Mass Movements

What Are Mass Movements?

Downslope movement of rock or soil by the force of gravity is one of the most common ways by which the surface of the Earth is shaped over time. These mass movements may be very rapid or imperceptibly slow. Mass movements are practically unstoppable once they are in motion and can damage or destroy roads, railroads, buildings, and houses in their paths. Because they require some topographic relief to get started, mass movements are most common in mountainous or hilly terrain.

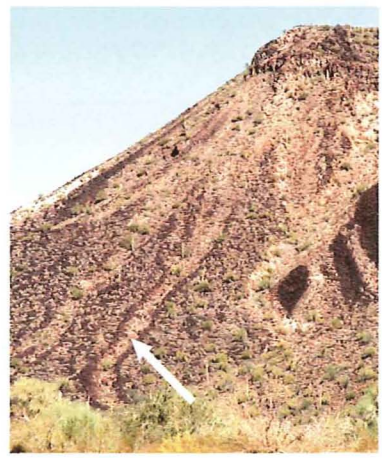
Mass movements occur in every state and cause about $1-2 billion in damages and 25 deaths across the country each year. These hazards cause greater damage and higher monetary losses in the United States, on average, than do earthquakes or hurricanes. For example, in September 1997, dissipating Hurricane Nora traveled across western Arizona from Yuma northeast to the Prescott area. Rainfall amounts of up to 12 inches in the two-day storm triggered numerous landslides and debris flows. Several highways and bridges suffered damage from the mass movements. Because the path of the storm passed through sparsely settled regions, relatively minor property damage occurred. Had a storm like Nora gone through Tucson or Phoenix, however, it might have caused tremendous destruction from flooding and associated landslides and debris flows.

Development has been encroaching onto mountain slopes surrounding many Arizona cities and towns. In addition, because many of our roads are built through steep terrain, excavations associated with road-building may enhance the potential for mass movement. As with all of the geologic hazards discussed in this book, knowledge of the possibility of mass movements can allow people to avoid problematic areas or to develop strategies to mitigate the hazards.

Characteristics Of Mass Movements

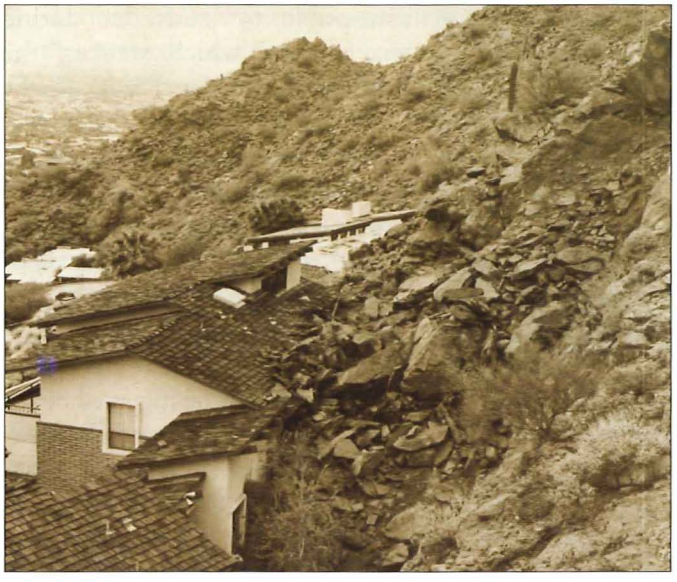
Mass movements are driven by gravity and are usually associated with steep slopes. They may behave quite differently depending on the type of material involved, the proportion of solid material versus water, and the steepness of the slope. Mass movements include debris flows, landslides, and rockfalls.

Debris flows consist of material saturated with water that moves as a fluid mass. They typically flow down valleys, following existing channels. Most of the debris flows that have occurred in Arizona in the past several decades have been restricted to mountain valleys and canyons. In larger debris flows, however, the upper-most part of an active alluvial fan may receive debris flows and is more susceptible to damage than sites lower down or adjacent to the fan. Because their density is much greater than water, debris flows are very effective at transporting large rocks.



This debris flow (arrow) in southwestern Arizona shows characteristic boulder "levees" on each side of the central scour channel. *(Photo by Larry D. Fellows)*

Landslides are large masses of rock and soil that slide along the ground surface. Although landslides typically move as a single, fairly coherent mass, faster-moving slides may become quite jumbled. Some landslides move very rapidly, whereas others creep at very slow rates and may be active only intermittently. In either case, a landslide can be very destructive to structures built on the landslide itself or in its path. Many landslides in Arizona occur where relatively resistant, coherent rock units such as sandstone or lava flows overlie clay-rich units. When the clay-rich units have abundant moisture in them, they may lose their cohesion, causing the overlying unit to slide down slope.



A rock slide nearly destroyed this home in Phoenix. Steep slopes underlain by highly fractured rock are vulnerable to such landslides. *(Photo by Troy L. Péwé)*

A large rockfall, triggered by heavy rains, temporarily closed this highway. *(Photo courtesy of Arizona Department of Transportation)*

Rockfalls are rocks that fall freely through the air, intermittently bouncing on the ground. Large rocks are obviously more dangerous because the mass of material is greater and they can fall and bounce farther from the source.

Causes Of Mass Movements

Landslides, debris flows, and even rockfalls are commonly triggered by heavy or prolonged rainfall. Water increases the weight of the soil and rock, lowers the cohesive strength of clay, and acts as a lubricant. In colder areas of Arizona, water freezing and expanding in cracks may loosen rocks, making them more susceptible to rockfalls. Slope failure caused by rain may occur during the summer "monsoon" rainy season (July to September) or during unusually wet winters.

Besides heavy rainfall, other factors that contribute to mass movement include lack of vegetation on steeper slopes, thickness of soil, and expansive clay. Other conditions that can trigger mass movements include earthquake shaking (or other sources of vibrations), number and orientation of bedrock fractures, forest fires, and construction-related slope modification. For example, numerous rockfalls were reported in southeastern Arizona during the 1887 Sonoran earthquake. Some of the most devastating landslides and debris flows that occurred in the world during the past century were triggered by volcanic eruptions. Landslides are more likely to be a hazard where fractures or bedding in the rocks are nearly parallel with the slope. In this situation, the fractures or bedding act as planes of weakness along which water infiltrates and provides lubrication. Weathering takes place more rapidly along fractures and other planes of weakness, providing an easier place for the rock to separate and fall.

Because so many factors control the initiation of slope failure, it is difficult to predict with certainty when and where a slope failure may occur. Steep terrain is an important consideration, as are the geologic units that exist in an area. When considering the possibility of mass movements in an area, one should be aware of evidence of past mass movements, which is sometimes obvious. Fresh scars from landslides and debris flows are lighter in color than the surrounding ground and little or no vegetation is present. Landslides commonly have steep scarps at their upper margins, and the topography of the landslide tends to be lumpy and irregular. Landslides may be quite small (several feet across), or they may be vast. The margins of debris flows are typically higher than the middle (similar to levees) and they commonly leave piles of boulders where they terminate. Large rocks or jumbles of rocks beneath steep slopes or cliffs are evidence of past rockfalls.

Areas At Risk In Arizona

Areas prone to mass movement are widespread in Arizona. As Arizona's population grows and more development takes place near mountain fronts and on steep slopes, the potential for property damage increases as people move into steeper areas more prone to slope failure.

Debris flows are the most common form of mass movement in the mountains of Arizona. Mountain soils

Boulders falling and rolling down slopes below cliffs pose a serious hazard. This hazard is common on the Colorado Plateau. *(Photo by Larry D. Fellows)*

typically are thin, and vegetation is sparse because of the relatively dry climate. Without extensive plant roots to help hold weathered rocks and soil in place, intense rainfalls can cause debris flows.

Rockfalls are a potential threat wherever extremely steep slopes exist. Loose boulders, up to the size of a small house, can tumble an amazing distance down a mountain onto the gentler slopes below.

On the Colorado Plateau and in the rugged mountains of central Arizona, mesas are commonly composed of relatively soft rock that is capped by hard, resistant layers. The underlying soft layers erode easily, leaving the capping layer overhanging with no support. Eventually, the cap rock breaks off and slides or falls to the bottom of the mesa. It is typical to see the lower slopes of mesas littered with large blocks that have fallen from the top. For this reason, buildings should not be constructed at the base of such mesas or cliffs. Areas where soils are thicker, especially those soils having expansive clay, are susceptible to landslides during heavy rains, which weaken the cohesion of the clay. Slopes on the Colorado Plateau are highly susceptible to landslides because of their high clay content of soil and weathered rock outcrops.

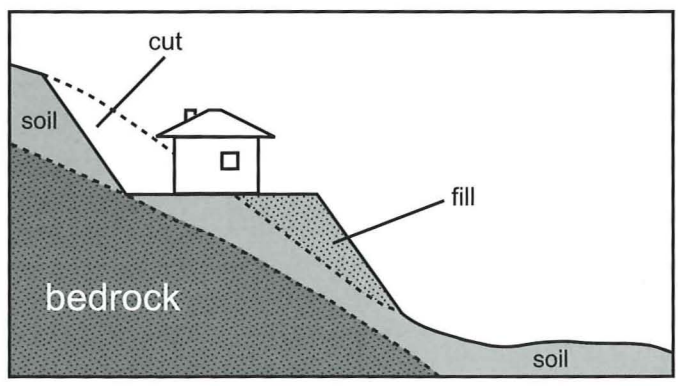
Reduction Of Risks

Debris Flows

Debris flows may be triggered by the same heavy rains that produce flooding and present similar hazards. Forest fires that denude steep slopes may set the stage for debris flows. As with floods, the best method of avoidance is to not build in a floodplain or on the edge of a wash in hilly or mountainous terrain.

Landslides

Because little can be done to mitigate large landslides or slope failures, areas having the potential for landslides should be avoided. Smaller slope failures may be triggered by construction practices. Development on slopes commonly requires construction of a flat site on which to put a house. With the cut-and-fill technique, material is removed from the uphill part of the site and placed on the downhill portion to form a level surface. The fill material may compact and settle later, and cause cracking of foundations and walls. The extra load of a building may trigger a slope failure on unrestrained fill. Retention walls and precompaction of fill may lessen the potential for that type of slope failure.

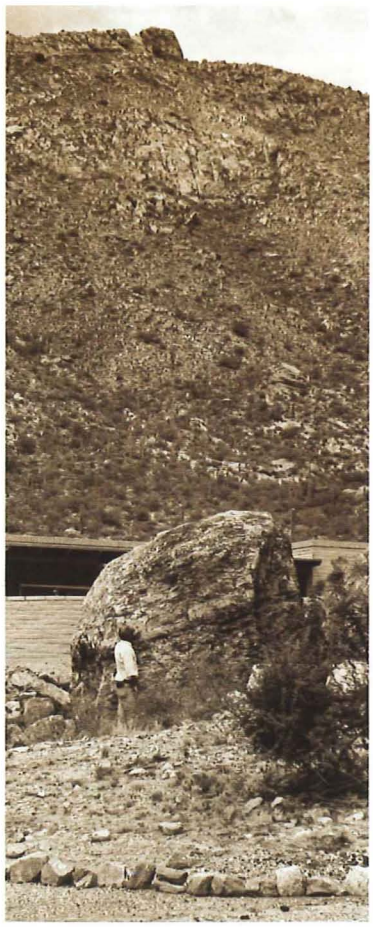


Construction excavation may oversteepen slopes, increasing the chance for slope failure. Fill material may settle, causing cracking in buildings.

Infiltration of water increases the weight and decreases the strength of slopes. Sources of water include rain runoff, leaking pipes or watering systems, deep landscape watering, and septic system drain fields. Preventing infiltration of water into slopes and fill material reduces the likelihood of failure. The stability of soil, weathered bedrock, and landslide deposits containing large amounts of clay may be improved by treating with calcium-bearing chemicals of the same type used to treat expansive soils. This treatment decreases the absorption of water, reduces expansion, and improves the strength of wet clay.

Rockfalls

In areas prone to rockfall, structures should not be built at the base of steep slopes or cliffs. On slopes that have weathered or loose rocks subject to falls or slides, stabilization measures include constructing barriers such as walls, anchoring large boulders with rock-bolts, or removing potentially unstable rocks.



A rock this large could destroy a house. Building on slopes that have large, loose boulders should be done with caution. *(Photo by H.W. Peirce)*

Mitigation considerations

Barriers such as walls, berms, or swales constructed at the upstream end of a property may reduce the risk from slope failure by diverting debris flows and small landslides away from structures. Walls must be reinforced and deeply anchored to withstand the force of a slide or flow. A permit is usually required to construct such a diversion structure. If a landslide, debris flow, or flood enters a neighboring property because of a diversion structure that you built, you could be held liable for damages.

Regular homeowners insurance does not cover debris flows and other events related to floods. Additional flood insurance coverage for mudflows, mudslides, and flood-related erosion (such as mass movement) is available as part of the National Flood Insurance Program. Contact your insurance company, the Federal Emergency Management Agency (FEMA), or the Arizona Division of Emergency Management for information on flood insurance.

Where To Go For Information

Although there has been no systematic compilation of hazards associated with mass movements in Arizona, numerous scientific papers have described mass movements in the state. The Arizona Geological Survey maintains bibliographic and map databases for Arizona. Current or prospective property owners can obtain this information about whether landslides, debris flows, or rockfalls have been recognized in their specific area of interest.

Several counties have adopted planning and zoning restrictions for building on slopes, although these regulations are mostly for aesthetic or environmental reasons, rather than for consideration of hazards. Check with your county Planning and Zoning or Engineering departments about any restrictions or building codes governing construction on slopes. Some information about debris-flow hazards may be obtained from county flood control districts or city floodplain management agencies. These agencies are listed in the blue Government section of the phonebook. Contact information and Internet links to these agencies are found on the AZGS website.

For advice on construction techniques, consult a structural, geotechnical, or geological engineer. Registered engineers are listed in the yellow pages of the telephone directory under "Engineers".

Selected References

Environmental Geology of the McDowell Mountains Area, Maricopa County, Arizona, by D.G. Welsh and T.L. Péwé, 1979: Arizona Bureau of Geology and Mineral Technology Geologic Investigations Series GI-1 (Map G - Geologic Hazards), scale 1:24,000.

Facing Geologic and Hydrologic Hazards - Earth-Science Considerations, by W.W. Hays, editor, 1981: U.S. Geological Survey Professional Paper 1240-B, 108 p.