



**Maps showing locations of damaging landslides caused by
El Niño rainstorms, winter season 1997-98,
San Francisco Bay region, California**

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Pamphlet to accompany Miscellaneous Field Studies Maps MF-2325-A-J

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This map was produced on request, directly from digital files, on an electronic plotter.
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INTRODUCTION

Heavy rainfall associated with a strong El Niño caused over \$150 million in landslide damage in the 10-county San Francisco Bay region during the winter and spring of 1998. Reports of landsliding began in early January 1998 and continued throughout the winter and spring. On February 9, President Clinton declared all 10 counties eligible for Federal Emergency Management Agency (FEMA) disaster assistance. In April and May of 1998, personnel from the U.S. Geological Survey (USGS) conducted a field reconnaissance in the area to provide a general overview of landslide damage resulting from the 1997-98 sequence of El Niño-related storms. Seven scientists from the USGS Landslide Hazards Program based in Reston, Virginia; Golden, Colorado; and Menlo Park, California; and five scientists from the USGS Geologic Mapping Program's San Francisco Bay Mapping Team based in Menlo Park, California, cooperated in the landslide-damage assessments. The assessments were done for 10 counties in the Bay area: Alameda, Contra Costa, Marin, Napa, San Francisco, Santa Clara, Santa Cruz, San Mateo, Solano, and Sonoma. USGS Maps in this series include: MF-2325-A (Napa County), MF-2325-B (Alameda County), MF-2325-C (Marin County), MF-2325-D (Santa Cruz County), MF-2325-E (Contra Costa County), MF-2325-F (Sonoma County), MF-2325-G (San Francisco City and County), MF-2325-H (San Mateo County), MF-2325-I (Solano County), MF-2325-J (Santa Clara County). In addition to USGS scientists providing data from the field evaluation, each of the counties, many consultants, and others cooperated fully in providing the landslide-damage information compiled here.

TYPES OF COSTS

Economic losses resulting from a natural disaster are often categorized as direct or indirect, public or private. Direct economic loss due to landslides has been defined as the costs of "replacement, repair, or maintenance due to damage to installations or property within the boundaries of the responsible landslide" (Schuster and Fleming, 1986). Included are the costs of material and labor to rebuild, repair, or replace roads, homes, buildings, sewer, water and electrical lines, and other components of the built environment. Also included are maintenance costs to remove landslide debris from roadways, driveways, sidewalks, yards, parks, and other areas. All other costs of landslides can be classified as indirect. Such costs can be substantial and difficult to quantify. Included are the costs of interruption of utility and transportation services. Costs of increased travel time, lost wages and revenues, decreases in property values, lost tax

revenue, litigation expenses and settlements, and mitigation efforts aimed at preventing damage from future landslides are also classified as indirect costs.

Public costs are defined as those borne by local, municipal, county, State and Federal governmental entities and ultimately by taxpayers. Public costs are mostly related to the maintenance and repair of roadways damaged by landslides (Fleming and Taylor, 1980). Costs are more easily defined for isolated damage by an individual landslide. Public agencies responsible for repair can often place a dollar figure on the amount spent to reopen or repair a road. In the case of large sections of highway affected by multiple slope failures, which may occur in mountainous areas during an intense rainstorm (MF-2325-H), costs are more difficult to define. Often public agencies will only have a total figure for what was spent following a storm, and damage caused by landslides may not be separated from damage caused by flood or other effects of the storm, such as downed trees. Other public costs include those associated with the response to emergency and relief needs by fire, police, and medical personnel. Building inspections, hazard evaluations, and evacuations are also supported by public funds.

Private costs are defined as those costs borne by individuals and businesses that result from damage to homes, buildings, and other property. Condemnation of a property and the requirement of demolition may compound the cost of damage to a residence. In some cases, the value of the land may be reduced or totally lost as well. Costs for construction, demolition, and real estate can generally be assessed if such information is made available. In practice, litigation and fear of condemnation of property may make this information difficult to obtain.

PREVIOUS WORK

Damaging landslides are common around the San Francisco Bay region (Brown, 1988), and their costs are well documented. In the following sentences, dollar amounts in parentheses are adjusted for inflation to 1998 dollars using the Consumer Price Index (CPI) for shelter for all consumers in the San Francisco Bay area. In an early study of economic loss, Taylor and Brabb (1972) documented about \$25 (\$155) million in direct costs incurred in the winter season of 1968-69. The data were later re-examined and costs to private property owners and municipalities were revised yielding an estimate of at least \$33 (\$205) million (Fleming and Taylor, 1980). In a followup to the 1972 study, Taylor and others (1975) identified \$10 (\$51) million in damages that occurred in 1972-73. During a single intense rainstorm in January 1982,

landslides in the San Francisco Bay region caused the loss of 25 lives and widespread destruction of both public and private property. Over \$66 (\$132) million in direct landslide losses were documented (Ellen and others, 1988; La Vopa-Creasy, 1988).

LANDSLIDES

For this study, we defined landslides in the broadest sense; any failure of hillside materials, both natural and engineered, that impacted the built environment qualified as a landslide. Damage from flooding was excluded. The approximately 300 landslides documented (fig. 1) included most types described by Varnes (1978) and ranged in size from a 25 m³ failure of engineered material to a reactivation of the massive (13 million m³) Mission Peak earthflow complex in Alameda County (Rogers, 1998). Debris flows, which are fast-moving slurries of mud, gravel, and organic debris, occurred throughout the region during the first week of February 1998 (MF-2325-B, H). A debris flow mobilized from the toe of a rotational failure above the community of Rio Nido in Sonoma County forced the evacuation of 140 homes on February 6-7 (MF-2325-F). In San Mateo County, a debris flow was responsible for the only fatality attributed to landslides in the region. However, debris flows were not as widespread or numerous in 1998 as in January of 1982 (Pike and others, 1998). In 1998, damage amounts due to debris flows varied by county throughout the region. For example, only 2 percent of the costs in Alameda County have been attributed to debris flows (MF-2325-B), but in Marin County they caused over 65 percent of the damage (MF-2325-C).

Many more landslides occurred during the winter season of 1997-98 than were investigated in this study. For two mostly rural areas in Alameda County, aerial photography, acquired by the Aircraft Sensor Facility of the NASA Ames Research Center, was used to determine the abundance of shallow landsliding. Several thousand debris flows and landslides have been identified (MF-2325-B; Coe and others, 1998). Other areas of the region likely experienced similar activity, but the scope of this study precludes the inventory of slope failure not associated with damage to the built environment.

PRECIPITATION

Type 1 ENSO (El Niño Southern Oscillation) climate phenomena have been linked to increased precipitation in California during the winter months (Schoner and Nicholson 1989; Mo and Higgins, 1998). During the winter season of 1997-98, much of central California experienced near-record rainfall, with some areas receiving as much as 240 percent of normal (table 1). Particularly intense rainfall struck the region during the first week of February. During this period, 200 mm (7.9 in) of rainfall was measured near La Honda in San Mateo County (Jayko and others, 1998) and approximately 102 mm (4 in) was measured by the National Weather Service Alert network in Alameda County.

Table 1. Percentage of normal precipitation for locations in the San Francisco Bay region.

County	Location	Precipitation total (7/97 - 3/98) ¹	Percentage of normal precipitation (7/97 - 3/98) ¹
Alameda	Oakland	1003 mm (39.5 in)	229
San Francisco	Airport	853 mm (33.6 in)	214
San Francisco	Downtown	996 mm (39.2 in)	240
Santa Clara	San Jose	597 mm (23.5 in)	215
Sonoma	Santa Rosa	1115 mm (43.9 in)	179

¹National Weather Service Daily Climatological Report

METHODS

To assess the direct economic impact of landslide damages throughout the San Francisco Bay region, a team of USGS scientific personnel and volunteer scientists conducted a field reconnaissance during April and May 1998. The study boundaries were defined as the jurisdictional limits of the 10 counties that include the urban environment surrounding the cities of San Francisco, San Jose, and Oakland. One or two individuals were assigned to each of the counties, and for several weeks they assessed the extent of landslide damage. The team followed the methodology that relies upon interviews with public agency personnel to compile cost information (Fleming and Taylor, 1980). Contact with the California Office of Emergency Services and the California Division of Mines and Geology provided information on problem areas in each county, and identified agencies and personnel that maintained records on landslide damage costs.

Table 2. Example data sheet.

General Information	
County Code and Site Number (I.e. SCR-2 or SM-1):	AI-18
Date of Report: (mo/dy/yr)	4/21/98
County:	Alameda
State:	CA
City Name/Street Address/Mile Post:	Oakland, failure affecting 5 addresses on 19th Ave. and 2 addresses on 14th Ave.
Location of Head of Slide (in decimal degrees)	
Latitude:	--
Longitude:	--
Elevation:	--
USGS 7.5 Minute Quadrangle:	Oakland East
Reporter's Name:	Site visited by Jeff Coe and Dianne Brien on 4/20 and 4/21/98.
Affiliation:	both USGS, Coe-Golden, Brien-Menlo Park
Phone:	Coe 303-273-8606
e-mail:	jcoe@usgs.gov
Slide Characteristics	
Landslide Type (following Varnes classification):	slow-moving landslide, probably rotational.
Date of Slide Occurrence:	End of January, 1998
Time of Slide Occurrence:	Not known
Nature of Ongoing Activity:	moving slightly, about 2 cm of deformation in concrete in front of toe since 3/15/98
Possible Contributing Factors:	none noted
Characterize Geologic Materials Involved:	soil
Nature of Vegetation Cover:	large trees
Estimated Dimensions	
Length:	~ 80 m
Width:	~ 50 m
Depth:	~ 3 m
Total Area:	--
Volume:	--
Characterize Slope:	16 degrees
Debris-Flow Run-Out Distance:	N/A
Damage	
Characterize Damage:	Two houses and one apartment building have been destroyed and are red-tagged. Three additional houses on 19th Ave. have mostly minor damages from settling. Garage of one residence on 14th Ave. destroyed by advancing toe and is red-tagged.
Facilities Damaged:	none
Transportation Network Damaged:	none
Deaths and/or Injuries:	none known
Estimated Dollar Value of Loss (source of data?):	732000
Source	\$732,000.00 total. Source for estimate of house damages: Shafi Refai, City of Oakland.
Existing land use	residential

Interviews with local, municipal, county, and State officials were conducted to collect damage cost data. To supplement agency reports on damage to private property, informal interviews were conducted with property owners, private consultants, engineers, and construction workers. Constraints on personnel, time, and budget, the large geographic area, and the many locations affected prevented a detailed investigation of every destructive landslide. Where possible, sites of damage were visited to estimate landslide length, type, volume, geologic setting, and direct costs. This information was recorded on a standardized data sheet to facilitate comparisons (table 2). Photo records were made of many areas of damage. (figs. 2a,b). Interviews with property owners determined the time of landslide occurrence, what efforts had been made to mitigate the situation, and what economic losses they may have suffered. Destructive landslides were located in the field using handheld Global Positioning Systems (GPS), and USGS 7.5-minute quadrangle maps. The locations were then placed in a Geographic Information System (GIS) database.

DIRECT COSTS

Table 3 lists the direct costs assessed to landslides for each county in the 10-county San Francisco Bay region. Used as a relative measure of the degree of landslide damage, these figures illustrate the magnitude and variability of economic impact throughout the region. Per-capita income is presented to give a sense of the relative ability of counties to adjust to this event.

Table 3. Direct cost data as compiled during this study.

County	Population (1998) ¹	Reported landslide costs	Per-capita costs	Per-capita income ²
Alameda	1,408,100	\$20,020,000.00	\$14.22	\$27,368.00
Contra Costa	900,700	\$27,000,000.00	\$29.98	\$32,881.00
Marin	245,900	\$2,540,000.00	\$10.33	\$45,305.00
Napa	123,300	\$1,120,000.00	\$9.08	\$29,336.00
San Mateo	715,400	\$55,000,000.00	\$76.88	\$38,380.00
Santa Clara	1,689,900	\$7,600,000.00	\$4.50	\$35,395.00
San Francisco	789,600	\$4,100,000.00	\$5.19	\$39,249.00
Solano	383,600	\$5,000,000.00	\$13.03	\$21,323.00
Sonoma	437,100	\$21,000,000.00	\$48.04	\$27,353.00
Santa Cruz	250,200	\$14,680,000.00	\$58.67	\$27,896.00
totals	6,943,800	\$158,060,000.00	\$22.76	\$32,448.60

¹State of California Department of Finance, City and County Population Estimates, May 1998

² State of California Department of Finance, California Statistical Abstract, 1998, Table D-7

The distribution of direct costs between public and private sectors varies significantly by county for the region (fig. 1). Counties that suffered widespread, significant damage from landslides (San Mateo, Alameda, and Santa Cruz) show approximately equal public and private direct costs. In other counties with high total cost figures, intense localized landslide activity biased the estimate. For example, most of the damage in Sonoma County resulted from the localized landslide disaster in the small community of Rio Nido. Three homes were completely destroyed and 32 other properties were rendered uninhabitable (MF-2325-F). In Santa Clara County, the reactivation of two local landslides by the El Niño rains caused a combined \$6.1 million in damage (MF-2325-J).

Our estimates likely reflect only a part of the total costs. No single agency is responsible for collecting information on landslide occurrence or damage and each agency compiles what information they do collect differently. Road, building-inspection, and engineering departments often provided separate accounts of costs for each county. Regional and State agencies such as the California Department of Transportation (Caltrans) provided estimates of costs over and above those incurred by counties and municipalities. Damage to private property, particularly in remote locations or minor in nature may not have been reported.

This study provides information on the direct public and private costs of damaging landslides that occurred during the El Niño winter season of 1997-98. Direct costs were assessed at over \$150 million and can be attributed to a wide variety of slope-failure processes. The built environment surrounding the cities of San Francisco, San Jose, and Oakland, California, continues to be adversely affected by slope failure of all types. Comparable events have occurred in the previous three decades, and this study illustrates the persistent nature of the landslide problem. In the absence of a comprehensive plan for mitigating the damage caused by landslides, taxpayers and private property owners of the San Francisco Bay region will likely continue to experience significant economic loss.

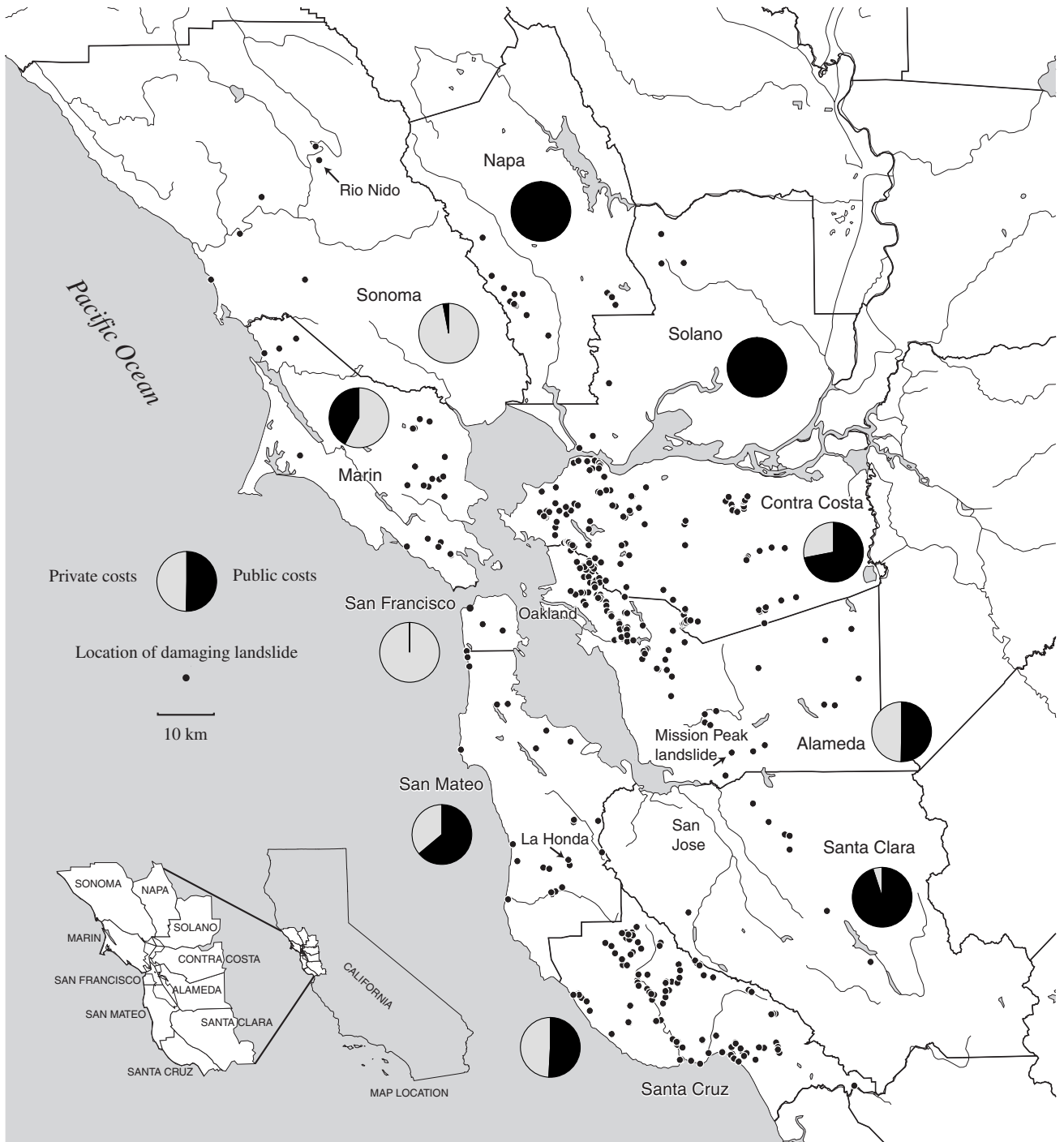


Figure 1. Map showing locations of damaging landslides in the San Francisco Bay region resulting from the 1997-98 El Niño rainstorms. Pie charts show the division of public and private costs.



Figure 2a. Example of photographic record. Damaged house located on 19th Avenue in Oakland, Alameda County. (Photograph, courtesy of J. Coe, USGS.)



Figure 2b. Example of photographic record. Typical roadway damage in Santa Cruz County. (Photograph courtesy of R. Baum, USGS.)

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