Answer Key

Answers to Study Questions

1. *Mass wasting* is a collective term referring to the movement of Earth material down a slope under the influence of gravity.

2. The term *landslide* describes the perceptible movement of soil or rock down a slope. The movement can range in speed from slow to quite rapid.

3. Scientists use different systems to classify mass wasting. The course textbook classifies mass wasting by the following three variables:
   - the rate of movement of Earth material down a slope,
   - the type of material involved, and
   - the character of the movement.

4. *Engineering soil* describes any loose or unindurated (unconsolidated) Earth material.

5. *Debris* describes a soil in which the proportion of coarse fragments predominates over finer fractions. *Earth* is a term used when soils chiefly comprise fine-grained components such as clay, silt, and sand. Mud is material largely made up of water, clay, and silt.

6. In a flow, the material moving downslope travels as a viscous fluid. In a slide, however, the moving Earth material moves as a block along a distinct surface.

7. In a translational slide, the material moving downslope travels along a plane parallel to the plane of the surface. In a rotational slide, however, the movement takes place on a curved surface such that the top part of the moving block moves down while the lower part moves up.

8. Climate can both weaken and strengthen stability on slopes, largely through its effect on vegetation that grows in a region. Climates characterized by moderate rain distributed throughout the year promote dense vegetation. Such vegetation has extensive root networks that bind earth materials on slopes, promoting stability. Climates where rainfall is heavy and confined to a limited part of the year elevate the chance of mass wasting. Mass wasting is also promoted by repetitive freezing and thawing cycles.

9. The shear strength of a soil refers to its ability to resist movement of deformation. The factors that influence shear strength include cohesiveness of the material, interparticle friction, pore pressure of water, the ability of roots to hold the soil together, and the normal force exerted by the Earth material on the slope.

10. The influence of water on slope material depends on the amount of water contained in the soil. Where soil pore spaces are saturated with water, the pore pressure of the water forces the particles apart, making the soil less viscous. As a result, the slope material is more prone to downslope movement.

    On the other hand, when the pore spaces in soils are partially filled with water, the water forms a thin film around the grains, creating a surface tension that causes the soil particles to stick together. Surface tension enhances the shear strength of a soil.

11. Events that occur suddenly are capable of triggering landslides. Such events include earthquakes, in which sudden shaking can initiate movement. Heavy rainfall can trigger a landslide when water in the soil leads to a sudden rise in soil pore pressure.

12. *Creep* describes the slow movement of soil down a slope, usually at rates of up to about one centimetre per year. Factors that influence creep include the amount of water in the soil and the daily freeze-thaw cycles that result from temperature dropping at night and rising during the day. The increase in volume that occurs as ice forms during a freezing cycle is accompanied by an expansion perpendicular to the surface of the slope. Upon thawing, the contracting material experiences gravitational pull and moves down the slope.

13. Earthflows usually occur on slopes covered by thick sequences of loose soil composed predominantly of fine fractions. The earthflows themselves are often triggered by heavy rains, which saturate the pore spaces in the soils, making flow more possible.

14. *Solifluction* refers to the process where a soil, saturated by water, flows over another material that is impermeable. Such an impermeable material is usually provided by bedrock or permafrost. This impermeable unit allows water to accumulate in the overlying unit, so it becomes saturated.

15. A mudflow describes a mixture of water and soil that can flow. Soils in mudflows usually comprise predominantly fine grains such as clay, silt, and sand. Mudflows usually flow along channels or valleys. Mudflows often occur where there is little or no vegetal plant cover such as in arid terrains. Ash on volcanic mountain slopes can also form mudflows following heavy rains. Similarly, melting glaciers on volcanic mountains can form mudflows when the volcanoes erupt, giving out heat.

16. A *debris avalanche* is a rapidly moving debris flow. Debris avalanches are the fastest category of debris flow: they can attain speeds up to several hundred kilometres an hour. Debris avalanches usually comprise a mixture of debris, water, and air.

17. *Rockslide* describes the very quick slippage of rock that occurs on a slope along a surface of weakness such as bedding plane, a fracture, or a foliation plane. The distance moved can range from a few metres to thousands of metres.

    A *rock avalanche*, on the other hand, refers to those rockslides in which the movement is so fast that the rock breaks up into smaller constituents. In essence, movement in a rock avalanche takes place by flowage as opposed to slippage.

18. Settings in which underwater landslides occur include steeper sections of the sea floor. A number of large landslides have been identified off the Hawaiian Islands. Underwater landslides have also been reported to have been triggered by earthquakes, such as landslides identified off the northeastern coast of Canada.

19. Modification of natural slopes that occurs during construction can lead to slope instability. Examples of such modifications include the undercutting of a slope, which eliminates the support for the upper reaches of the slope, rendering it unstable. Clearing vegetation from a slope also removes the binding effect of vegetation, leaving the slope more susceptible to instability.

    Erecting buildings on slopes adds weight to the slope, which could trigger failure. Finally, construction work can lead to an increase in the amount of water that seeps into a slope. Such water could elevate pore pressure, ultimately weakening the slope.

20. Preventive measures that can be taken during construction to avoid slope failure include the erection of retention walls to support cuts made into the slope. To insure the viability of such retention walls, drainage pipes are installed that go through the retention wall to the material being supported. These drainage pipes allow for groundwater that would otherwise weaken the slope to be withdrawn.

    Making only gentle slopes should be practiced whenever possible. This can be achieved by constructing terraced slopes that avoid steep faces. Terracing also reduces the weight of the slope, lowering the shear force in the process. Planting vegetation on slopes is an effective measure for impeding erosion.

    Transportation routes through steep sections in mountainous terrain can be covered by reinforced concrete roof so as to allow passing debris or snow avalanches to migrate downslope without blocking the route.

21. The town of Oso, Washington is located in a wide valley that the Stillaguamish River created by cutting through terrace deposits. The terrace deposits comprise layers of gravel and sands that were laid down during the last glacial period. Due to the lack of finer sediments such as clay or silt that can bind the clasts together, the gravel and sand sediments form unstable landforms that are susceptible to sliding. Furthermore, downcutting of the weak sediments by the Stillaguamish River has formed steep slopes that slump easily. Just prior to the disaster of 2014, the area received more than twice its normal rainfall budget which weakened the slopes further, leading to the catastrophe of March 22. The fatalities were particularly high because previous efforts to depopulate the area had failed.

22. Structures such as joints, bedding planes, and foliation planes constitute planes of weakness in a landform. When such planes of weaknesses slope into the hill, rockslides cannot occur easily along those planes. In settings where the planes of weakness are parallel to the slope of the hillside, however, failure will likely result along those planes.