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Map showing principal debris-flow source areas in the San Francisco Bay region, California

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Fast-moving landslides called debris flows or mudslides can be expected to originate largely in the areas shown on this map. In any one rainstorm only a small fraction of these source areas may be activated. Hazard from moving mud and debris can extend well downslope from source areas.

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MAP SHOWING PRINCIPAL DEBRIS-FLOW SOURCE AREAS IN THE SAN FRANCISCO BAY REGION, CALIFORNIA

by
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INTRODUCTION

This map identifies the principal areas in the San Francisco Bay region that are likely to produce debris flows, which are also called "mudslides." Debris flows that occur in the bay region are fast-moving downslope flows of mud that may include rocks, vegetation, and other debris. These flows begin during intense rainfall as shallow landslides on steep slopes. The rapid movement and sudden arrival of debris flows pose a hazard to life and property during and immediately following the triggering rainfall.

Debris flows in a given storm originate from a number of sources scattered throughout steep parts of the landscape, as shown in figure 1 (on map sheet; files sfbr-df.ps, al-df.ps, etc.). During subsequent storms, new debris flows originate from different sources. These various sources, however, are similar in topographic form because debris-flow initiation requires steep slopes and prefers concave parts of hillsides. These topographic characteristics are used to predict the likely future source areas shown on this map.

MAP UNITS

The red zones of the map portray the principal areas from which debris flows can be expected during future storms. The black dots represent the debris-flow sources mapped after the catastrophic storm of January 1982. The dots provide an example of the abundance of debris flows that might be expected during a major rainstorm, and they illustrate the approximate nature of this predictive map.

HAZARD

Because debris flows travel downslope and downstream from source areas, hazards commonly extend beyond the red zones of the map. In the vicinity of the red zones, common areas of hazard are 1) near the base of steep hillsides, 2) near the mouths of steep sidehill drainages, and 3) in and near the mouths of canyons that drain steep terrain. Examples of these hazardous settings are shown in figure 1 (on map sheet).

USE OF THE MAP

The map shows the principal source areas of debris flows from natural hillslopes in the region. Debris flows and other fast-moving landslides may also occur from man-made slopes, such as the cut slopes along highways in hilly terrain, but such sources generally are not shown on the map. Debris flows also are possible from unmodified steep areas outside of the red zones, but we expect that most debris flows will originate in or near the red zones of the map.

Because the map depicts source areas and not flow paths, and because of its broad areal coverage and small scale, the map is intended to be used as a guide to general areas of debris-flow hazard rather than as a predictor of hazard at specific sites. Appropriate uses include storm-preparedness planning for emergency access and response.

PREPARATION OF THE MAP

The map was produced using a Geographic Information System (GIS) from a 30-meter-square grid of topographic elevations in the region. The grid of elevations, called a digital elevation model (DEM), permits calculation of hillslope steepness and curvature for each 30-m cell. The potential debris-flow sources shown on the map were determined using the values of steepness and curvature defined in table 1.

The parameters in table 1 were determined from values of steepness and curvature at mapped sources of historical debris flows in two calibration areas, one near Montara Mountain in San Mateo County (Wentworth, 1986) and one in Marin County (plate 6 of Ellen, Cannon, and Reneau, 1988). Typical plots describing these measures are shown in figure 2. The values in table 1 were selected by eye from four sets of such plots (two different types of geologic materials in each of the two calibration areas), with the aim of including most of the range of values associated with the mapped sources. Specifically, we used the values where the "sources" curves (fig. 2) attained 50 percent of their maximum value and where the "ratio" curves attained about 50 percent of the value at which they reach a crude plateau.

In the meticulously mapped calibration areas, the red zones defined by table 1 include 82 percent of the mapped debris-flow sources. In the bay region as a whole, only 53 percent of the black dots of the map lie within the red zones. This low percentage probably results at least in part from inaccurate location of the black dots due to small-scale base maps used for some of the region-wide mapping.

THE DIGITAL DATABASE

This Open-File Report is a digital map database, and the remainder of this pamphlet serves to introduce and describe the digital data. See Open-File Report 97-745A for information on how to download the digital data and on the organization of the numerous data files involved. Files are provided for a map of the entire San Francisco Bay region and for maps of each of the 10 counties in the region. There are no paper maps included in the report. The report does, however, include PostScript plot files (sfbr-df.ps, al-df.ps, etc.) that contain images of the map sheets with their explanations.

Digital Compilation

The predicted debris-flow source areas were generated from maps of slope and plan curvature, which in turn were generated from a 30-m elevation grid of the region. This elevation grid, described by Graham and Pike (1997), is also the source of the shaded-relief topographic base used for the map plotfiles. The culture layer of the base map in the plotfiles is from Aitken (1997).

The debris-flow sources mapped after the storm of January 1982 were digitized by hand in the 1980's from scale-stable greenline base maps at 1:24,000 and 1:62,500 scales, onto which features had been transferred from aerial photographs. The locations of many of these mapped sources may be inaccurate because of the sparse (200 ft) topographic contours present in the 1:62,500-scale base maps, which previously had been enlarged from 1:125,000-scale materials.

Spatial Resolution

Uses of this digital map should not violate the spatial resolution of the data. Although the digital form of the data removes the constraint imposed by the scale of a paper map, the limitations on detail and accuracy inherent in map scale are also present in the digital data. Because part of this database has an effective resolution of 1:125,000, plotting is appropriate at scales no larger than 1:125,000.

Database Specifics

The map databases consist of ARC/INFO (Environmental Systems Research Institute, Redlands, California) coverages and GRIDs that are stored in UTM projection (table 2). In coverages, digital tics define a 7.5 minute grid of latitude and longitude that correspond with the corners of the 7.5' quadrangles that fall within the region.

The content of the map database can be described in terms of the lines, areas, and points that compose the map, which are summarized in table 3. Descriptions of the database fields use the terms explained in table 4.

Lines

Lines (arcs) are recorded as strings of vectors and are described in the arc attribute table (see table 5). Except for lines in the base materials, which are described by Graham and Pike (1997), the lines on this map simply define the approximate extent of mapping of the debris-flow sources triggered during the storm of January 1982.

Areas

The principal areas of potential debris-flow sources are shown on the map by a GRID coverage, consisting of 30-m cells derived from values of hillslope steepness and curvature, as described in table 1. Cells representing potential sources have a value of 1; all other cells have no data. The grid is described in the grid attribute table (see table 6).

Points

Point information, specifically the locations of debris-flow sources triggered by the storm of January 1982, is recorded as coordinates and related information and is described in the point attribute table (see table 7).

ACKNOWLEDGMENTS AND RESPONSIBILITY

The predicted debris-flow source areas were determined by Ellen and Mark by analysis of detailed mapping (Wentworth, 1986; Ellen, Cannon, and Reneau, 1988) that was meticulously digitized by Ramsey and May. The mapped debris-flow sources triggered by the 1982 storm were digitized by Wieczorek and Mark from mapping documented in Ellen and Wieczorek (1988); the boundary of this mapping was digitized by Beukelman. The shaded-relief topographic base was created by Graham using relations provided by R.A. Haugerud.

REFERENCES CITED

Aitken, D.S., 1997, A digital version of the 1970 U.S. Geological Survey topographic map of the San Francisco Bay region, three sheets, 1:125,000 scale: U.S. Geological Survey Open-File Report 97-500.

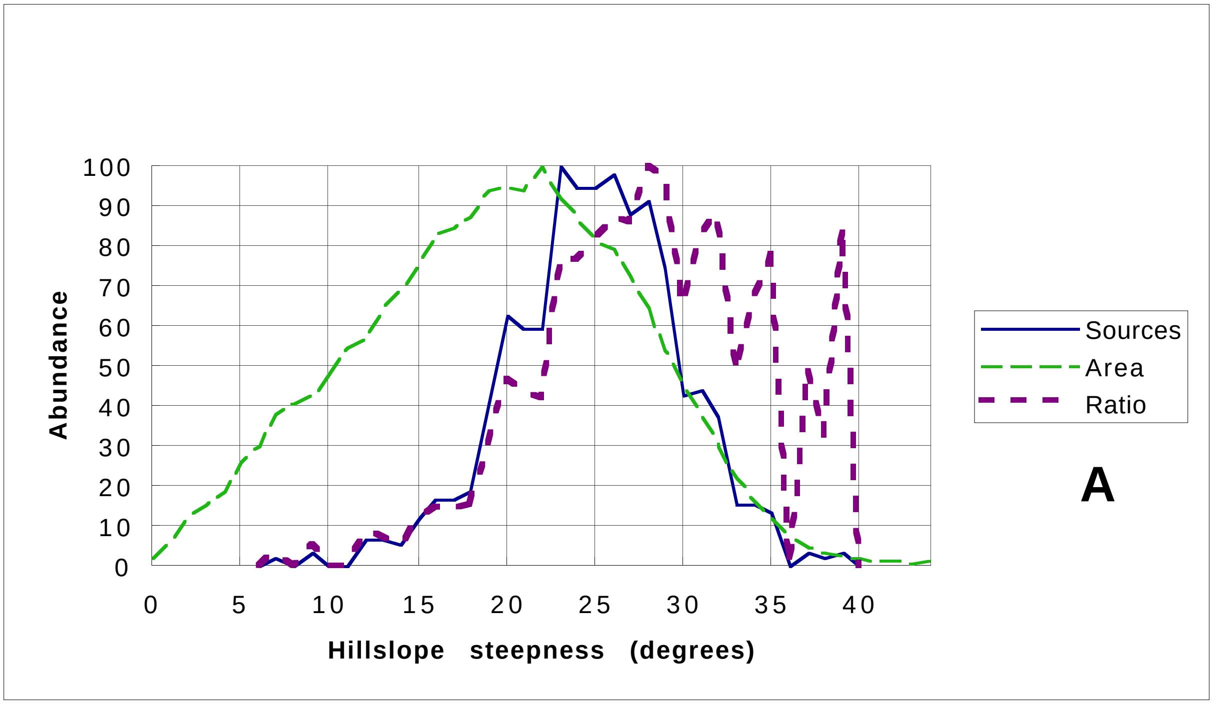
Ellen, S.D., Cannon, S.H., and Reneau, S.L., 1988, Distribution of debris flows in Marin County, plate 6, *in* Ellen, S.D., and Wieczorek, G.F., eds., Landslides, floods, and marine effects of the storm of January 3-5, 1982, in the San Francisco Bay region, California: U.S. Geological Survey Professional Paper 1434, 310 p., plate 6 at 1:24,000 scale.

Graham, S.E., and Pike, R.J., 1997, Shaded relief map of the San Francisco Bay region, scale 1:275,000: U.S. Geological Survey Open-File Report 97-745 B.

Wentworth, C.M., 1986, Maps of debris flow features evident after the storms of December 1955 and January 1982, Montara Mountain area, California: U.S. Geological Survey Open-File Map 86-363, 2 sheets at 1:24,000 scale.

FIGURES AND TABLES

Figure 1 (on map sheet): Perspective view showing typical debris flows (yellow) resulting from a major storm, in relation to potential source areas (red zones) like those shown on the map. In any one storm only a small fraction of the potential source areas may be activated. Most debris flows in the San Francisco Bay region travel only several tens of yards or less, but some may travel hundreds of yards downslope from their sources and others have traveled as much as a mile or more down stream channels. Numbers refer to typical hazardous locations discussed in text.



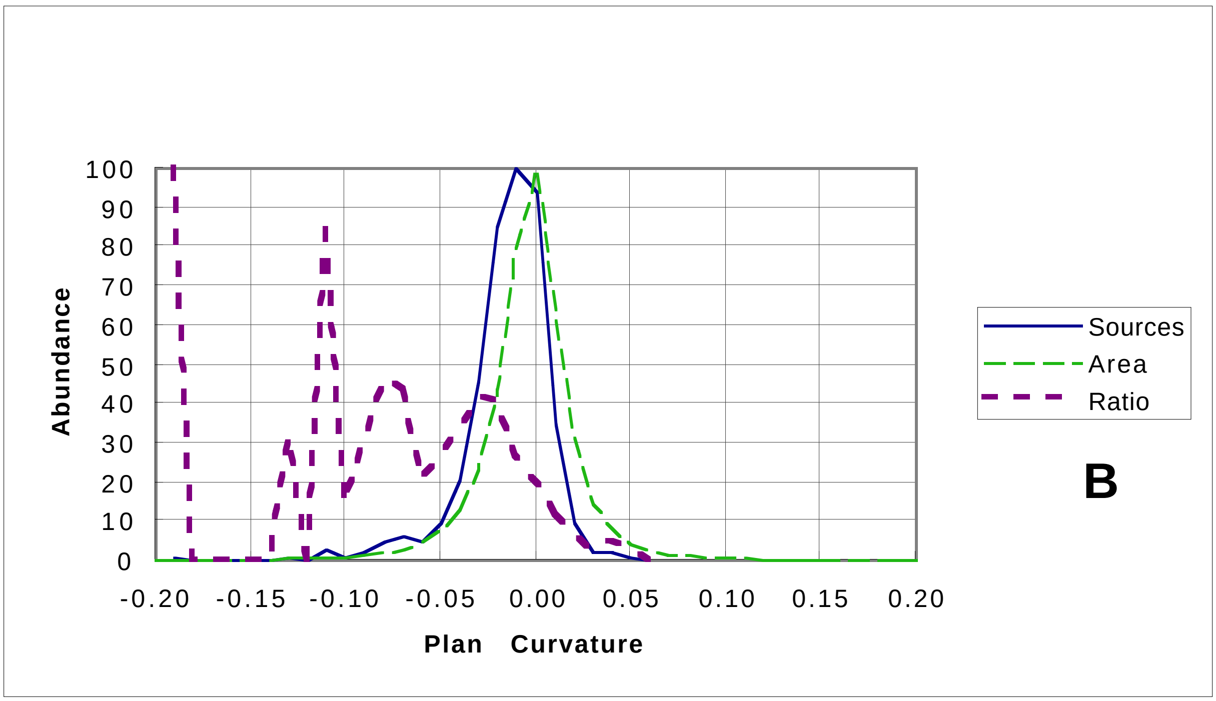


Figure 2: Plots of hillslope steepness (A) and plan curvature (B) at mapped debris-flow sources in areas of non-granitic bedrock near Montara Mountain. Values are measured from 30-m elevation grid; maximum value of each curve is adjusted to 100. Sources, values at mapped debris-flow sources; area, values in area as a whole; ratio, the ratio of "sources" to "area." Erratic behavior of ratio at high values of steepness and low values of curvature results from sparsity of data points.

Table 1 - Hillslope steepness and curvature used to map potential debris-flow source areas [Values as measured on 30-m elevation grids. Plan curvature is curvature of the ground surface in a horizontal plane; it is measured as 1/r, where r is radius of curvature in meters and negative values indicate concave areas such as swales. Hillslope steepness is dominant in determining potential source areas of the map; plan curvature excludes only 6.5 percent of hillslopes 20 degrees and steeper]

Hillslope steepness	Plan curvature
20 degrees and greater	+0.01 and less (including all negative values)

Table 2 - Map projection
The map is stored in Universal Transverse Mercator projection

PROJECTION UTM	
UNITS METERS	-on the ground
ZONE 10	-UTM Zone 10
DATUM NAD27	
PARAMETERS	-none

Table 3 - Summary of database components

LAYER	TYPE	FILE NAMES
Potential debris-flow source areas	Grid	sfbr-df, etc.
Mapped 1982 debris-flow sources	Points	sfbr-dfs, etc.
Boundary of mapping of 1982 sources	Arcs	sfbr-dfml, etc.

Table 4 - Field definition terms

ITEM NAME	name of the database field (item)
WIDTH	maximum number of digits or characters stored
OUTPUT	output width
TYPE	B-binary integer, F-binary floating point number, I-ASCII integer, C-ASCII character string
N. DEC.	number of decimal places maintained for floating point numbers

Table 5 - Content of the arc attribute tables (sfbr-dfml.aat, etc.)

ITEM NAME	WIDTH	OUTPUT	TYPE	N. DEC

FNODE#	4	5	B		starting node of arc (from node)
TNODE#	4	5	B		ending node of arc (to node)
LPOLY#	4	5	B		polygon to the left of the arc
RPOLY#	4	5	B		polygon to the right of the arc
LENGTH	4	12	F	3	length of arc in meters
<coverage>#	4	5	B		unique internal control number
<coverage>-ID	4	5	B		unique identification number

Table 6 - Content of the grid attribute tables (sfbr-df.vat, al-df.vat, cc-df.vat, etc.)

ITEM NAME	WIDTH	OUTPUT	TYPE	N. DEC	
VALUE	4	10	B		Value of cell in the grid
COUNT	4	10	B		Number of cells of that value

Table 7 - Content of the point attribute tables (sfbr-dfs.pat, al-dfs.pat, etc.)

ITEM NAME	WIDTH	OUTPUT	TYPE	N. DEC	
AREA	4	12	F	3	not used
PERIMETER	4	12	F	3	not used
<coverage>#	4	5	B		unique internal control number
<coverage>-ID	4	5	B		unique identification number
PTTYPE	35	35	C		point type