Local erosion can be intensified by footpath trampling in recreational areas. Some mass movements are created by humans piling up waste soil and rock into unstable accumulations that move without warning. Landslides can be created by undercutting or overloading. Most changes to slopes caused by human activities have been very minor in relation to the scale of the natural land surface. Human interference with slopes tends to have been most effective in speeding up naturally occurring processes rather than creating new features.

In urban areas, the intensity of slope modification is often very high, given the need for buildings and roads to be constructed safely, using sound engineering principles. Almost all buildings with foundations cause some modification to the natural slope of the land, and even on flat sites, large modern buildings generally involve the removal of material to allow for proper foundations. Slope modification tends to increase as a construction moves on to steeper slopes. In these conditions, in order to provide a horizontal base plus reasonable access, a cut-and-fill technique is often used (Figure 3.27), thereby creating a small level terrace with an over-steepened slope at both ends. The steep slopes, devoid of soil and vegetation, are potentially much less stable than the former natural slope and are, in times of intense rainfall, susceptible to small but quite damaging landslips.

Strategies to reduce mass movement

As well as causing mass movements, human activities can reduce them (Table 3.6).

Table 3.6 Examples of methods of controlling mass movement

Type of movement	Method of control
Falls	Flattening the slope Benching the slope Drainage Reinforcement of rock walls by grouting with cement, anchor bolts Covering of wall with steel mesh
Slides and flows	Grading or benching to flatten the slope Drainage of surface water with ditches Sealing surface cracks to prevent infiltration Subsurface drainage Rock or earth buttresses at foot Retaining walls at foot Pilings through the potential slide mass

Source: Goudie, 1993

Pinning is used to attach wire nets (or sometimes concrete blocks) to a rock face or slope so that the risk of rock falls is reduced or the risk of erosion is reduced. **Netting** may help collect fragments of scree, which can be safely removed at a later date. This is often used in areas where tourism is important, and where the risk of rock fall is high.

Grading refers to the re-profiling of slopes (see Figure 3.27) so that they become more stable. Afforestation is the planting of new forest in upper parts of a catchment to increase interception and reduce overland flow. They may take many years to be effective as the young, immature trees intercept relatively small amounts of water.

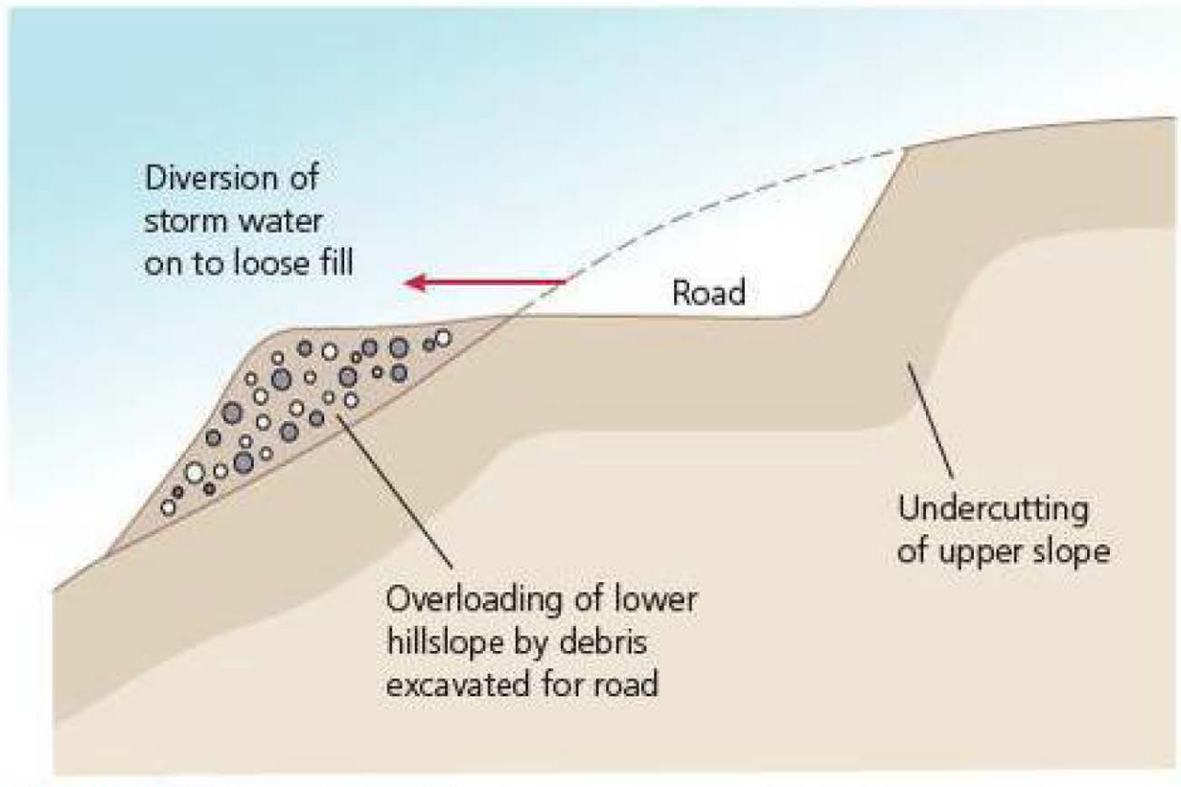
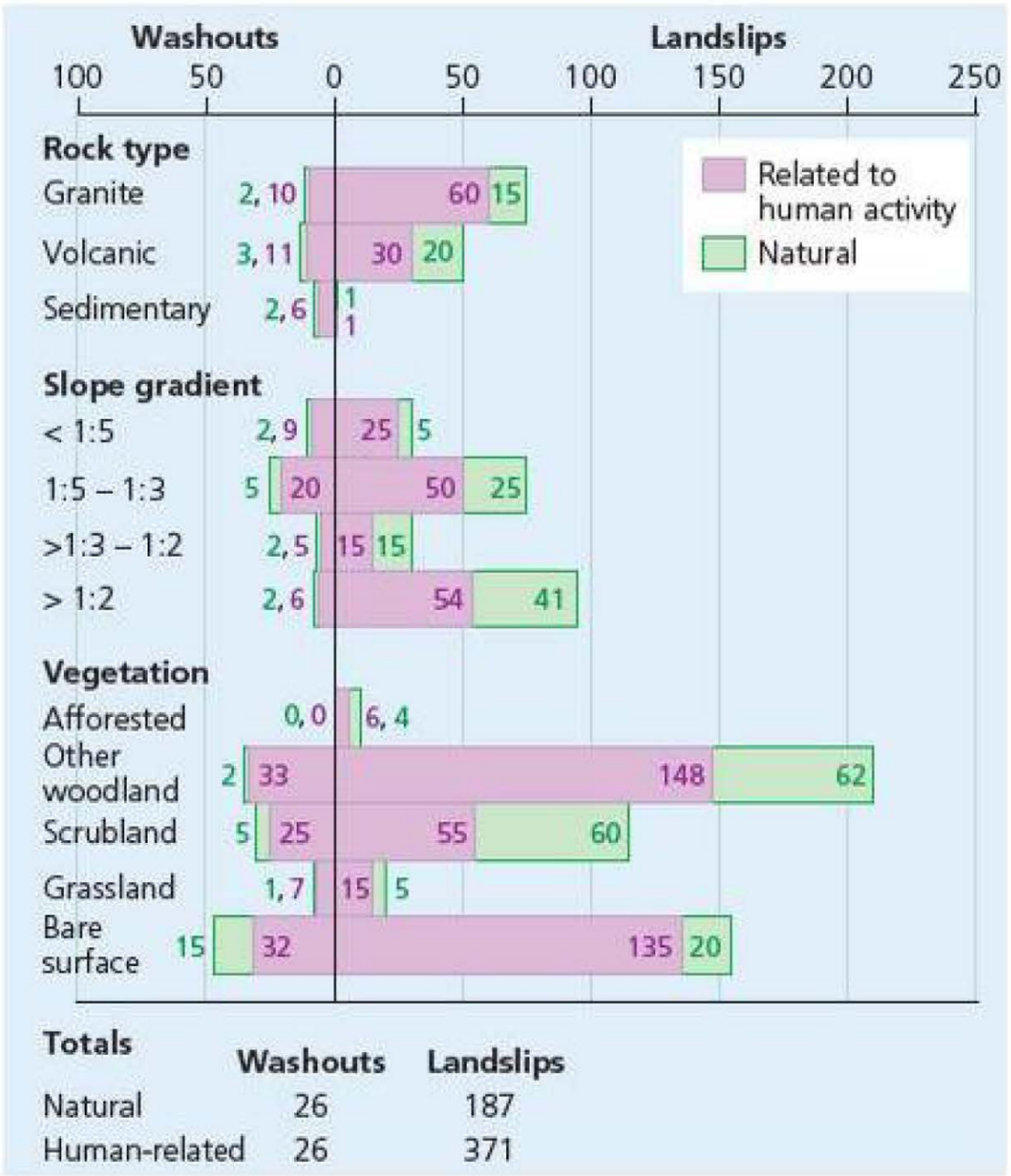


Figure 3.27 Slope instability caused by road building

Case Study: Landslides in Hong Kong

Hong Kong has a long history of landslides – largely due to a combination of high rainfall (the wet season is from May to September), steep slopes and dense human developments on the islands (Figure 3.28). Between 1947 and 1997, more than 470 people died as a result of landslides.



Totals	Washouts	Landslips
Natural	26	187
Human-related	26	371

Figure 3.28 Number of mass movements per 100 km² in Hong Kong in the 1960s and 1970s

In June 1966, rainstorms triggered massive landslides that killed 64 people. Over 2500 people were made homeless and a further 8000 were evacuated. Rainfall had been high for the first ten days in June. Over 300 millimetres had fallen, compared with 130 millimetres in a normal year. On 11 and 12 June, over 400 millimetres fell – nearly a third of this occurred in just one hour! By 15 June, the area had received over 1650 millimetres of rain. Over 700 landslides were recorded in Hong Kong that month.

Some geographers believe that vegetation increased the problem. The trees held back many of the smaller landslides and allowed the larger ones, **washout**, to occur. Other forms of landslides included debris avalanches and rockslides.

At 1075 km², Hong Kong is one of the most densely populated urban areas worldwide, with a population of over 7 million (2015). It consists of the main island of Hong Kong, the peninsula of Kowloon, the New Territories and more than 230 islands with natural steep terrain and hills. The upper slopes are steeper than 30°. Most of the population is concentrated along the less steep urban areas on both sides of Victoria Harbour (Figure 3.30). With urban development, landslides are triggered by excavation and building works (Figures 3.31 and 3.32).

Figure 3.29 Hong Kong landscape

Figure 3.30 Map of Hong Kong showing Victoria Harbour

Figure 3.31 Landslide warning sign

Figure 3.32 Steep slopes and dense urban development combine to create a landslide risk

Geology

The geology of Hong Kong is constructed mainly from three rock types: sedimentary rocks, granites and volcanic rocks. The sedimentary rocks generally form the lowlands. The granites and volcanic rocks, however, are situated on higher ground and are prone to failure. Both are seriously weathered, although granite rocks tend to be weathered more deeply than volcanic rocks. Volcanic rocks are more resilient and less prone to weathering and therefore less prone to slope failure.

Managing landslides in Hong Kong

The Hong Kong government has a responsibility to manage landslides. The Slope Safety System is managed by the Geotechnical Engineering Office (GEO) of the Civil Engineering Development Department (CEDD). The GEO has a staff establishment of over 700 for its wide range of activities. The GEO maintains its slope safety through investigating and researching the causes of significant and serious landslides to improve the Slope Safety Systems. The GEO is continuously updating, maintaining and disclosing the Catalogue of Slopes, which contains information of some 57 000 sizeable man-made slopes in Hong Kong.

One of Hong Kong's government interventions is to ensure that the private owners of slopes take responsibility for slope safety. If a slope owner does not comply with the regulation, prosecution will lead to a HK$50 000 fine, and to imprisonment for up to one year.

The government intervention in Hong Kong has had successful results. The risk from landslides has been reduced by 50 per cent since 1977. However, as a result of continued population growth, developers increasingly build further up the slopes. The risk from landslides, therefore, increases and the damages from a potential slide become greater.

Figure 3.33 Drainage channel

Maintenance of slopes

Since heavy rainfall and surface runoffs are contributing to slope failure in Hong Kong, it is vital to remove excess water from slopes. Surface draining systems and protective covers are two methods used to protect slopes.

Surface drains are very vulnerable to blockage. Without proper drain maintenance, landslides are more common than on slopes without drains. Unfortunately, due to confusion over the responsibility, many drains are not properly maintained.

Man-made slopes are one of the main methods of slope stabilisation used in Hong Kong. These contain drains to intercept and direct water away from the slopes. The slope is usually protected from infiltration and the erosive effects of water by impermeable hard covers.

Greening techniques refer to the use of natural vegetation to reduce the risk of mass movements. There are three main types of greening techniques that are used in Hong Kong:

- The mulching system provides a protective cover that makes it possible for natural vegetation to grow on the slope; a natural vegetative cover is able to grow through the mat, securing it in place.
- The use of **long-rooting grass** is a fast and cost-effective system to cover man-made slopes. This system is applied by drilling planter holes into a hard cover. The drilled hole is then filled with soil mix and fertilisers, and finally the long-rooting grass is planted within.
- The **fibre reinforced soil system** is constructed by mixing polyester fibre into sandy soils. This mixture is capable of resisting tension.

Some of the advantages of greening techniques are outlined in Table 3.7.

Table 3.7 The advantages of greening techniques

Greening techniques	Advantages
Mulching system	Higher adhesive capacity on steep slopes High resistance to rain erosion High water-retaining capacity Long-lasting fertilisers Adaptable to rough surfaces
Planting long-rooting grass	Natural and environmentally friendly Cost-effective Fast and easy installation Can be applied on steep slopes Low maintenance
Fibre reinforced soil system	Self-sustained vegetation system with low maintenance Fibre strengthens soil particles to prevent erosion Visual improvement of the slope with various plant species Restoration of natural habitats on the slope

Section 3.4 Activities

1 Using the data in Table 3.8, draw a climate graph for Hong Kong. Describe the main characteristics of Hong Kong's climate.

Table 3.8 Climate data for Hong Kong

Month	Average temperature (°C)	Rainfall (mm)
January	16	30
February	15	60
March	18	70
April	22	133
May	25	332
June	28	479
July	28	286
August	28	415
September	27	364
October	25	33
November	21	46
December	17	17
Average/total	**23**	**2265**

2 Study Figure 3.28, which provides details of landslides in Hong Kong.
   - **a** Using the data, describe and explain the relationship between mass movements and **i** rock type, **ii** gradient and **iii** vegetation.
   - **b** What type of mass movement was most common in Hong Kong?
   - **c** What do you think is the difference between a washout and a landslip? Give reasons for your answer.
   - **d** Which type of rock was most affected by **a** washouts and **b** landslips?
   - **e** What type of mass movement most affected **a** granite and **b** volcanic rocks? How do you explain these differences?
   - **f** What is the relationship between gradient and mass movement? Give reasons for your answer.
   - **g** What impact does vegetation have on the type and number of mass movements? Briefly explain your answer.
   - **h** Briefly discuss the impact of human activity on mass movements. Use the evidence in Figure 3.28 to support your answer.
3 Study Figure 3.30, a map of Hong Kong. Using map evidence, suggest why landslides are a hazard in Hong Kong.
4 Suggest how population growth in Hong Kong contributes to the landslide hazard.
5 Describe the methods of landslide management that are used in Hong Kong.