Answer Key

Answers to Study Questions

1. The hydrologic cycle refers to the natural transfer and exchange of water between land, sea, and air. This system demonstrates the linkages between the hydrosphere, geosphere, biosphere, and atmosphere.

2. Approximately 15-20% of rainfall usually ends up as surface runoff in rivers. Runoff rates may increase up to 100% with steady, persistent rainfall that leads to the saturation of the ground and the atmosphere.

3. The cross section of a stream close to its source is usually a v-shaped valley, and is often cut into solid rock. The stream itself occupies the narrow bottom of the valley, and no flood plains are found adjacent to the valley floor. Close to the mouth of the river, however, the cross section changes to a wide, flat-floored valley with a flood plain on either side.

4. Sheet erosion occurs when a thin surface layer, usually comprising top soil, is washed away by a sheet of water. This is usually produced by sheetwash, which develops when a thin layer of unchannelled water flows over the landscape.

5. A drainage basin refers to the aggregate area over which a stream and its tributaries drain.

6. In a radial drainage pattern, streams spread out from a focal point in a pattern similar to that of the spokes of a wheel. Elevated topography promotes the development of radial drainage patterns.

7. A dendritic drainage pattern is characterized by tributaries that form an outline similar to the branches of a tree. Such drainage patterns usually develop in rocks or material that erodes at a uniform rate. A trellis drainage pattern is constituted by a set of parallel main streams that develop short tributaries between the streams to merge with the streams orthogonally.

8. The two main factors that control stream erosion and deposition are a stream's velocity and discharge, of which velocity plays a greater role. Factors that influence a stream's velocity include gradient, channel shape, and channel roughness.

9. Silt and clay particles are more difficult to erode than sand grains because molecular forces operating on the surfaces of the sand and clay particles bind the particles together to form a cohesive body.

10. The gradient of a stream refers to the vertical distance through which a river's channel drops per unit of horizontal distance. In Canada (and other countries that use the metric system), the gradient of a river is measured in metres per kilometre. In the United States, the gradient is measured in feet per mile.

11. Hard, erosion-resistant rocks result in narrow channels. When a river flows through a constricted channel, its velocity increases. When flowing through soft rock that erodes more easily, however, the river carves out a broad channel. As the river passes through a broad section, its velocity slows down.

12. Whenever human activities reduce the cross-sectional area of a channel, it affects the velocity of the stream. For example, when a culvert or bridge is constructed across a stream and reduces its width in the process, the velocity of the stream will increase past that point.

13. In regions with humid climates, the discharge from streams increases because groundwater seeps into the stream channel through the stream bed. Also, the cumulative contribution by tributaries along the length of the stream adds to the net discharge from the stream. While rivers may increase their width and depth downstream in response to this increase in discharge, the channel modification alone may be inadequate to accommodate the increase. In such cases, the stream velocity may increase despite a reduction in the stream gradient.

14. Streams erode rock by hydraulic action, solution, and abrasion. *Hydraulic action* involves the picking up and transportation of sediments and rock by moving water. *Solution* describes the process through which soluble minerals and rocks are dissolved and transported by water. The grinding action provided by friction and impact from the sediment load onto the stream channel is called *abrasion*.

15. Hydraulic action of a stream refers to the picking up and transportation of sediments and rock by moving water. As moving water flows downstream, its force can break down rock or dislodge particles of sediments from their position of rest. Abrasion, on the other hand, describes the grinding action that results from friction by the sediment load on the stream channel. An increase in sediment load results in an increase in abrasion of a stream channel.

16. Sediment transported by streams can be classified into three main categories: bed load, suspended load, and dissolved load. The bed load travels on the streambed. Usually bed load is made up of heavy or large sediment particles that are transported along the streambed.

In contrast to bed load, suspended load remains suspended within the water body, because it is lighter. Silt and clay usually constitute the suspended load of the stream. The dissolved load comprises that component of sediment that travels in solution. This is usually made up of soluble ions produced by chemical weathering of rocks.

17. Bed load material travels on a streambed through processes of traction or saltation. Traction describes the movement of sediment along the streambed by rolling and sliding. Such actions may erode the stream channel or wear down other particles by abrasion. Hence, with traction, particles may never lose contact with the streambed.

    In contrast, saltation describes the movement of sediment by bouncing along the streambed in short leaps. The forces behind such short leaps are gravity and the alternating effects of turbulence and stillness of the water.

18. Materials that constitute soluble load come predominantly from chemical weathering. Such soluble ions include bicarbonate, calcium, potassium, sodium, chloride, and sulfate species.

19. Sediments are usually deposited in bars when the velocity of the stream or its discharge decreases such that the stream's capacity to carry sediment recedes. Bars are usually made up of gravel or sand.

20. Placer deposits form when products of weathering are selectively concentrated by the process of erosion such that valuable minerals form. Running water is the primary agent that carries away lighter, less valuable minerals, leaving behind heavier and mechanically-resistant sediments. Placer deposits may concentrate on river bars located on the inside of meanders, in depressions below waterfalls, or in potholes on the streambed.

    Minerals that can be obtained from placer deposits include gold nuggets, native platinum, gemstones, and oxides of tin and titanium.

21. When water flowing down a stream encounters a mid-channel bar, stream flow is deflected to the sides of the channel. The impact of the water against the stream bank may result in erosion, widening the channel.

    The development of braided streams is promoted by high sediment loads in the stream, especially bed load. Banks that erode easily also facilitate the development of braided streams, since these enable the channel to widen as mid-channel bars deflect water flow.

22. The sediment load of meandering streams is typically characterized by fine-grained silt and clay sediments. Such sediments are transported in suspension. Sediments are predominantly fine in the lower segment of a river's profile, closer to its mouth. Hence, meanders commonly develop in this region.

23. Point bars form from the deposition of sediment as the water moves around a meander. On the inner side of the curve, the water movement slows down, whereas on the outside, it accelerates. The lower velocity on the inside results in sediment being deposited to form point bars.

24. Flood plains can form in two main ways. In some settings, the deposits that form the flood plain comprise fine-grained sediments that are emplaced in horizontal layers when flood waters breach the channel. In other settings, however, the flood plain comprises sandy deposits deposited laterally as point bars by a meandering channel on top of coarse channel deposits. A thin unit of fine-grained sediments may be found at the surface, completing a fining upwards sequence.

25. Deltas form when sediment is deposited at points where a stream enters a body of still water such as a lake or a sea. As the water loses its velocity, the sediment in the stream is emplaced at the point of entry of the still water to form a delta.

26. The shape of a marine delta (viewed from above) is influenced by the amount of sediment supplied by the stream and the ability of waves and tides from the sea to erode the sediment deposited by the stream.

27. Whether a delta continues to exist as dry land or whether it becomes submerged in water depends on the rate at which sediments are supplied to the delta by the stream and the rate at which the land subsides. Subsidence may occur tectonically, or it may occur from the compaction of water-saturated sediment.

28. Alluvial fans form at the point of inflexion where the gradient of a narrow mountain stream transitions from high to low as the stream emerges on to a flat plain. The rapid loss of velocity forces the stream to deposit most of its sediment load to form an alluvial fan.

    Large alluvial fans are usually characterized by sediments that grade outwards with increasing distance from the mountain front. The sediments closest to the mountains are coarsest while those farthest from the mountain are finest. Small alluvial fans do not usually display any sediment grading.

29. Slot canyons are narrow valleys with nearly vertical sides. They occur in terrain where the rock is erosion resistant and stands vertically without collapsing and in areas where fractures in the rock are oriented in a preferable direction. Slot canyons are also likely to develop in settings where downcutting occurs rapidly, such as during flash floods. Generally, the development of the steep valley walls of slot canyons is rare because valley walls typically collapse due to mass wasting and sheet erosion to form V-shaped valleys.

30. Downcutting refers to the deepening of a valley as water erodes the bed of a stream. Lowering the base level of a stream results in greater downcutting rates. Conversely, raising the base level lowers the downcutting rate. A lowering of the sea level (such as occurs during an ice age) is one way in which the base level can be lowered, whereas a rise in sea level (such as from melting glaciers) results in a lowering of the rate of downcutting.

31. An ungraded stream refers to a stream with irregular, longitudinal profiles, displaying features such as rapids and waterfalls. Such a stream uses most of its energy to smooth out these gradient irregularities. As the stream smoothes out its course to form a longitudinal profile that takes on a concave-upward shape, the stream becomes graded. A graded stream has a balance between its ability to transport sediment and its available sediment load. It maintains this balance by smoothing out longitudinal irregularities in the stream profile.

32. Terraces can form when a river cuts into its own flood plain. This occurs when a stream changes from a depositional regime to an erosional one. Remnants of the flood plain that are left over can form bench- or step-like terraces. The transformation of a stream environment from depositional to erosional can occur under a number of scenarios:

    - A regional uplift event that raises a stream that is close to its base level to well above the base level would result in a episode of downcutting into the flood plain as the stream gradient is elevated.
    - If a climate changes from dry to wet, increased discharge in the stream would result in increased erosion, which may increase downcutting into the flood plain.
    - Downcutting into outwash deposits deposited by melting glaciers can produce terraces.

33. Sediment deposits from floods chiefly comprise silt and mud, which are usually transported by water as suspended load. When river water breaches the stream banks during a flood, it introduces a layer of clay and silt (mud) to the flood plain. This layer is typically fertile, and essentially rejuvenates the land, which can be of benefit for agricultural purposes.

34. The extensive paving and the construction of storm sewers that characterizes most urban development contributes significantly towards flooding. Paving of surfaces prevents the infiltration of water into the ground. Typically such water is directed to storm sewers for delivery to streams. Overall, river levels rise more rapidly when rain falls in paved areas than when it falls in unpaved regions, creating "flashy discharges." Such sudden discharges can cause floods.

35. Flash floods occur when the discharge in a stream increases suddenly, so that water spills over the banks of the stream. Typically, flash floods are localized and short-lived. They are caused by weather events such as thunderstorms.

36. Flood walls are designed to keep flood waters within their channel to protect adjacent land from water damage. Naturally, such structures constrict the channel, so stream velocity increases through the constriction. As the water continues further downstream, it flows with a higher velocity and erosive power than it would have in the absence of floodwalls.