New Jersey Landslides

Landslides are a major geologic hazard that occur in all 50 states. Nationwide they cause over 3 billion dollars in damage and account for over 25 fatalities annually (Highland, 2004). Landslides in New Jersey are a hazard in areas with steep to moderate slopes and where geologic formations are prone to failure. Landslides can damage utilities, property and transportation routes. The average annual cost of New Jersey landslides is likely in the hundreds of thousands of dollars. Over time, 19 fatalities have been attributed to them.

Introduction

The New Jersey Geological Survey (NJGS) has mapped landslide locations, also known as mass wasting events, throughout the state (fig. 1), and assesses earthquake hazard by mapping areas prone to landslides. The accumulated information is used by several federal, state, and local government agencies to plan disaster responses.

A landslide is the downslope transport of soil, rock and debris under the influence of gravity. A variety of triggers can make this happen. Heavy rain, earthquakes and human activity are common causes. The rate that a landslide moves may be rapid or slow, and slope angles may be steep or gentle (Delano and Wilshusen, 2001). Landslides may involve large or small volumes of material that can move as nearly-intact blocks or as a flow of unconsolidated material.

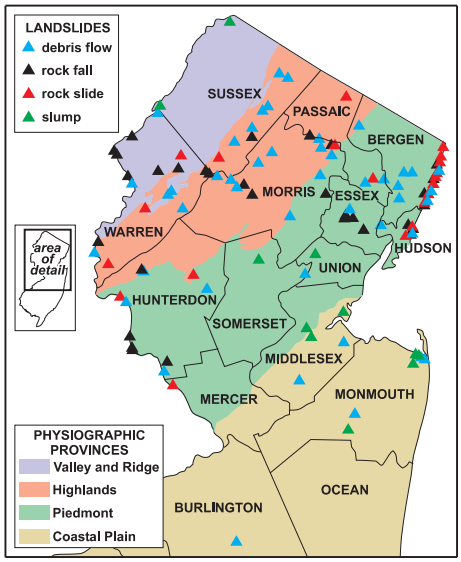

Figure 1. Map of New Jersey showing landslide locations as of September 2007.

Landslides are usually associated with mountainous areas, but can also occur where relief is generally low. In these areas, landslides result from the undercutting of slopes due to roadway and building excavations, river bluff failures, collapse of mine waste piles, and a wide variety of incidents associated with quarries and open-pit mines (Highland, 2004).

Notable Examples of Landslides in New Jersey

July 23, 1887 - After three days of heavy rain, a landslide demolished a house and a quarter mile of railroad track killing two people near Manunka Chunk Mountain, Warren County (New York Times, 1887).

July 1929 - A rockslide killed a quarry worker and injured five others in Oxford, Warren County (New York Times, 1929).

November 1936 - A Works Progress Administration (WPA) worker was crushed to death in a rockslide while laboring on a road project below Henry Hudson Drive in Palisades Interstate Park, Bergen County (New York Times, 1936).

July 1945 - Four people were killed and their apartment house was destroyed when a retaining wall collapsed triggering a landslide after heavy rain in Phillipsburg, Warren County (New York Times, 1945).

November 1948 - Two men were killed when they were buried by a rockslide in a Lambertville quarry, Hunterdon County (New York Times, 1948).

December 1952 - A 10-year-old boy was killed in a rockslide while playing outside a cave on Panther Mountain in Byram Township, Sussex County (New York Times, 1952).

November 1963 - A 15-year-old boy died in a rockslide when he was buried under several hundred tons of rock and debris at an abandoned open pit iron mine in Ringwood, Passaic County. The boy's body was never recovered (New York Times, 1963).

September 1971 - A 24-year-old man was killed after heavy rains in Wood Ridge, Bergen County, when the earth collapsed on the cliffside parking lot of the restaurant where he worked, burying him beneath three feet of rocks and mud (New York Times, 1971).

January 1996 - A landslide triggered by heavy rain and melting snow destroyed a home in the Lake Mohawk section of Sparta Township, Sussex County.

January 1999 - During heavy rain, a landslide destroyed one condominium and damaged three others in Atlantic Highlands, Monmouth County.

September 1999 - Three homes were damaged in Oakland, Bergen County, by a landslide caused by rain from Hurricane Floyd.

August 2000 - A slow-moving storm dropped more than a foot of rain triggering large landslides that damaged homes and businesses on Glen Road in Sparta Township, and blocked Route 15 South on Mase Mountain in Jefferson Township, Morris County.

April 15-16, 2007 - Several damaging landslides occurred during a northeaster. The most destructive one occurred in Lodi, Bergen County, along Farnham Avenue and was triggered by as much as eight inches of rain. Fifty families were displaced from six homes and an apartment building after they were deemed too dangerous to inhabit. A landslide also caused a highway accident on Route 208 southbound near Lincoln Avenue in Glen Rock, Bergen County. There were no injuries but the highway was closed until the vehicles and mud could be cleared. At least six landslides occurred along the Palisades in Bergen County from Fort Lee to Alpine, closing Henry Hudson Drive for over a month (fig. 2). Also, a small rockfall blocked traffic for a time along Sinatra Drive in Hoboken (fig. 3) and a small debris flow occurred in a residential area in Highlands Borough, Monmouth County (fig. 4).

Figure 2. Scar of debris flow above Henry Hudson Drive, Alpine, Bergen County. Photograph by T. Pallis, N.J. Geological Survey.

Types of Landslides in New Jersey

Landslides are categorized by the different materials they contain and the mode of movement of the slide (Varnes, 1978). Landslides mapped by NJGS were slumps, debris flows, rockfalls and rockslides. Slumps are coherent masses that move downslope by rotational slip on surfaces that underlie and penetrate the landslide deposit

Figure 3. Small rockfall along Sinatra Drive, Hoboken, Hudson County. Photograph by T. Pallis, N.J. Geological Survey.

Figure 4. Landslide in Highlands Borough, Monmouth County, triggered by heavy rains from the April 15-16, 2007, northeaster. Photograph by S. Stanford, N.J. Geological Survey.

(Briggs et al, 1975). A debris flow, sometimes referred to as a mudslide, is a form of rapid mass movement in which a combination of loose soil, rock, organic matter, air, and water mobilize as a slurry that flows down slope. Debris flows are commonly caused by intense surface water flow from heavy precipitation or rapid snowmelt that erodes and mobilizes loose soil or rock on steep slopes. Rock falls are common in roadway cuts and steep cliffs and are abrupt movements of masses of geologic materials, such as rock and boulders that become detached from steep slopes or cliffs. Rockslides are the movement of newly detached segments of bedrock sliding on bedding, joint, or fault surfaces or any other surface as a relatively cohesive unit (Delano and Wilshusen, 2001). Some landslides are composites of two or more of these types but are usually named for the dominant type. For example, a large slump may have rock falls at its head (Briggs et al, 1975).

Landslide Causes in New Jersey

There are many geologic factors that contribute to landslide formation in New Jersey. Rock strength, attitude of rock layers and fractures, contrast in water content between surficial materials, and slope degree are the most important. Landslides can also occur where slopes have been undercut by stream, wave, or human action. The following examples illustrate the most common geologic settings of landslides in New Jersey.

Natural Causes

Located along the south shore of Sandy Hook Bay, Atlantic Highlands has a long recorded history of slumping that goes back hundreds of years and continues to this day. Most older slumps were probably caused by undercutting from Atlantic Ocean wave action during a time when Raritan Bay was open to the ocean hundreds of years ago (Minard,1974). One of these slumps occurred in 1782, making it the earliest recorded landslide in New Jersey. There have been other smaller landslides in this area during the last 100 years.

Today the western slump block (fig. 5) is 400 feet wide and 2,500 feet

Figure 5. Aerial photograph with arrows showing the old slump blocks in the Atlantic Highlands area.

long, the eastern one, 450 feet wide and 1,400 feet long (Minard,1969). The eastern slump block is the result of two large landslides in the past. The first included the entire mass, the second, a smaller section of the first dropped down farther (Minard,1974). These slump blocks are now stable and can be viewed from Mt. Mitchill Overlook,

Figure 6. Map showing location of Mt. Mitchill Overlook, cartography by B. Graff.

a Monmouth County Park where there is also an interpretive plaque that explains the history of slumping in the Atlantic Highlands (fig. 6).

One the most active landslide areas is the Palisades located in northeastern New Jersey along the Hudson River. Here, large rockfalls and rockslides occur along high cliffs formed of Triassic diabase (figs. 7 and 8). They are most common in the winter and spring after freeze-thaw cycles have loosened pieces of rock along joints and fractures. Surface water also seeps into joints or cracks in the rock, increasing the weight of the rock and causing expansion of joints when it freezes, thus prying blocks of rock away from the main cliff (Hansen, 1995).

Figure 7. Photograph of a rockfall on Henry Hudson Drive March 8, 1933, in Bergen County. Photograph courtesy of "Palisades Interstate Park - NJ Section."

A rockslide on December 17, 2005 occurred above the Alpine Boat Basin destroying approximately eighty feet of the Alpine Approach Road. The majority of the rockslide stopped at the boat basin parking area where it

Figure 8. Rockslide north of Twombly's Landing, Alpine, 1938. Photograph courtesy of "Palisades Interstate Park - NJ Section."

demolished a cinderblock transformer shed. One large boulder bounced beyond the end of the slide landing in the Hudson River. The estimated cost for the cleanup and repairs from this rockslide was more than $100,000 (Sangha 2006). There were no witnesses to this rockslide because it happened in the middle of the night (figs. 9 and 10).

There were witnesses to a rockslide in the same area one summer morning

Figure 9. Photograph of the December 17, 2005, rockslide on the Alpine Approach Road in Alpine. Photograph courtesy of "Palisades Interstate Park - NJ Section."

Figure 10. Photograph of the December 17, 2005, rockslide damage on the Alpine Approach Road in Alpine. Photograph courtesy of "Palisades Interstate Park - NJ Section."

during August of 1961. Nearly 2,000 tons of rock slid off the Palisades, tearing up 100 feet of the Alpine Approach Road. About fifty people waiting for a ferry were chased to the shore of the Hudson River. It stopped just 100 feet short of them in the parking area of the Alpine Boat Basin (New York Times, 1961).

The fracturing of rock by frost heave caused a rockslide on County Route 627 north of Milford, Hunterdon County along the Delaware River in an area known locally as "The Narrows" (fig. 11). Large and small rockslides are an ongoing problem in this area.

Figure 11. Photograph of February 29, 2000, rockslide on County Route 627 in Holland Township, Hunterdon County. Photograph courtesy of Hunterdon County Road Dept.

Heavy rain and excessive saturation of unconsolidated slope material triggers many landslides in New Jersey. During October 1995, a massive debris flow occurred just downstream from Wallpack Bend in Hardwick Township, Warren County (fig. 12). It was sited along the steep undercut northwest slope of Kittatinny Mountain at the outer bend of a meander of the Delaware River. Heavy rain (3.3 inches) fell near the site of the

Figure 12. Photograph of a massive landslide in the Delaware Water Gap National Recreation Area, Hardwick Township, Warren County, New Jersey. Photograph by R. Witte, N.J. Geological Survey.

landslide making the thin soil unstable and causing it to slide on the glacially polished bedrock surface. The slide area measured from 40 to 50

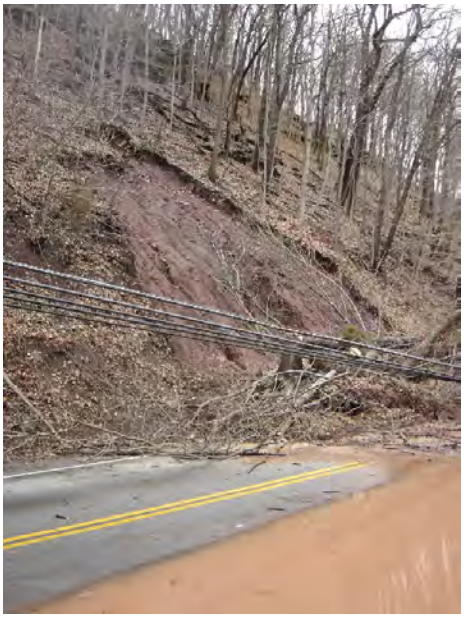

Figure 13. April 2005 landslide one mile south of Milford in Holland Township, Hunterdon County. Photograph courtesy of Hunterdon County Road Dept.

feet in width and 600 feet downslope, extending into the Delaware River an additional 60 feet. The total volume of soil displaced was calculated to be about 48,000 cubic feet (Epstein 2001). Figure 13 shows a smaller, but similar landslide in Hunterdon County. Here, thin soil and loose rock, slid off a steep slope of Triassic shale during a period of heavy rain, blocking Milford-Frenchtown Road.

Human Causes

Over steepening of slopes by human activity causes many landslides in New Jersey. Road construction, cutting of trees and other vegetation on landslide-prone slopes, land development, mining and quarrying have made steep slopes susceptible to landslides.

Figure 14. Landslide which destroyed Bellwood Farm Road, Bethlehem Township, Hunterdon County in 1989. Photograph by S. Stanford, N. J. Geological Survey.

In 1989, a 250 foot-wide slump occurred when a slope adjacent to a quarry failed in Bethlehem Township, Hunterdon County, causing Bellwood Farm Road to be destroyed and permanently closed (fig. 14). Approximately 2 acres of land collapsed at the edge of the quarry and the ground surface dropped nearly 60 feet at the site. As in this case, landslides can occur when the toe of a slope is removed.

Conclusion

The mapping of landslides is an essential part in planning disaster response. They will continue to be a geologic hazard in New Jersey as more land is developed. Education, knowledge, and planning are the most valuable tools in preventing damage and injury from landslides. In many situations, problem areas can be identified and appropriate engineering and construction measures applied to allow safe development in landslide prone areas.

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