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Prepared in Cooperation with the California Geological Survey

Southern California Landslides—An Overview

Introduction

Southern California lies astride a major tectonic plate boundary defined by the San Andreas Fault and numerous related faults that are spread across a broad region. This dynamic tectonic environment has created a spectacular landscape of rugged mountains and steep-walled valleys that compose much of the region's scenic beauty. Unfortunately, this extraordinary landscape also presents serious geologic hazards. Just as tectonic forces are steadily pushing the landscape upward, gravity is relentlessly tugging it downward. When gravity prevails, landslides can occur.

Southern California's Complex Landscapes Contribute to Landslides

Southern California is tectonically active and geologically complex, and this complexity strongly controls when and where landslides occur throughout the region. (See the USGS Web site that describes the geological setting and history of southern California, *http://scamp.wr.usgs.gov/scamp/html/scgeo.html* for more information.) In general, landslides are more common where slopes are steep and rocks are weak, and these conditions are all too common in southern California. Steep slopes are abundant because ongoing tectonic deformation pushes up rock that is too weak to support the steep slopes. Some of the uplifted material is geologically very young sediment that has not consolidated into more resistant rock. However, even older and harder rocks have been sheared and fractured by tectonic movement along the plate boundary, and thus they can be quite weak too. The weak rock weathers and erodes rapidly to form steep-sided gullies and larger valleys. It is this steep, rugged terrain carved into relatively weak material that sets the stage for widespread landsliding. Southern California experiences many kinds of landslides: shallow, rapid debris flows triggered by heavy rainfall, rock falls from steep slopes as a result of earthquakes, and slower moving slumps and earth flows on slopes that can fail under many different conditions.

Winter Rainstorms and Debris Flows

Almost all of southern California's rain falls during the winter rainy season, which typically lasts from November through April. The most common landslides triggered by winter storms are debris flows (popularly called "mudslides"), which are shallow

View of the La Conchita landslide taken March 16, 2005. The lightest-colored, exposed rock to the left of the center of the photo is the main scarp of the 1995 slide. The southeast part of the 1995 deposit (central part of photo; it extends into a housing development) remobilized in 2005. Photograph by Jonathan Godt, USGS. A report on the La Conchita landslide is available online: *http://pubs.usgs.gov/of/2005/1067*

landslides of water-saturated soil and rock fragments that travel downslope rapidly as muddy slurries. The flowing mud carries rocks, vegetation, and other natural and man-made debris as it rushes down the slopes. Debris flows can reach speeds up to 56 kilometers/hour (35 miles/hour). Hillsides left denuded by wildfires, and drainages filled by debris washed off these denuded slopes, are also susceptible to flooding and debris flows during and immediately following heavy rainstorms. Debris flows most commonly form after heavy rainfall onto steep slopes underlain by weak rock units. Although many steep slopes appear stable when dry, they can, without warning, produce damaging debris flows when saturated by intense rainfall, water from broken pipes, or misdirected drainage from roads, roofs, or large paved areas.

As a general rule, at least 250 millimeters (10 inches) of seasonal rainfall are needed to make southern California hillsides susceptible to debris flows. Once the seasonal rainfall exceeds 250 millimeters, intense rainfall—more than 50 millimeters (2 inches) in 6 hours in the lowlands or more than 100 millimeters (4 inches) in 6 hours in the mountains—can trigger debris flows. Although the likelihood of debris flows begins to decline after a day or more of dry weather, deeper, generally slow-moving landslides can occur days, weeks, or months after a period of prolonged rainfall has ended.

Deep-Seated Landslides

Although much of the water from prolonged rainfall runs off or evaporates, some soaks into the ground. It gradually moves downward through soil and bedrock, particularly during years of above-average rainfall. In many places, fractures or impermeable layers of rock or soil deflect this downward-moving water laterally toward a slope face. There, the water can weaken the slope and cause landslides long after the rain has stopped. Movement is usually triggered by cumulative rainfall during long periods (weeks to years). Most landslides that result from this process are relatively deep earth flows and translational or rotational earth slides and rock slides. Translational landslides are typically a few meters to tens of meters deep, and rotational slides range in depth from several meters to tens of meters. Deep-seated translational and rotational landslides, including rock slides, tend to fail a little at a time and move more slowly than debris flows, but a few do accelerate to rapid movement. Consequently, these deep slides rarely cause loss of life, but they commonly destroy homes and infrastructure in hillside areas.

Earthquake-Induced Landslides

Ground shaking from earthquakes is another important cause of landslides in southern California. The most common types of earthquake-induced landslides are relatively shallow falls and slides, in which highly disrupted masses of rock and soil travel down slopes at high speed. For example, the January 17, 1994, Northridge, California, earthquake (M = 6.7), triggered more than 11,000 landslides in an area of about 10,000 square kilometers (6,200 square miles), and almost all of the triggered slides were shallow, brittle failures of surficial rock and soil. The majority of the landslides were concentrated in the Santa Susana Mountains and the mountains north of the

Denudation of slopes in the Santa Susana Mountains. All of the light-colored areas are landslides that failed during the Northridge earthquake; many of these existed before the earthquake and were reactivated. Harp, E.L., and Jibson, R.W., 1995, Inventory of landslides triggered by the 1994 Northridge, California earthquake: U.S. Geological Survey Open-File Report 95–213, 17 p. *http://pubs.usgs.gov/of/1995/ofr-95-0213/*

Santa Clara River valley, where most of the earthquake energy was directed. These areas are underlain by weak, geologically young rock that is being uplifted and severely deformed by compressional forces generated along the tectonic plate boundary. Analysis of the distribution of landslides induced by the Northridge earthquake forms the basis for seismic landslide hazard analysis of southern California. It was later discovered that dust generated by these same landslides caused an outbreak of valley fever (coccidioidomycosis) that hospitalized dozens of people and led to three fatalities. (See *http://landslides.usgs.gov/recent/archives/1997northridge.php* for more information on the valley fever outbreak.)

Bluebird Canyon landslide, June 1, 2005, near Laguna Beach, California. This area experienced a landslide in 1978, about 50–100 meters (150–300 feet) to the west of the 2005 event. The 2005 landslide caused 350 homes to be evacuated, of which 15 were damaged or destroyed. The movement was most likely caused by heavy rains in January and February 2005. This type of deep-seated landslide movement is common in southern California in the months following a season of heavy rainfall. Photograph by Jim Bowers, USGS.

Man-Made Landslides

Although several types of human-induced landslides are common in southern California, most can be avoided or mitigated. They are most commonly a result of building roads and structures without adequate grading of slopes, of poorly planned alteration of drainage patterns, and of disturbing old landslides. Most of these situations can be avoided through careful planning and design by qualified professionals and knowledgeable oversight by appropriate regulatory agencies.

Landslide scars above US 101 west of Ventura. Photograph by Jonathan Godt, March 2005.

For more information

1. The California Geological Survey (CGS)
phone: (213) 239-0878, *http://www.consrv.ca.gov/cgs/*

2. U.S. Geological Survey, *http://www.usgs.gov, http://landslides.usgs.gov*

3. Information on southern California geology and the Southern California Areal Mapping Project (SCAMP): *http://scamp.wr.usgs.gov/*

4. Campbell, R.H., 1975, Soil slips, debris flows, and rainstorms in the Santa Monica Mountains and vicinity, southern California: U.S. Geological Survey Professional Paper 851, 51 p.

5. Many cities and counties also employ geologists or contract with consulting companies that are knowledgeable about landslides. For lists of registered professionals please see the Association of Engineering Geologists (AEG): *http://www.aegweb.org*, and the American Society of Civil Engineers (ASCE): *http://www.asce.org*.

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http://landslides.usgs.gov

This fact sheet is available on-line at
http://pubs.usgs.gov/fs/2005/3107

Publication layout by Margo L. Johnson

What Can You Do If You Live Near Steep Hills?

Before a Storm:

1. Watch the patterns of storm-water drainage on slopes near your home, and note especially the places where runoff water converges, increasing flow over soil-covered slopes. Watch the hillsides around your home for any signs of land movement, such as small landslides or progressively tilting trees.
2. Become familiar with the land around you. Learn whether landslides have occurred in your area by contacting local officials, state geological surveys or departments of natural resources, and university departments of geology. Slopes that contain known landslides are likely to move again in the future.
3. Support your local government in efforts to develop and enforce land-use and building ordinances that regulate construction in areas susceptible to landslides and debris flows. Buildings should be located away from steep slopes, streams and rivers, intermittent-stream channels, and the mouths of mountain channels.
4. Contact your local authorities to learn about the emergency-response and evacuation plans for your area, and develop your own emergency plans for your family and business.

During Heavy Rainfall:

1. Stay alert and stay awake! Many debris-flow fatalities occur when people are sleeping. Listen to a radio for warnings of intense rainfall. Be aware that intense short bursts of rain may be particularly dangerous, especially after longer periods of heavy rainfall and damp weather.
2. If you are in areas susceptible to landslides and debris flows, consider leaving if it is safe to do so. Remember that driving during an intense storm is hazardous.
3. Listen for any unusual sounds that might indicate moving debris, such as trees cracking or boulders knocking together. A trickle of flowing or falling mud or debris may precede larger flows. If you are near a stream or channel, be alert for any sudden increase or decrease in water flow and for a change from clear to muddy water. Such changes may indicate debris-flow activity upstream, so be prepared to move quickly. Don't delay! Save yourself, not your belongings.
4. Be especially alert when driving. Embankments along roadsides are particularly susceptible to landslides. Watch the road for collapsed pavement, mud, fallen rocks, and other indications of possible debris flows.

After Heavy Rains—When the Danger Is Slow-Moving Landslides:

Areas prone to landslides:

- On or immediately above old landslides
- On or at the base of slopes
- In or at the base of minor drainage hollows
- At the base or top of an old fill slope
- At the base or top of a steep cut slope
- Developed hillsides where leach field septic systems are used

Features that might indicate potential landslides:

- Springs, seeps, or saturated ground in areas that have not typically been wet
- New cracks or unusual bulges in the ground, street pavements or sidewalks
- Soil moving away from foundations
- Ancillary structures such as decks and patios tilting or moving relative to the main house
- Tilting or cracking of concrete floors and foundations
- Broken water lines and other underground utilities
- Leaning telephone poles, trees, retaining walls, or fences
- Offset fence lines
- Sunken or down-dropped road beds
- Rapid increase in creek water levels; water may be darker or look muddier than usual
- Sudden decrease in creek water levels although rain is still falling or has just recently stopped
- Sticking doors and windows, and open spaces around jambs and frames that indicate they are out of plumb

What to do if you suspect imminent landslide danger:

1. Get out now!
2. Contact your local fire, police, or public works department.
3. Inform affected neighbors.