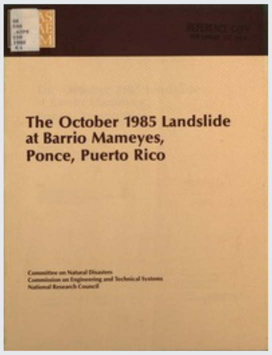

The October 1985 Landslide at Barrio Mameyes, Ponce, Puerto Rico

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The October 1985 Landslide at Barrio Mameyes, Ponce, Puerto Rico

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Committee on Natural Disasters
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National Research Council

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THE OCTOBER 1985 LANDSLIDE AT BARRIO MAMEYES, PONCE, PUERTO RICO

INTRODUCTION

During the early hours of the morning on Monday, October 7, 1985, a landslide destroyed a large section of the Mameyes neighborhood in Ponce, Puerto Rico. On Saturday, October 12, the Committee on Natural Disasters requested that the author visit Ponce to assess the need for an in-depth technical study of the landslide. The author arrived in Puerto Rico on October 13 and spent the following two days in the landslide area.

This report summarizes observations made at Mameyes, outlines tasks for an engineering study of the landslide, and strongly recommends actions to assess the safety of other heavily populated slopes in the area.

THE MAMEYES LANDSLIDE

The landslide occurred during an intense storm that developed into Hurricane Isabel after moving away from the Puerto Rico area. According to the San Juan Office of the National Weather Service, the storm produced the heaviest precipitation in Puerto Rico since 1899. A record rainfall of 18.20 in. was recorded between 8:00 a.m. on Sunday, October 6, and 8:00 a.m. on Monday, October 7, the day the landslide occurred. In addition to the Mameyes landslide, the rainfall caused extensive flooding throughout the island.

The slope apparently failed around 4:30 a.m. and moved in sections.* According to USGS geologist Russell H. Campbell, there were three to four segments of movement over a 1/2- to 1-hour period. According to witness accounts reported by the U.S. Army Corps of Engineers, the slope failed in five separate segments.

The Mameyes landslide destroyed or damaged over 200 houses. Estimates of lives lost range from 130 to 500.

SLIDE GEOMETRY

Figures 1 through 3 show aerial views of the Mameyes landslide. The roughly triangular slide covers an area of about 25,000 m^2 (the base of the triangle equals approximately 190 m and the height of the triangle equals approximately 230 m, measured from a 1:1,000 aerial photograph displayed at the disaster operations center). The subsoil consists of weathered Juana Diaz formation, a calcareous sandstone overlain by chalky limestone, with bedding planes striking N 87 W and dipping 20 SW. Before the slide, the ground surface sloped 20 to 25 degrees in the general direction of the bedding planes' dip. Two intersecting joint sets with a nearly vertical dip and strikes of N 63 E and N 60 W define the head of the slide (the apex of the triangle). The scarp at the head of the slide varies in height from 5 to 10 m. A relatively intact soil block dominates the center of the slide area. Slide debris surrounds this soil block, which moved downslope about 30 m. Near the toe of the landslide, debris 10 to 12 m deep accumulated over a reinforced concrete box culvert through which La Colectora Creek flows. The culvert apparently remained functional after the landslide.

The local and national press referred to the Mameyes disaster as a mud flow or an avalanche. However, field inspection indicates that Mameyes experienced a wedge-type landslide explainable by soil and rock mechanics principles. Determination of the slide geometry, pore pressures, and strengths acting at failure will require additional investigation.

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*U.S. Army Corps of Engineers rescue teams found two electric clocks in the rubble. One had stopped at 3:00 a.m. and the other at 4:50 a.m.

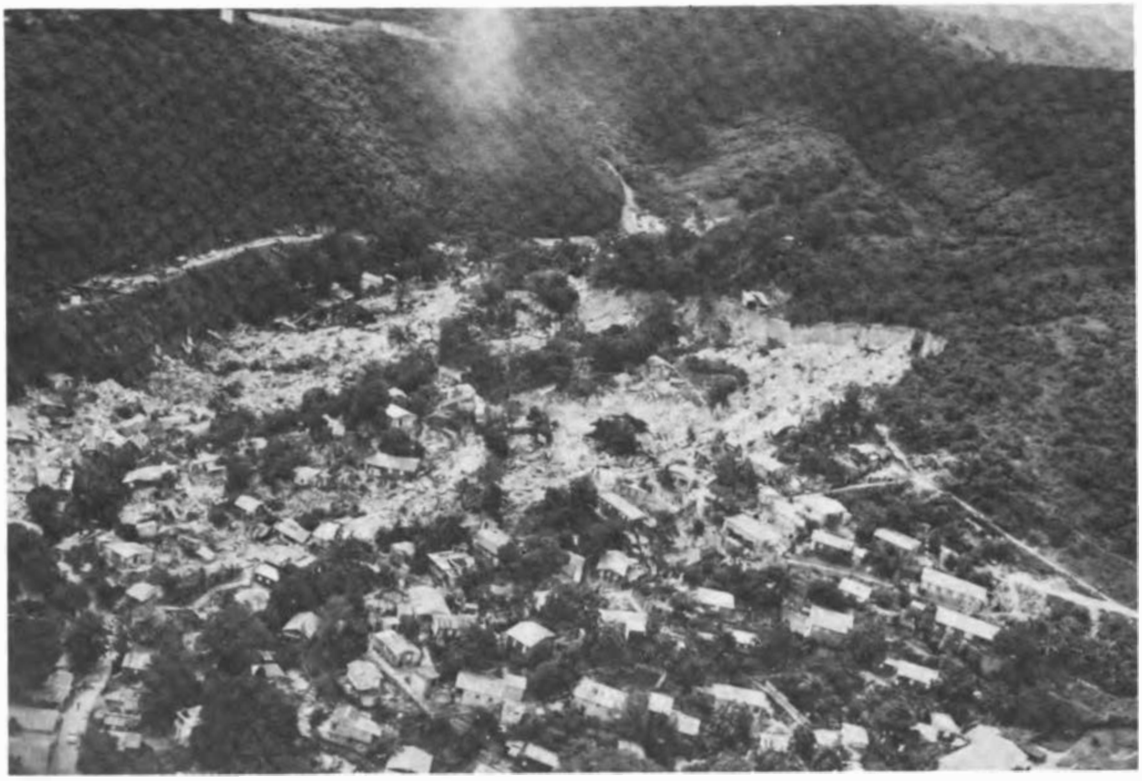

FIGURE 1 Aerial view of Mameyes landslide.

FIGURE 2 Toe of landslide.

FIGURE 3 Head of Landslide.

An inspection of the area from a helicopter revealed other slopes that are densely built with houses and appear similar to the slope on which the Mameyes landslide occurred. Figure 4 shows a 140-m-wide active landslide detected behind the Las Terrazas public housing development. The landslide exits the slope 15 m above the ground floor elevation of a four-story building located less than 12 m from the toe of the slope.

SHEAR STRENGTH

The high vertical scarp at the head of the Mameyes slide suggests that the weathered rock at this location cracked along joint planes and probably contributed little resistance to the sliding mass. The shear strength of the material along the sliding surface undoubtedly played an important role in controlling the landslide. The slide could have occurred along a "clean" bedding plane or, more probably, along a clay

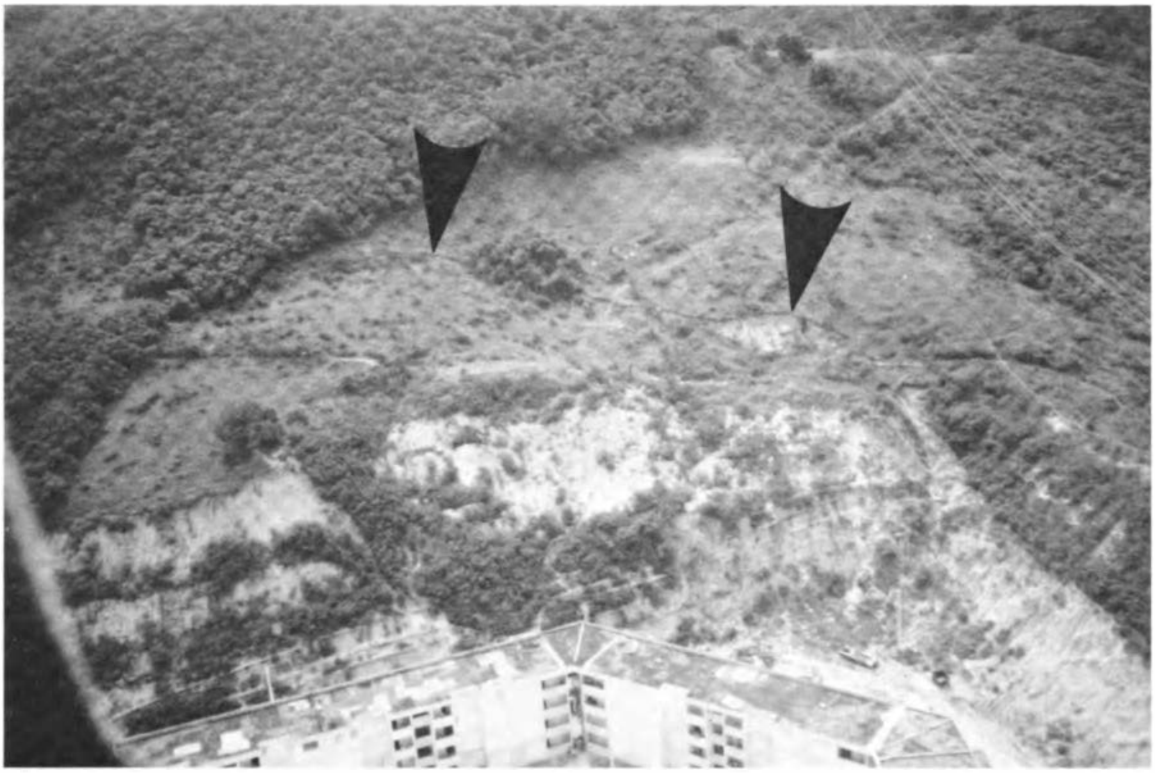

FIGURE 4 Active landslide above Las Terrazas housing development.

layer like the one shown in Figure 5. This 8-cm-thick layer contained a stiff, fissured, plastic clay. Similar clays frequently sustain large changes in effective stress upon wetting (pore pressures change from highly negative to zero or positive) and experience strain softening. At other locations in the landslide area, boulder-size clay pockets existed and joints and bedding planes contained thin clay deposits.

PORE PRESSURES

Almost certainly, high positive pore pressures existed along the failure surface at the time of failure. Sources of these positive pore pressures include:

1. Rainfall National Weather Service records indicate that Ponce received 18.20 in. of rain between 8:00 a.m. Sunday and 8:00 a.m. Monday

FIGURE 5 Stiff, fissured, plastic clay layer (8 cm thick).

and a total of 22.08 in. for the week ending Friday, October 11, 1985.

2. Seepage from Domestic Sewage According to persons familiar with the neighborhood, dwellings with indoor plumbing discharged sewage to cesspools built beneath the houses. Other houses used outdoor latrines. Showers and sinks commonly drained directly onto the surface of the ground.

3. Leaks from Pipes A pressurized 8-in. cast iron water pipe traversed the area near the head of the slide. Rust stains near the joints suggest that small leaks existed before the slide. Upon rupturing, the pipeline emptied a nearby 1-million-gallon water tank into the landslide area. Numerous small-diameter galvanized steel pipes supplied water to the houses. Many of these pipes showed signs of improper installation (e.g., not buried, susceptible to traffic damage, haphazard connections).

The numerous discontinuities in the weathered rock mass provided the water easy access to the failure plane. One week after the landslide, water continued to seep out near the toe of the slide.

RECOMMENDATIONS

The author recommends that a detailed investigation of the Mameyes landslide be made, and very strongly recommends that a geotechnical safety program be undertaken for other densely populated slopes in the Ponce area.

The investigation of the Mameyes landslide should focus on determining the mechanism of failure, including the failure sequence, geometry, strength, and pore pressures. Determining the failure sequence requires prompt systematic collection and analysis of perishable data. The appendix lists some of the tasks required for the investigation.

A study of the Mameyes landslide should provide an understanding of the events and conditions leading to the disaster. More important, a thorough analysis of the landslide constitutes the logical first step toward assessing the safety of similar nearby areas.

The geotechnical safety program should seek to predict and prevent similar landslides. The program should include establishment of performance criteria, a safety assessment of potentially unstable slopes, field instrumentation and field surveillance, periodic performance evaluations, design and construction of remedial measures (if needed), and development of contingency plans. The program should also seek to provide the Commonwealth of Puerto Rico with a sound technical basis to regulate development on potentially unstable slopes.

APPENDIX:

TASKS FOR MAMEYES LANDSLIDE INVESTIGATION

FAILURE SEQUENCE

1. Compile and analyze accounts of survivors
2. Study aerial photographs
3. Survey and map slide area
4. Plot movement vectors
5. Collect promptly and analyze perishable data
    a. Clocks
    b. Breakage patterns for pipes and power lines
6. Review records of water pumping station (pressure records for 8-in. line)
7. Monitor postfailure movements
8. Review seismograph records

GEOMETRY

1. Determine original topography
    a. Use aerial photographs to delineate surface features or landslide areas
    b. Include drainage patterns from extreme rainfall and any natural channels feeding into the landslide area.
2. Determine subsurface geometry
    a. Study existing borings (e.g., water tank, apartment buildings)

b. Make new borings near landslide (continuous sampling to detect thin clay layers)

c. Undertake geologic mapping of weathered rock formation and potential failure surfaces

3. Locate failure surface

a. Make exploratory borings in slide area (continuous sampling) and make use of inclinometers

b. Sink exploratory pits at selected locations

- Attempt to measure strike and dip of failure surface

- Sample material on failure surface

PORE PRESSURES

1. Measure pore pressures in failure plane

a. Install piezometers in borings used to determine location of failure surface

b. Use shortest collection zone possible

2. Measure pore pressures in areas adjacent to slide

a. Measure pore pressures just on top of failure plane

b. Measure pore pressures at several locations along slope cross section (e.g., head, middle, toe)

c. Measure negative pore pressures in clay layers away from developed areas

d. Install piezometers in borings used to determine soil profile

SHEAR STRENGTH

1. Sample materials along failure surface (during field exploration to determine location of failure surface)

2. Sample materials found on failure surface from areas adjacent to slide (during field exploration to determine prefailure subsoil geometry)

3. Perform direct shear tests to determine peak and residual shear strength of clay

a. Perform tests at stress levels similar to those existing in the field

b. Determine strain rate required for dissipation of excess pore pressures during shear

c. Check failure plane in shear box with potential failure plane in the field

d. Measure strength on sample from failure plane if possible

ANALYSIS

1. Select method of analysis compatible with failure mechanism (failure sequence, failure geometry, strengths, pore pressures)

2. Estimate pore pressure required for incipient instability of the Mameyes landslide

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