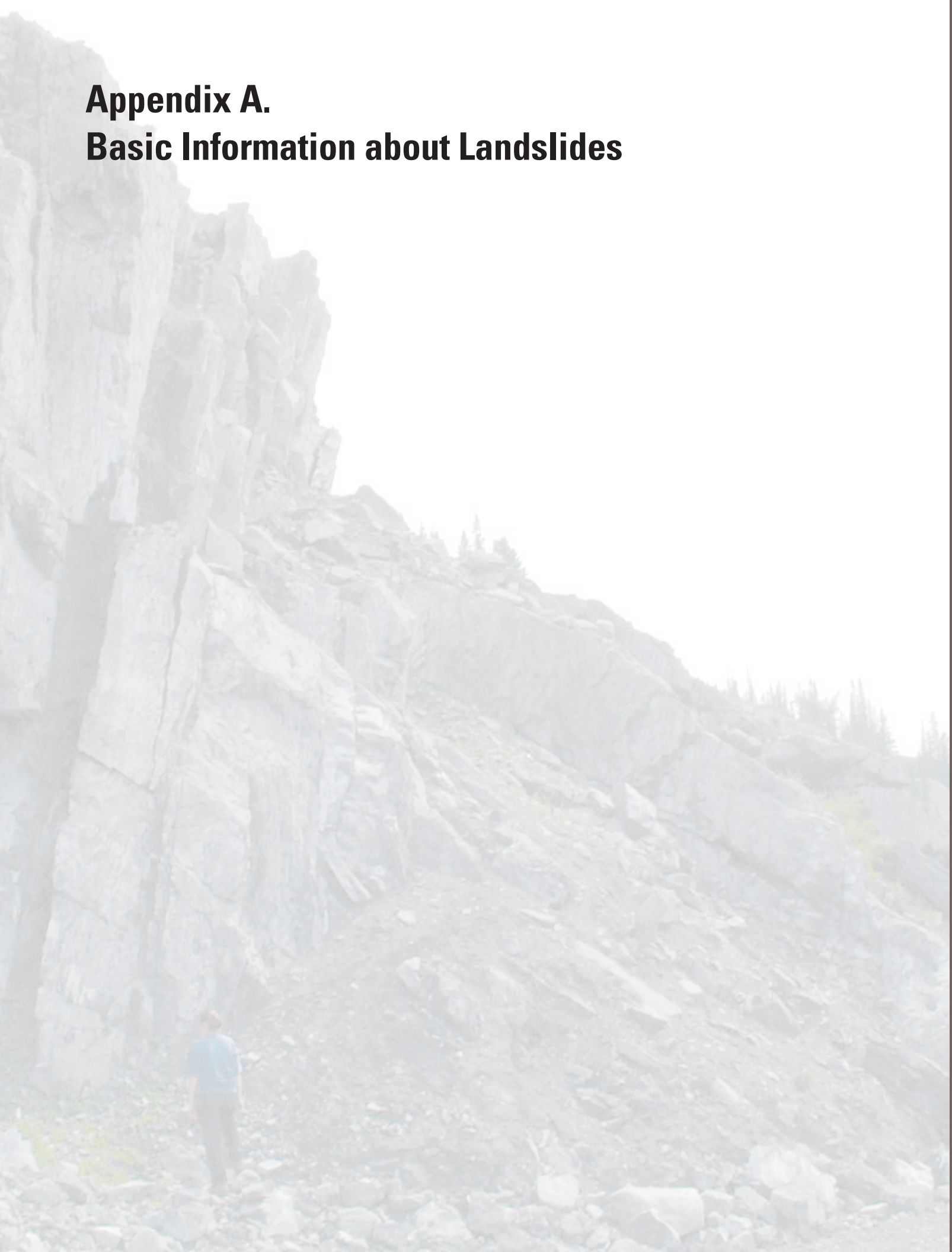
Appendix A.
Basic Information about Landslides



Part 1. Glossary of Landslide Terms

Full references citations for glossary are at the end of the list.

alluvial fan An outspread, gently sloping mass of alluvium deposited by a stream, especially in an arid or semiarid region where a stream issues from a narrow canyon onto a plain or valley floor. Viewed from above, it has the shape of an open fan, the apex being at the valley mouth. (Reference 3)

bedding surface/plane In sedimentary or stratified rocks, the division planes that separate each successive layer or bed from the one above or below. It is commonly marked by a visible change in lithology or color. (Reference 3)

bedrock The solid rock underlying gravel, sand, clay, and so forth; any solid rock exposed at the surface of the earth or overlain by unconsolidated superficial material. (Reference 3)

borehole A circular hole drilled into the earth, often to a great depth, as a prospective oil, gas, or water well or for exploratory purposes. (Reference 3)

check dams Check dams are small sediment storage dams built in the channels of steep gullies to stabilize the channel bed. A common use is to control channelized debris-flow frequency and volume. Check dams are expensive to construct and are therefore usually only built where important installations or natural habitat (such as a camp or unique spawning area) lies downslope. (Reference 2)

colluvium A general term applied to loose and incoherent deposits, usually at the foot of a slope or cliff and brought there chiefly by gravity. (Reference 2)

debris basin (*sometimes called catch basins*) A large excavated basin into which a debris flow runs or is directed and where it quickly dissipates its energy and deposits its load. Abandoned gravel pits or rock quarries are often used as debris basins. (Reference 3).

delta-front landsliding Delta fronts are where deposition in deltas is most active—underwater landsliding along coastal and delta regions due to rapid sedimentation of loosely consolidated clay, which is low in strength and high in pore-water pressures.

Digital Elevation Model (DEM) A digital elevation model (DEM) is a digital file consisting of terrain elevations for ground positions at regularly spaced horizontal intervals. (A commercial definition – new technology)

Digital Terrain Model (DTM) The term used by United States Department of Defense and other organizations to describe digital elevation data. (Reference 3)

drawdown Lowering of water levels in rivers, lakes, wells, or underground aquifers due to withdrawal of water. Drawdown may leave unsupported banks or poorly packed earth that can cause landslides. (Reference 3)

electronic distance meter (EDM) A device that emits ultrasonic waves that bounce off solid objects and return to the meter. The meter's microprocessor then converts the elapsed time into a distance measurement. Sound waves spread 1 foot wide for every 10 feet measured. There are various types available.

epicenter The point on the Earth's surface directly above the focus of an earthquake. (Reference 3)

expansive soils Types of soil that shrink or swell as the moisture content decreases or increases. Structures built on these soils may shift, crack, and break as soils shrink and subside or expand. Also known as swelling soils. (Reference 5)

extensometer An instrument for measuring small deformations, as in tests of stress. (Reference 3)

factor of safety The factor of safety, also known as Safety Factor, is used to provide a design margin over the theoretical design capacity to allow for uncertainty in the design process. The uncertainty could be any one of a number of the components of the design process including calculations and material strengths for example. Commonly, a factor of safety of less than 1, for instance, on an engineered slope indicates potential failure, where a factor of safety of greater than 1, indicates stability. (Reference 6)

geodesic/geodetic measurements The investigation of any scientific questions connected with the shape and dimensions of the Earth. (Reference 3)

fracture Brittle deformation due to a momentary loss of cohesion or loss of resistance to differential stress and a release of stored elastic energy. Both joints and faults are fractures. (Reference 3)

Geographic Information System (GIS) A computer program and associated data bases that permit cartographic information (including geologic information) to be queried by the geographic coordinates of features. Usually the data are organized in "layers" representing different geographic entities such as hydrology, culture, topography, and so forth. A geographic information system, or GIS, permits information from different layers to be easily integrated and analyzed. (Reference 3)

geologic hazard A geologic condition, either natural or manmade, that poses a potential danger to life and property. Examples: earthquake, landslides, flooding, faulting, beach erosion, land subsidence, pollution, waste disposal, and foundation and footing failures. (Reference 3)

geologic map A map on which is recorded the distribution, nature, and age relationships of rock units and the occurrence of structural features. (Reference 3)

geomorphology The science that treats the general configuration of the Earth's surface; specifically, the study of the classification, description, nature, origin, and development of landforms and their relationships to underlying structures, and the history of geologic changes as recorded by these surface features. (Reference 3)

geophysical studies The science of the Earth, by quantitative physical methods, with respect to its structure, composition, and development. It includes the sciences of dynamical geology and physical geography and makes use of geodesy, geology, seismology, meteorology, oceanography, magnetism, and other Earth sciences in collecting and interpreting Earth data. (Reference 3)

hydraulic Of or pertaining to fluids in motion; conveying, or acting, by water; operated or moved by means of water, as hydraulic mining. (Reference 3)

hydrology The science that relates to the water of the Earth. (Reference 3)

inclinometer Instrument for measuring inclination to the horizontal. (Reference 3)

landslide dam An earthen dam created when a landslide blocks a stream or river. (Reference 3)

lahar Landslide, debris flow or mudflow, of pyroclastic material on the flank of a volcano; deposit produced by such a debris flow. Lahars are described as wet if they are mixed with water derived from heavy rains, escaping from a crater lake, or produced by melting snow. Dry lahars may result from tremors of a cone or by accumulating material becoming unstable on a steep slope. If the material retains much heat, it is termed a hot lahar. (Reference 3)

liquefaction The transformation of saturated, loosely packed, coarse-grained soils from a solid to a liquid state. The soil grains temporarily lose contact with each other, and the particle weight is transferred to the pore water. (Reference 4)

landslide inventory maps Inventories identify areas that appear to have failed by landslide processes, including debris flows and cut-and-fill failures. (Reference 4)

landslide susceptibility map This map goes beyond an inventory map and depicts areas that have the potential for landsliding. These areas are determined by correlating some of the principal factors that contribute to landsliding, such as steep slopes, weak geologic units that lose strength when saturated, and poorly drained rock or soil, with the past distribution of landslides. (Reference 5)

landslide hazard map Hazard maps show the areal extent of threatening processes: where landslide processes have occurred in the past, where they occur now, and the likelihood in various areas that a landslide will occur in the future. (Reference 5)

landslide risk map Landslide hazards and the probability that they will occur, expressed in statistical recurrence rates; risk maps may show cost/benefit relationships, loss potential and other potential socioeconomic effects on an area and (or) community.

lithology The physical character of a rock, generally as determined at the microscopic level, or with the aid of a low-power magnifier; the microscopic study and description of rocks. (Reference 3)

loess A widespread, homogenous, commonly nonstratified, porous, friable, slightly coherent, usually highly calcareous, fine-grained blanket deposit (generally less than 30 m thick) consisting predominantly of silt, with subordinate grain sizes ranging from amounts of clay to fine sand. (Reference 3)

mitigation Activities that reduce or eliminate the probability of occurrence of a disaster and (or) activities that dissipate or lessen the effects of emergencies or disasters when they actually occur. (Reference 5)

mudslide An imprecise but popular term coined in California, USA, frequently used by the general public and the news media to describe a wide scope of events, ranging from debris-laden floods to landslides. Not technically correct. Please see "mudflow," next Glossary entry. (Reference 5)

mudflow A general term for a mass-movement landform and process characterized by a flowing mass of predominately fine-grained earth material possessing a high degree of fluidity during movement. The water content may range up to 60 percent. (Reference 3)

perched ground water Unconfined ground water separated from an underlying main body of ground water by an unsaturated zone. (Reference 3)

piezometer An instrument for measuring pressure head in a conduit, tank, or soil—it is a small diameter water well used to measure the hydraulic head of ground water in aquifers. (Reference 3)

pore-water pressure A measure of the pressure produced by the head of water in a saturated soil and transferred to the base of the soil through the pore water. This is quantifiable in the field by the measurement of free water-surface level in the soil or by direct measurement of the pressure by means of piezometers. Pore-water pressure is a key factor in failure of a steep slope soil and operates primarily by reducing the weight component of soil shear strength. (Reference 2)

pore water, or interstitial water Subsurface water in an interstice, or pore. (Reference 3)

quick clay A clay that loses nearly all its shear strength after being disturbed; a clay that shows no appreciable gain in strength after remolding. (Reference 3)

reconnaissance geology/mapping A general, exploratory examination or survey of the main features of a region, usually preliminary to a more detailed survey. It may be made in the field or office, depending on the extent of information available. (Reference 2)

relief The difference in elevation between the high and low points of a land surface. (Reference 3)

risk The probability of occurrence or expected degree of loss, as a result of exposure to a hazard. (Reference 4)

rock mechanics The theoretical and applied science of the mechanical behavior of rocks, representing a "branch of mechanics concerned with the response of rock to the force fields of its physical environment." (Reference 3)

sag pond A small body of water occupying an enclosed depression or sag formed where active or recent fault or landslide movement has impounded drainage. (Reference 3)

seepage Concentrated subsurface drainage indicated by springs, sag ponds, or moist areas on open slopes, and seepage sites along road cuts. The locations of these areas of concentrated subsurface flow should be noted on maps and profiles as potential sites of active, unstable ground. (Reference 2)

sea cliff retreat A cliff formed by wave action, causing the coastal cliff to erode and recede toward land. (Reference 3)

shear A deformation resulting from stresses that cause contiguous parts of a body to slide relative to each other in a direction parallel to their plane of contact. (Reference 3)

slurry A highly fluid mixture of water and finely divided material; for example, pulverized coal and water for movement by pipeline or of cement and water for use in grouting. (Reference 3)

soil mechanics The application of the principles of mechanics and hydraulics to engineering problems dealing with the behavior and nature of soils, sediments, and other unconsolidated accumulations; the study of the physical properties and utilization of soils, especially in relation to highway and foundation engineering. (Reference 3)

strainmeter A seismometer that is designed to detect deformation of the ground by measuring relative displacement of two points. (Reference 3)

stress In a solid, the force per unit area, acting on any surface within it, and variously expressed as pounds or tons per square inch, or dynes or kilograms per square centimeter; also, by extension, the external pressure that creates the internal force. (Reference 3)

sturzstroms (*German language term for "fall stream"*) A huge mass of rapidly moving rock debris and dust, derived from the collapse of a cliff or mountainside, flowing down steep slopes and across low ground, often for several kilometers at speeds of more than 100 km/hr. Sturzstroms are the most catastrophic of all forms of mass movement. (Reference 3)

subaqueous (submarine) landslide Conditions and processes, or features and deposits, that exist or are situated in or under water. Generally used to specify a process that occurs either on land (the slide extending underwater) or that begins under water; for example, slumping, gravitational slides. (Reference 3)

subsidence Sinking or downward settling of the Earth's surface, not restricted in rate, magnitude, or area involved. Subsidence may be caused by natural geologic processes, such as solution, compaction, or withdrawal of fluid lava from beneath a solid crust or by human activity such as subsurface mining or the pumping of oil or ground water. (Reference 3)

surficial geology Geology of surficial deposits, including soils; the term is sometimes applied to the study of bedrock at or near the Earth's surface. (Reference 3)

swelling soils These are soils or soft bedrock that increases in volume as they get wet and shrink as they dry out. They are also commonly known as bentonite, expansive, or montmorillinitic soils. (Reference 1)

tensile stress A normal stress that tends to pull apart the material on the opposite sides of the plane on which it acts. (Reference 3)

weathering The destructive process by which earth and rock materials exposed to the atmosphere undergo physical disintegration and chemical decomposition resulting in changes in color, texture, composition, or form. Processes may be physical, chemical, or biological. (Reference 4)

weathering, differential When weathering across a rock face or exposure occurs at different rates mainly due to variations in the composition and resistance of the rock. This results in an uneven surface with the more resistant material protruding. (Reference 4)

weathering, mechanical The physical processes by which rocks exposed to the weather change in character, decay, and crumble into soil. Processes include temperature change (expansion and shrinkage), freeze-thaw cycle, and the burrowing activity of animals. (Reference 4)

zonation A term used generally, even vaguely, for a region of latitudinal character more or less set off from surrounding regions by some distinctive characteristic, for instance, the Earth's torrid zone, two temperate zones, and two frigid zones. For hazards, zones are geographic regions or designations that are differentiated through a variety of different criteria, for example, residential zones, zones of low hazard, zones of high hazard. (Reference 3)

References for Glossary:

1. Creath, W.B., 1996, Homebuyers' guide to geologic hazards: An AIPG issues and answers publication: Department of Natural Resources, Colorado Geological Survey, Miscellaneous Publication (MI) no. 58, 30 p.
2. Chatwin, S.C., Howes, D.E., Schwab, J.W., and Swanston, D.N., 1994, A guide for management of landslide-prone terrain in the Pacific Northwest, 2d edition: Research Branch, Ministry of Forests, Province of British Columbia, Victoria, British Columbia, Crown Publications.
3. Jackson, Julia A., ed., 1997, Glossary of geology, fourth edition: Prepared by the American Geological Institute, Alexandria, Virginia, USA, Doubleday.
4. Jochim, Candice L., Rogers, William P., Truby, John O., Wold, Robert L., Jr., Weber, George, and Brown, Sally P., 1988, Colorado landslide hazard mitigation plan: Department of Natural Resources, Colorado Geological Survey, Bulletin 48.
5. Shelton, David C., and Prouty, Dick, 1979, Nature's building codes, geology and construction in Colorado: Department of Natural Resources, Colorado Geological Survey Special Publication No. 48, 72 p.
6. Turner, A. Keith, and Schuster, Robert L., 1996, Landslides—Investigation and mitigation: National Research Council, Transportation Research Board, Special Report 247, National Academy Press, Washington, D.C., 673 p.

Part 2. Parts of a Landslide—Description of Features/Glossary

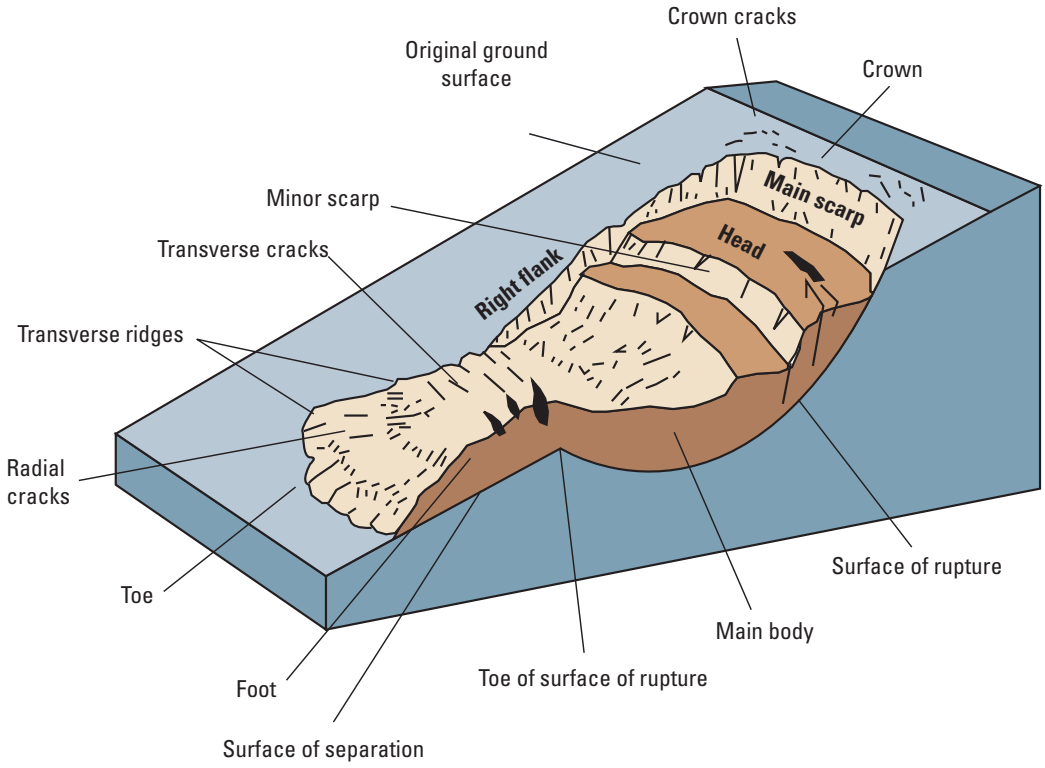


Figure A1. Parts of a landslide. (Modified from Varnes, 1978, reference 43).

accumulation The volume of the displaced material, which lies above the original ground surface.

crown The practically undisplaced material still in place and adjacent to the highest parts of the main scarp.

depletion The volume bounded by the main scarp, the depleted mass and the original ground surface.

depleted mass The volume of the displaced material, which overlies the rupture surface but underlies the original ground surface.

displaced material Material displaced from its original position on the slope by movement in the landslide. It forms both the depleted mass and the accumulation.

flank The undisplaced material adjacent to the sides of the rupture surface. Compass directions are preferable in describing the flanks, but if left and right are used, they refer to the flanks as viewed from the crown.

foot The portion of the landslide that has moved beyond the toe of the surface of rupture and overlies the original ground surface.

head The upper parts of the landslide along the contact between the displaced material and the main scarp.

main body The part of the displaced material of the landslide that overlies the surface of rupture between the main scarp and the toe of the surface of rupture.

main scarp A steep surface on the undisturbed ground at the upper edge of the landslide, caused by movement of the displaced material away from the undisturbed ground. It is the visible part of the surface of rupture.

minor scarp A steep surface on the displaced material of the landslide produced by differential movements within the displaced material.

original ground surface The surface of the slope that existed before the landslide took place.

surface of separation The part of the original ground surface overlain by the foot of the landslide.

surface of rupture The surface that forms (or which has formed) the lower boundary of the displaced material below the original ground surface.

tip The point of the toe farthest from the top of the landslide.

toe The lower, usually curved margin of the displaced material of a landslide, it is the most distant from the main scarp.

top The highest point of contact between the displaced material and the main scarp.

toe of surface of rupture The intersection (usually buried) between the lower part of the surface of rupture of a landslide and the original ground surface.

zone of accumulation The area of the landslide within which the displaced material lies above the original ground surface.

zone of depletion The area of the landslide within which the displaced material lies below the original ground surface.

Sources of information on nomenclature:

1. Cruden, D.M., 1993, The multilingual landslide glossary: Richmond, British Columbia, Bitech Publishers, for the IUGS Working Party on World Landslide Inventory in 1993.

2. Varnes, D.J., 1978, Slope movement types and processes, *in* Schuster, R.L., and Krizek, R. J., eds., Landslides—Analysis and control: Transportation Research Board Special Report 176, National Research Council, Washington, D.C., p. 11–23.

Part 3. Landslide Causes and Triggering Mechanisms

Physical Causes—Triggers

- Intense rainfall
- Rapid snowmelt
- Prolonged intense precipitation
- Rapid drawdown (of floods and tides) or filling
- Earthquake
- Volcanic eruption
- Thawing
- Freeze-and-thaw weathering
- Shrink-and-swell weathering
- Flooding

For further reading:
References 9, 3, and 45

Natural Causes

Geological causes

- Weak materials, such as some volcanic slopes or unconsolidated marine sediments, for example
- Susceptible materials
- Weathered materials
- Sheared materials
- Jointed or fissured materials
- Adversely oriented mass discontinuity (bedding, schistosity, and so forth)
- Adversely oriented structural discontinuity (fault, unconformity, contact, and so forth)
- Contrast in permeability
- Contrast in stiffness (stiff, dense material over plastic materials)

Morphological causes

- Tectonic or volcanic uplift
- Glacial rebound
- Glacial meltwater outburst
- Fluvial erosion of slope toe
- Wave erosion of slope toe
- Glacial erosion of slope toe
- Erosion of lateral margins
- Subterranean erosion (solution, piping)
- Deposition loading slope or its crest
- Vegetation removal (by forest fire, drought)

Human Causes

- Excavation of slope or its toe
- Use of unstable earth fills, for construction
- Loading of slope or its crest, such as placing earth fill at the top of a slope
- Drawdown and filling (of reservoirs)
- Deforestation—cutting down trees/logging and (or) clearing land for crops; unstable logging roads
- Irrigation and (or) lawn watering
- Mining/mine waste containment
- Artificial vibration such as pile driving, explosions, or other strong ground vibrations
- Water leakage from utilities, such as water or sewer lines
- Diversion (planned or unplanned) of a river current or longshore current by construction of piers, dikes, weirs, and so forth