Kansas Geological Survey
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Landslides in Kansas

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Introduction

In May of 1995, a Kansas landslide made news when a local TV station filmed the collapse of a $400,000 home in Overland Park, Kansas (fig. 1). This Johnson County landslide also destroyed one other home and affected four vacant lots. That same month, a landslide near Manhattan closed McDowell Creek Road and subsequently cost Riley County $880,000 to stabilize the slope and repair the road.

Kansas landslides have damaged or destroyed houses and other structures, closed roads, and disrupted transportation systems. Every year, structures must be repaired and landslide debris removed from highways and railroad tracks. Nationally, landslides cause an estimated $1.5 billion in property losses.

Many areas of Kansas have all the required conditions for landslides. The growth of the Kansas City metropolitan area and other cities in the state creates the potential for more property damage as a result of landslides. This circular provides property owners, government officials, and developers an introduction to landslides in Kansas and outlines common approaches for their remediation. **Bold terms** are defined in the glossary.

Landslide Features

A **landslide** is the downhill movement of masses of soil and rock by gravity. **Soil**, as defined by civil engineers, is the loose material between the ground surface and the underlying **bedrock**. Landslides come in many forms. **Rock falls** occur along cliffs and outcrops where blocks of rock break off and fall down the slope. **Block slides** and **slumps** occur where blocks or masses of intact soil or rock move downslope along a failure surface. Block slides have straight **failure surfaces**, and the motion is analogous to a box (the landslide mass) sliding down a ramp (the failure surface). Slumps, on the other hand, have concave failure surfaces. As the landslide mass moves along this curved surface, it rotates and tilts trees and other objects so that they point uphill. **Earth flows** (fig. 2) are landslides in soil in which the landslide mass breaks apart instead of remaining relatively intact as in a slump or block slide. The motion in an earth flow is analogous to a thick mixture of soil and water oozing down the slope. **Creep** is the slow, imperceptible downslope movement of soil and rock. Because creep rarely fractures the ground surface, other evidence such as tilted trees, telephone poles, or walls must be used to identify affected areas. Creep is widespread on hillsides throughout Kansas.

Scarps, tension gashes, and lobes are features that identify active or recently active landslides (fig. 2). A **scarp** is a steep (nearly vertical) region of exposed soil and rock at the head of the landslide where the failure surface ruptures the ground surface. Tension gashes are breaks in the ground surface that are oriented parallel to the

Figure 1. A 1995 landslide in Overland Park, Kansas, destroyed two homes and damaged four lots.

Figure 2. An earth flow near Interstate Highway 70, Ellsworth County. The head is the upslope portion of the landslide. The scarp, the steeply inclined failure surface with exposed soil and rock, marks the top of a landslide. The toe is the downslope portion of the landslide. A mound of soil called a lobe marks the toe of the landslide.

scarp and are found throughout the landslide mass. Lobes are bulges in the ground surface where the landslide mass mounds up at the toe of the landslide. With time, tension gashes fill with soil, the scarp erodes back, and vegetation covers the surface muting the features of the landslide. Old landslides can be recognized by the irregular, bulging ground surface that remains long after other features have vanished.

Damage to human-made structures can be another indicator of landslide activity. Sidewalks and roads out of alignment, retaining walls that lean downslope, broken utility lines, cracked foundations and walls, and doors and windows out of plumb are examples of such structural damage. However, this damage is not necessarily due to landslides. Other geologic hazards, including **subsidence** and **expansive soil**, can cause similar structural damage.

Causes of Landslides

Landslides are natural phenomena that occurred in Kansas long before human occupation. The basic ingredients for landslides are gravity, susceptible soil or rock, sloping ground, and water.

The most common rocks found in Kansas are shales, limestones, and sandstones. Shales — rocks composed of **clay**- and silt-sized grains — are most often associated with landslides. When shale is near the ground surface where the **water content** fluctuates, it **weathers** into a clayey soil that could be landslide prone. Block slides, slumps, and earth flows commonly occur in shales and the soils developed on shales. Limestones are usually hard sedimentary rocks composed of calcium carbonate and can provide strength to slopes. Sandstones, rocks composed of sand-sized grains, can be either loosely cemented and soft or hard and resistant. Hard rock layers that resist weathering are termed **competent rocks**. Sandstones and limestones exposed in cliffs or roadcuts can pose a risk for rock fall, especially when they overlie shales.

Landslides require hilly terrain. In general, as the slope angle increases, the potential for landslides also increases. Anything that increases the slope angle can trigger a landslide. For example, a stream that is actively eroding a hill increases the slope angle at the base. Construction practices that increase slope angle can also cause landslides. The maximum safe slope angle for any hillside is a function of the type, thickness, and water content of soil and rock. Water acts as a lubricant in soil and rock. As water content increases, the strength of the soil and rock decreases. This can lead to landslides.

Landslide-Prone Areas of Kansas

The U.S. Geological Survey (Radbruch-Hall et al., 1982) identified several regions of Kansas as landslide prone, including the Missouri River Corridor in northeastern Kansas, the Smoky Hills in northern and central Kansas, and a small area in northwestern Hamilton County (fig. 3). The Missouri River Corridor includes the Kansas City Metropolitan Area (Johnson, Leavenworth, and Wyandotte counties). Though not shown on the U.S. Geological Survey map, the region along the Kansas River and its tributaries from Kansas City to Junction City should also be considered landslide prone. This includes the cities of Lawrence, Manhattan, and Topeka. Although landslides are more likely in these regions, they can occur anywhere in the state.

Landslide Warning Signs

One or more of the following features may be early signs of a potential landslide: (1) saturated soil, seeps, or springs in areas that were dry in the past, (2) growth of reeds and wetlands vegetation on the lower portions of the slope, (3) fresh breaks and cracks in the ground surface, (4) ground-surface bulges in the lower portion of the slope, (5) new structural defects including out-of-alignment roads and sidewalks, cracked foundations, out-of-plumb doors and windows, and cracked walls, (6) tilted retaining walls, trees, and telephone poles, and (7) leaking water and sewer lines.

Construction Practices and Landslides

Construction and maintenance practices can affect the stability of a hillside. The risk of initiating a landslide on a landslide-prone slope is increased by (1) excavating into the base or side of the slope, (2) placing fill and constructing buildings at the top or side of the slope, (3) changing surface-water drainage patterns, (4) adding water to the soil or rock, (5) removing layers of competent rock, and (6) removing vegetation.

Figure 4 illustrates how construction practices can increase the risk of landslide for a house built on a landslide-prone hillside. In this example, vegetation was removed to prepare the lot for construction and to improve the view. Soil and rock were excavated upslope of the site and placed downslope to create a flat area, or pad, for the house. A competent layer of rock might be removed to construct the pad or add a basement. The horizontal pad collects more rainwater, which infiltrates the soil. An automatic sprinkler system adds more water to the soil. Any or all of these factors increases the potential for landslides that could damage or destroy the house.

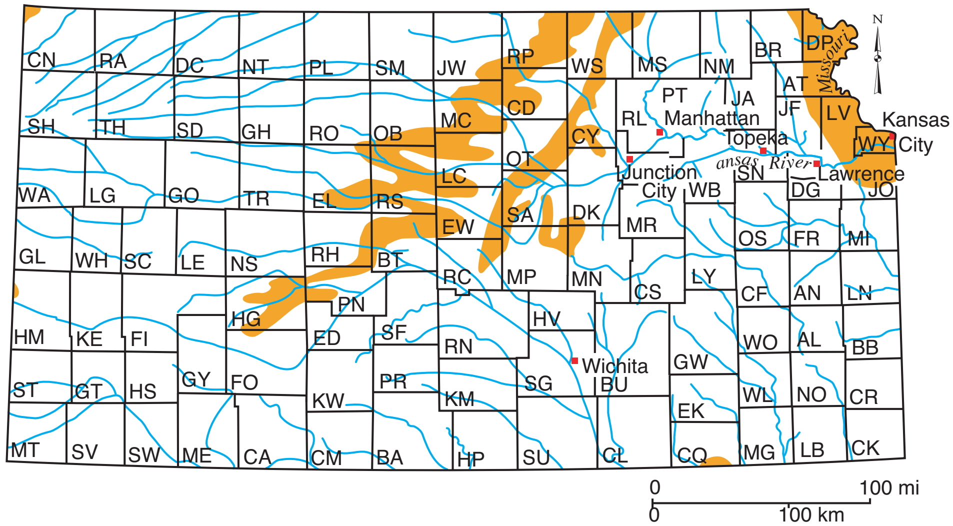

Figure 3. Landslide-prone areas in Kansas as identified on the 1982 U.S. Geological Survey landslide map of the conterminous United States (Radbruch-Hall et al., 1982). Landslide risk is moderate in the shaded areas (1.5% to 15% of the area is landslide prone). Other areas in Kansas have a low landslide risk (less than 1.5% of area). Though not shown on this map, the region along the Kansas River and its tributaries from Kansas City to Junction City may also have a moderate landslide risk.

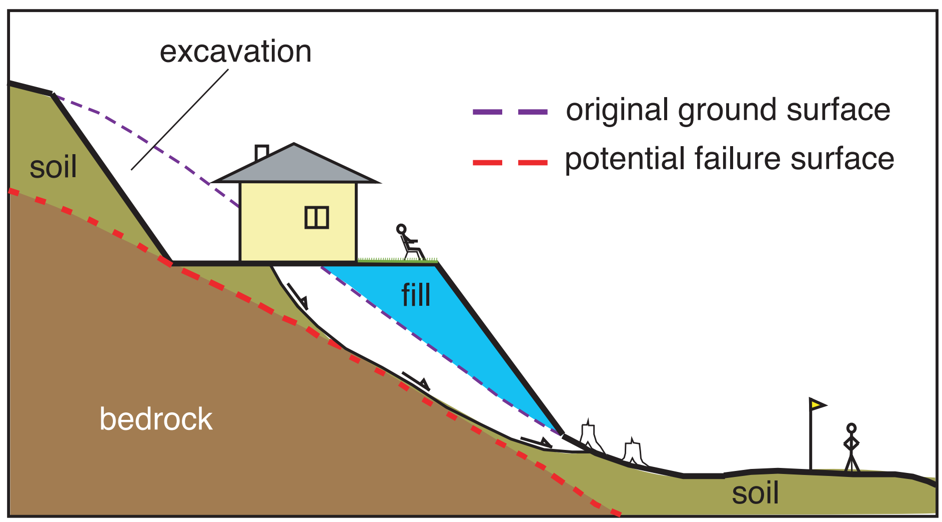

Figure 4. Diagram of a house built on a landslide-prone hillside, constructed with questionable practices. The soil upslope from the house was excavated leaving a steep soil face. This soil was placed as fill on top of existing soil to create a building lot (pad). Vegetation was removed from the slope, and surface water might pond on the lot. A potential failure surface is shown below the house.

Prevention and Remediation of Landslides

Many methods are used to remedy landslide problems. The best solution, of course, is to avoid landslide-prone areas altogether. Before purchasing land or an existing structure or building a new structure, the buyer should consult an **engineering geologist** or a geotechnical engineer to evaluate the potential for landslides and other geology-related problems.

Listed below are some common remedial methods used when landslide-prone slopes cannot be avoided. There is no guarantee that any one method or combination thereof will completely stabilize a moving hillside.

Improving surface and subsurface drainage: Because water is a main factor in landslides, improving surface and subsurface drainage at the site can increase the stability of a landslide-prone slope. Surface water should be diverted away from the landslide-prone region by channeling water in a lined drainage ditch or sewer pipe to the base of the slope. The water should be diverted in such a way as to avoid triggering a landslide adjacent to the site. Surface water should not

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be allowed to pond on the landslide-prone slope.

Groundwater can be drained from the soil using trenches filled with gravel and perforated pipes or pumped water wells. Swimming pools, water lines, and sewers should be maintained to prevent leakage, and the watering of lawns and vegetation should be kept to a minimum. Clayey soils and shales have low **hydraulic conductivity** and can be difficult to drain.

Excavating the head: Removing the soil and rock at the head of the landslide decreases the driving pressure and can slow or stop a landslide. Additional soil and rock above the landslide will need to be removed to prevent a new landslide from forming upslope. Flattening the slope angle at the top of the hill can help stabilize landslide-prone slopes.

Buttressing the toe: If the toe of the landslide is at the base of the slope, fill can be placed over the toe and along the base of the slope. The fill increases the resisting forces along the failure surface in the toe area. This, in turn, blocks the material in the head from moving toward the toe. However, if the toe is higher on the slope, adding fill would overload the soil and rock below the toe, thus causing a landslide to form downslope of the fill.

Constructing piles and retaining walls: Piles are metal beams that are either driven into the soil or placed in drill holes. Properly placed piles should extend into a competent rock layer below the landslide. Wooden beams and telephone poles are not recommended for use as piles because they lack strength and can rot.

Because landslides can ooze through the gaps between the piles, retaining walls are often constructed. Retaining walls can be constructed by adding lagging (metal, concrete, or wooden beams) horizontally between the piles. Such walls can be further strengthened by adding tiebacks and buttressing beams (fig. 5). Tiebacks are long rods that attach to the piles and to a competent rock layer below the ground surface. Buttressing beams are placed at an angle downslope of the piles to prevent the piles from toppling or tilting. Retaining walls also are constructed of concrete, cinder blocks, rock, railroad ties, or logs, but these may not be strong enough to resist landslide movement and could topple.

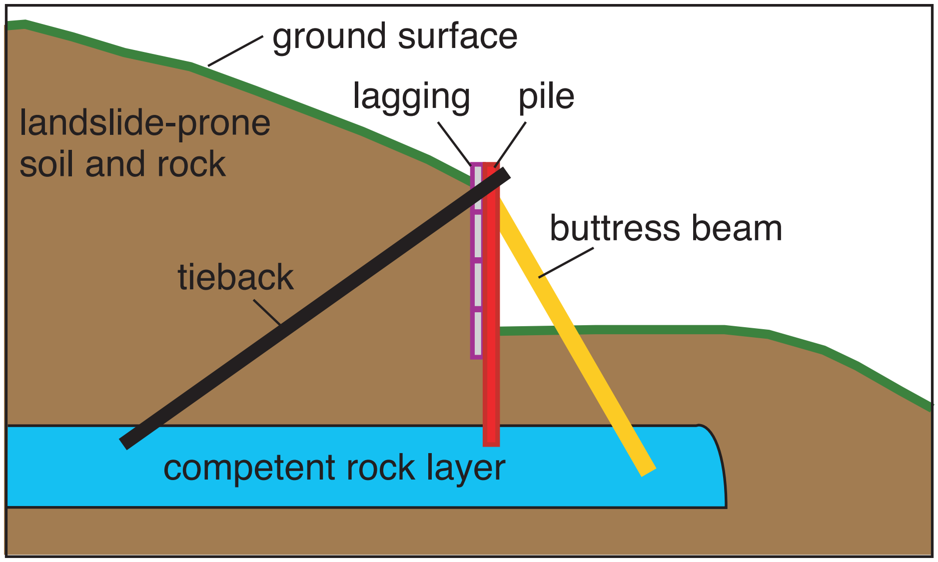

Figure 5. Diagram of a retaining wall with tiebacks and buttress beams. Tiebacks are metal rods that extend from the piles to a competent rock layer below the ground surface. Buttress beams are metal beams that are inclined downslope from the piles that prevent the piles from toppling. Lagging consists of wooden, metal, or concrete beams placed upslope and between the piles to fill in the gaps.

Removal and replacement: Landslide-prone soil and rock can be removed and replaced with stronger materials, such as silty or sandy soils. Because weathering of shales can form landslide-prone soils, the removal and replacement procedure must include measures to prevent continued weathering of the remaining rock. Landslide material should never be pushed back up the slope. This will simply lead to continued motion of the landslide.

Preserving vegetation: Trees, grasses, and vegetation can minimize the amount of water infiltrating into the soil, slow the erosion caused by surface-water flow, and remove water from the soil. Although vegetation alone cannot prevent or stop a landslide, removal of vegetation from a landslide-prone slope may initiate a landslide.

Rock fall protection: Rock falls are contained by (1) ditches at the base of the rock exposure, (2) heavy-duty fences, and (3) concrete catch walls that slow errant boulders that have broken free from the rock outcrop. In some cases, loose blocks of rock are attached to bedrock with rock bolts, long metal rods that are anchored in competent bedrock and are threaded on the outside for large nuts. A metal plate with a center hole, like a very large washer, is placed over the end of the rod where it extends from the loose block, and the nut is then added and tightened. Once constructed, remedial measures must be inspected and maintained. Lack of maintenance can cause renewed landslide movement.

Geologists

What is an engineering geologist?

An engineering geologist is an individual with a degree in geology who has taken specialized courses and has work experience in evaluating the effects of geology and geologic processes on structures (buildings, roads, dams, etc.).

What should I expect from an engineering geologist?

Engineering geologists begin by collecting background data on the site and surrounding area, including published reports of geologic problems in the vicinity, geologic maps, geologic hazard maps, and soils maps. They will then inspect the site and surrounding area. Based on the background search and the site inspection, they may want to drill or trench the site to better define the problem and to collect soil and rock samples for testing. Additionally, they may suggest placement of instruments to monitor ground-water flow and movement of soil and rock. Finally, engineering geologists will provide a written report on the extent of geologic problems and may make recommendations on suitable remedial methods.

Where can you find an engineering geologist?

Generally, engineering geologists work for civil, geotechnical, and environmental engineering firms. Some own their own companies or work independently. Check the Yellow Pages under geologists or engineers for local companies. You can also use internet search engines to find geologists and engineering firms. Local governments should also be a good source of information.

Glossary

Bedrock: General term for the solid rock that underlies the soil.

Block slide: A mass of soil and rock that moves along a straight failure surface without rotation or internal deformation in the landslide mass.

Clay: A group of submicroscopic silicate minerals related to mica. Clay-sized particles are less than 0.0039 mm in diameter.

Competent rock: Hard rock layers that resist weathering.

Creep: Slow, imperceptible movement of soil and rock downslope.

Earth flow: A mass of soil that moves downslope and undergoes internal deformation. During an earth flow, the landslide mass breaks apart.

Expansive soil: Soil containing clay minerals that increase in volume when wet and decrease when dry.

Failure surface: A planar surface at the base of the landslide along which motion has occurred; it separates the material that has moved from the stationary material.

Head: The upslope portion of a landslide.

Hydraulic conductivity: Capability of water to move through soil or rock.

Landslide: A mass of soil and rock that moved downslope by gravity.

Lobe: A bulge in the ground surface where soil and rock mounds at the toe of a landslide.

Rock fall: Free-fall of rock blocks from a cliff or rock outcrop.

Scarp: Steeply dipping region of exposed soil and rock that marks the upslope end of a landslide.

Slump: A mass of soil and rock that moves along a curved failure surface with rotation but without internal deformation of the landslide material.

Soil (engineering usage): All loose (unconsolidated) material between the ground surface and the underlying bedrock, including stream, river, and glacial sediments.

Subsidence: Sinking or settling of the ground surface caused when soil or rock collapses into a void. Subsidence can be natural (a sinkhole) or human induced (due to underground mining or pumping of petroleum or water).

Tension gashes: Cracks in the ground surface caused by stretching or buckling of the landslide mass during failure.

Toe: The downslope portion of a landslide.

Water content: The amount of water by weight in the soil. Water content is found by dividing the weight of water in the soil by the weight of dry soil.

Weather, Weathering: Physical and chemical processes that disintegrate bedrock and form soil.

Additional Reading

Creath, W. B., 1996, Home Buyer's Guide to Geologic Hazards: The American Institute of Professional Geologists, Arvada, Colorado, 30 p.

Nuhfer, E. B., Proctor, R. J., and Moser, P. H., 1993, The Citizen's Guide to Geologic Hazards: The American Institute of Professional Geologists, Arvada, Colorado, 134 p.

Radbruch-Hall, D. H., Colton, R. C., Davies, W. E., Lucchitta, I., Skipp, B. A., and Varnes, D. J., 1982, Landslide Overview Map of the Conterminous United States: U.S. Geological Survey, Professional Paper 1183, 25 p.

Schuster, R. L., and Fleming, R. W., 1981, Landslides; in, Facing Geologic and Hydrologic Hazards--Earth-Science Considerations, W. W. Hays, ed.: U.S. Geological Survey, Professional Paper 1240-B, p. 55-65.

Schuster, R. L., and Krizek, R. J., 1978, Landslides — Analysis and Control: National Research Council, Transportation Research Board, Special Report 176, 234 p.

Sidle, R. C., Pearce, A. J., and O'Loughlin, C. L., 1985, Hillslope Stability and Land Use: American Geophysical Union, Water Resources Monograph 11, 140 p.

Turner, A. K., and Schuster, R. L., 1996, Landslides — Investigation and Mitigation: National Research Council, Transportation Research Board, Special Report 247, 673 p.

Landslide information from the U.S. Geological Survey

Geologic hazards — Select landslides

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The Kansas Geological Survey (KGS) is a research and service division of the University of Kansas that investigates and provides information about the state's natural resources. KGS scientists pursue research related to surface and subsurface geology, energy resources, groundwater, and environmental hazards. They develop innovative tools and techniques, monitor earthquakes and groundwater levels, investigate water-quality concerns, and map the state's surface geology.

The KGS has no regulatory authority and does not take positions on natural resource issues. The main headquarters of the KGS is in Lawrence in the West District of the University of Kansas, and the Kansas Geologic Sample Repository of the KGS is in Wichita.

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