LANDSLIDES IN ALAMEDA COUNTY, CALIFORNIA, A DIGITAL DATABASE EXTRACTED FROM PRELIMINARY PHOTOINTERPRETATION MAPS OF SURFICIAL DEPOSITS BY T.H. NILSEN IN USGS OPEN-FILE REPORT 75-277

by

Sebastian Roberts[1], Michelle A. Roberts[1], and Eileen M. Brennan[1]

with a preface by

Richard J. Pike[1] and Sebastian Roberts[1]

Open-File Report 99-504
Version 1.1

1999

U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards or with the North American Stratigraphic Code. Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

This database, identified as 'Landslides in Alameda County, California, a digital database extracted from preliminary photointerpretation maps of surficial deposits by T.H. Nilsen in USGS Open-file Report 75-277', has been approved for release and publication by the Director of the USGS. Although this database has been reviewed and is substantially complete, the USGS reserves the right to revise the data pursuant to further analysis and review. This database is released on condition that neither the USGS nor the U.S. Government may be held liable for any damages resulting from its use.

---

[1] Menlo Park, CA

Cover illustration: Reactivated 40-hectare (100-acre) earth flow on Mission Peak, in southern Alameda County, which threatened several homes in the town of Fremont in the spring of 1998, when it moved downslope at the rate of a meter per day. The Mission Peak slide is part of a much larger landslide complex initially mapped by Nilsen (1973b) and included in the digital database released in this report. Photo 1998 by J.D. Rogers

ABSTRACT

All or part of 25 7.5-minute quadrangles identifying 8465 landslides—largely slow-moving slides and earth flows—in Alameda County, California, have been converted to a digital-map database, compiled at 1:24,000 scale and plotted at 1:62,500 scale, that can be acquired from the U.S. Geological Survey over the Internet or on magnetic tape.

PREFACE

Public agencies in the 1960's became increasingly aware of their responsibility to take geologic hazards into consideration when planning future regional development. One reason for this growing awareness was a series of court decisions that increased the liability of public agencies in cases where property was damaged by natural hazards—and the agency had been involved in approving the affected site for development. Another was the realization that many geologic hazards can be anticipated and thus can be used to make informed development decisions (Camerotto and Johnson, 1972). As a result of this shift in attitude the San Francisco Bay Region Environmental and Resources Planning Study (SFBRS) was formed in 1970 with support from the U.S. Geological Survey (USGS) and the Department of Housing and Urban Development's Office of Policy Development and Research. The study sought to provide, in forms understandable and usable by non-specialists, the earth-science information needed to solve problems related to growth and development in the nine-county, 7,400-square-mile San Francisco Bay Region (Nilsen and others, 1979).

Among the scores of publications resulting from the SFBRS effort was a 1:24,000-scale photointerpretive inventory of (predominantly) old and ancient landslides measuring over 200 feet across and other surficial geologic deposits in the southeastern part of the Bay Region (Nilsen and others, 1975). The present report is a 1:24,000-scale digital database that reproduces the landslide content (n = 8465) of that inventory for Alameda County. The area included by the database was mapped by Nilsen only.

Several series of vertical aerial photographs taken for USGS were used by Nilsen to prepare the original maps; series BUU taken in 1958, 1959, and 1966 at the scale of 1:20,000, series GS-Yf taken in 1953 at the scale of 1:23,600, and series GS-JL taken in 1949 at the scale of 1:23,600. In addition larger scale maps at the scale of 1:80,000 from series GS-VCMI were used over the entire county.

The 1:24,000-scale landslide-inventory maps that cover Alameda County had been drafted prior to 1975 and released in the SFBRS publications series as six paper maps at 1:62,500-scale (Nilsen, 1971, 1972a-c, 1973a, b; see also, Nilsen and others, 1976). These coarser-scale maps do not contain the fine detail of the 1:24,000 source maps—all of which is, however, preserved in the digital database of this report. A generalized broad-scale compilation of landslide deposits in Alameda and nine other Bay Region counties was also published as a paper map by Nilsen and others (1979) and in digital-map format by Wentworth and others (1997).

Although the information in this database has not been updated or amended beyond that in the original publication, we are releasing it in digital form because it is the only systematic landslide-inventory that covers Alameda County in its entirety. Users are cautioned that these 35- to 40-year-old data have shortcomings in addition to caveats cited in the original map text (see Part I, below). Information on the hazard is incomplete; no slope failures since 1966 are shown. The many landslides from the severe winters of 1982, 1983, and 1998 (Coe and others, 1999) are absent. Detailed mapping by private consultants also is not included here, nor are landslides mapped more recently by the California Division of Mines and Geology (Majmundar, 1991a, b; 1995a, b).

Because landslides in the database were mapped remotely, from aerial photographs, Nilsen ascribed two levels of certainty to his interpretations. Deposits are queried "?" where identification was uncertain. The 8465 deposits are not attributed as to type of movement, but consist primarily of slow-moving slides and earth flows (Wentworth and others, 1997). Their time of formation ranges from perhaps a few hundred thousand years ago to 1966. Deposit thickness ranges from about three meters to a few hundred meters; larger deposits are thicker; many small deposits may be thin and involve surficial materials only. Debris flows are absent from the database (The January 3-5, 1982, storm alone triggered many such failures; Ellen and others, 1997). Locations in Alameda County that might be susceptible to this type of small landslide are indicated in a recent terrain-based mathematical model that predicts source areas for debris flows (Ellen and others, 1997). Nilsen and others (1976) offer further background on slope-failure problems in Alameda County.

This report comprises three separate and distinct parts. The first reproduces excerpts from T.H. Nilsen's explanatory text printed on the source maps. Part II describes compilation of the source maps as a digital database and the conventions adopted in encoding the landslide information in a geographic information system (GIS). The final section describes details of the digital-map database, its constituent data files, and their computer formats. Part III further lists the steps required to obtain the contents of the landslide-map database, and the 1:62,500-scale paper plot derived from it, from USGS. Roberts and others (1998) is an earlier report in this series of digital re-releases of mapped USGS and other landslide inventories for San Francisco Bay Region counties.

REFERENCES

Camerotto, O.G., and Johnson, S.S., 1972, Public works engineering: San Francisco Bay Region Study—multi-disciplinary study, first meeting, Menlo Park, CA, October 11, 1972, unpublished typescript of presentation, 16 p.

Coe, J.A., Godt, J.W., Brien, Dianne, and Houdre, Nicolas, 1999, Map showing locations of damaging landslides in Alameda County, California, resulting from 1997-98 El Niño rainstorms: U.S. Geological Survey, Miscellaneous Field Studies Map MF-2325-B, scale 1:125,000.

Ellen, S.D., Mark, R.K., Wieczorek, G.F., Wentworth, C.M., Ramsey, D.W., and May, T.E., 1997, Map showing principal debris-flow source areas in the San Francisco Bay region, CA: U.S. Geological Survey, Open-File Report 97-745 E. <http:wrgis.wr.usgs.gov/open-file/of97-745/index.html>.

Majmundar, H.H., 1991a, Landslides and related features, *in* Landslide hazards in Livermore Valley and vicinity, Alameda and Contra Costa Counties, California: Calif. Div. Mines and Geology, Open-file Report 91-2, plates B1 and B2, map scale 1:24,000.

Majmundar, H.H., 1991b, Landslides and related features, *in* Landslide hazards in the Tassajara and Byron Hot Springs 7.5' quadrangles, Alameda and Contra Costa Counties, California: Calif. Div. Mines and Geology, Open-file Report 92-5, plate B, map scale 1:24,000.

Majmundar, H.H., 1996a, Landslides and related features, *in* Landslide hazards in the Hayward quadrangle and parts of the Dublin quadrangle, Alameda and Contra Costa Counties, California: Calif. Div. Mines and Geology, Open-file Report 95-14, plate B, map scale 1:24,000.

Majmundar, H.H., 1996b, Landslides and related features, *in* Landslide hazards in the Las Trampas Ridge quadrangle and parts of the Diablo quadrangle, Alameda and Contra Costa

Counties, California: Calif. Div. Mines and Geology, Open-file Report 95-15, plate B, map scale 1:24,000

Nilsen, T.H., 1971, Preliminary photointerpretation map of landslide and other surficial deposits of the Mount Diablo area, Contra Costa and Alameda Counties, California: U.S. Geol. Survey Misc. Field Studies map MF-310, scale 1:62,500.

Nilsen, T.H., 1972a, Preliminary photointerpretation map of landslide and other surficial deposits of the Altamont and Carbona 15-minute quadrangles, Alameda County, California: U.S. Geol. Survey Misc. Field Studies map MF-321, scale 1:62,500.

Nilsen, T.H., 1972b, Preliminary photointerpretation map of landslide and other surficial deposits of the Byron area, Contra Costa and Alameda Counties, California: U.S. Geol. Survey Misc. Field Studies map MF-338, scale 1:62,500.

Nilsen, T.H., 1972c, Preliminary photointerpretation map of landslide and other surficial deposits of the Mount Hamilton quadrangle and parts of the Mount Boardman and San Jose quadrangles, Alameda and Santa Clara Counties, California: U.S. Geol. Survey Misc. Field Studies map MF-339, scale 1:62,500.

Nilsen, T.H., 1973a, Preliminary photointerpretation map of landslide and other surficial deposits of the Concord 15-minute quadrangle and the Oakland West, Richmond, and part of the San Quentin 7.5-minute quadrangles, Contra Costa and Alameda Counties, California: U.S. Geol. Survey Misc. Field Studies map MF-493, scale 1:62,500.

Nilsen, T.H., 1973b, Preliminary photointerpretation map of landslide and other surficial deposits of the Livermore and parts of the Hayward 15-minute quadrangles, Alameda and Contra Costa Counties, California: U.S. Geol. Survey Misc. Field Studies map MF-519, scale 1:62,500.

Nilsen, T.H., Bartow, J.A., Frizzell, V.A., and Sims, J.D., 1975, Preliminary photointerpretation maps of landslide and other surficial deposits of 56 7.5-minute quadrangles in the southeastern San Francisco Bay region, Alameda, Contra Costa, and Santa Clara Counties, California: U.S. Geological Survey Open-File Report No. 75-277, scale 1:24,000.

Nilsen, T.H., Taylor, F.A., and Brabb, E.E., 1976, Recent landslides in Alameda County, California (1940-71)—An estimate of economic losses and correlations with slope, rainfall, and ancient landslide deposits: U.S. Geologic Survey Bulletin 1398, 21 p.

Nilsen, T.H., Wright, R.H., Vlasic, T.C., and Spangle, W.E., 1979, Relative Slope Stability and Land-use Planning in the San Francisco Bay Region, California: U.S. Geologic Survey Professional Paper 944, 96 p.

Roberts, Sebastian, Barron, Andrew, Brabb, E.E., and Pike, R.J., 1998, Digital compilation of "Preliminary map of landslide deposits in Santa Cruz County, CA, by Cooper-Clark and Associates, 1975": U.S. Geol. Survey, Open-file Report 98-792, 22 p.

Wentworth, C.M., Graham, S.E., Pike, R.J., Beukelman, G.S., Ramsey, D.W., and Barron, A.D., 1997, Summary distribution of slides and earth flows in the San Francisco Bay region, CA: U.S. Geol. Survey, Open-file Report 97-745 C, 10 p. plus 11 maps. <http:wrgis.wr.usgs.gov/open-file/of97-745/index.html>.

I.

THE SOURCE MAP

The following excerpts from Nilsen (1972c) are reproduced verbatim.

INTRODUCTION

The nine San Francisco Bay region counties lie within a geologically active, young, and dynamic part of the central and northern Coast Ranges of California. Significant movements of the earth's crust are occurring here at the present time, posing numerous problems to urbanization, including some of special concern. Geological processes such as fault movements, earthquakes, land subsidence, landsliding, slow downslope movement of bedrock and surficial materials, coastal and stream erosion, flooding, and sedimentation are all potentially hazardous. Because of these factors, an understanding of the operation of physical processes in the Bay region is desirable for harmonious, efficient, and safe land-use planning, particularly now, with greatly expanded pressures for urban growth.

This map presents preliminary information about one aspect of the physical environment necessary to sound land-use planning; the nature and distribution of surficial deposits. Because surficial deposits are common and well developed in much of the Bay region, it is useful to know how and why they have formed, as well as what properties they possess. When maps like this are used in combination with other types of environmental information, such as data on soils, bedrock geology, slopes, vegetation, climatic variation, seismic response, and hydrology, it should be easier to arrive at sound decisions regarding the physical aspects of land use. The U.S. Geological Survey is studying many of these factors in the Bay region and hopes to provide the community with much of the required information as part of its San Francisco Bay Region Study in cooperation with the Department of Housing and Urban Development.

The representation of surficial deposits on this map reflects the way in which a geologist, working exclusively with aerial photographs, interpreted the origin of various elements of the present landscape. The deposits shown here have not been examined in the field. However, by viewing overlapping vertical aerial photographs through a stereoscope, the geologist sees a three-dimensional relief model of the ground surface and can study and interpret the origins of landforms with considerable ease. In fact, for mapping surficial deposits, particularly in reconnaissance-type studies, photointerpretation has advantages over both ground observations and laboratory studies of surficial materials. Of course, better information can be provided when all aspects of the study are integrated. These preliminary photo interpretation maps are only the first stage in a detailed study of surficial deposits in the Bay region, but they should provide land-use planners with immediately useful information about the regional distribution of landslide and other surficial deposits.

This map indicates the dominant surficial processes that have probably been operative by showing the distribution of different types of surficial deposits. Processes such as weathering, erosion, and the slow as well as rapid downslope movement of earth materials have constantly reshaped the land surface in the past and will continue to in the future, although at varying rates. The processes are interrelated to varying degrees. For example, crustal uplift of the Coast Ranges will lead to increased erosion and downcutting by streams that in turn generally results in increased deposition of sediments in river valleys, lakes, and shoreline areas. Older flood plains and river deposits may be eroded, leaving elevated terrace deposits. In addition, downcutting, by streams may cause adjacent slopes to become unstable, thereby increasing the possibility of slope failures.

Man's activities can alter natural physical processes in many ways. Simple acts such as overwatering a lawn or placing a septic tank drainfield in ground that is marginally stable may weaken the bedrock and surficial materials enough to induce landsliding. Relatively stable areas may be made unstable as a result of construction activities that involve cutting or oversteepening of natural slopes. Engineers, builders, conservationists, and others concerned with land use must evaluate the potential effects of all types of development, and maps that show the nature and distribution of surficial deposits should provide much of the basic information they need.

This map, then, shows the cumulative effects of various processes that have yielded surficial deposits up to the time the photographs used for photointerpretation were taken. It does not indicate directly areas where processes will be most active, nor does it show the rate at which they will operate. However, knowledge of the history of geologic events is a key to understanding and predicting the evolution of an area, even where man's activities significantly change the character of the land. Almost all new landslides, for example, occur in areas with a history of landslide activity.

EXPLANATION FOR LANDSLIDE DEPOSITS SHOWN ON THE MAP

Landslide deposits: debris composed of fresh and weathered rock fragments, sediment, colluvial material, and artificial fill, or any combinations thereof, that has been transported downslope by falling, sliding, rotational slumping, or flowing. Landslide deposits smaller than approximately 200 feet in longest dimension are not shown on the map.

- (polygon symbol) - Landslide deposit larger than approximately 200 feet in longest dimension (except in the La Costa Valley quadrangle, where the size cutoff is 500 feet); arrows indicate general direction of downslope movement; queried where identification is uncertain.

- (arrow symbol; La Costa Valley quadrangle only) - Landslide deposit between approximately 200 feet and 500 feet in longest dimension; arrow indicates general direction of downslope movement, and is positioned over location of deposit; queried where identification uncertain.

Complex landslide deposits, which result from combinations of different types of downslope movement, are perhaps the most common type of landslide deposit in the Bay region. In particular, materials near the head of landslide deposits typically move in a different manner than materials at the toe. The landslide deposits shown on this map have not been classified according to either type of movement or type of material of which the deposit is composed. The deposits vary in appearance from clearly discernible, largely unweathered and uneroded topographic features to indistinct, highly weathered and eroded features recognizable only by their characteristic topographic configurations. The time of formation of the mapped landslide deposits ranges from possibly a few hundred thousand years ago to 1966. No landslide deposits that formed since 1966 are shown. The thickness of the landslide deposits may vary from about 10 feet to several hundred feet. The larger deposits are generally thickest; many small deposits may be very thin and may involve only surficial materials.

FACTORS AFFECTING MAP ACCURACY

<u>Date of photography</u>: Modifications of the landscape that have occurred since the date the aerial photographs were taken are not shown on this map. Thus, landslide deposits and large artificial fills that postdate the photography are not delineated, although some of the topographic base maps were photorevised in 1968 and do show the extent of urbanization to that date.

<u>Urbanization</u>: Surficial geologic features can be obscured in urbanized areas by (1) modification of the natural landscape by grading (leveling, cutting, filling, or terracing), and (2) man-made structures that cover the natural land surface. Less than 10 percent of the area included in this map has been extensively urbanized.

<u>Forest cover:</u> Surficial deposits may be difficult to recognize in forested areas, so that such areas

may be mapped less accurately than grass-covered areas. Many landslide deposits may be impossible to recognize on slopes covered with dense stands of tall trees. Less than 15 percent of the area included in this map is densely forested.

Quality of photography: The accuracy of the map varies directly with the clarity and contrast of the aerial photographs used. Accordingly, haze, cloud cover, or poor sun angles make photointerpretation more difficult; also, the steepness of the topography and the location and extent of shaded areas-affect the usefulness of individual photographs. In general, however, the photographs used to prepare this map are of excellent quality.

Scale of maps and photography: Landslide and other surficial deposits less than about 200 feet long are not shown because they are too small to be clearly identified on the photographs or clearly portrayed on the topographic base map. In addition, no attempt has been made to show the numerous small areas covered by artificial fill along highways, railroads and airstrips, in cemeteries, in populated and farming areas, or near quarries and mines, even though some are more than 200 feet in longest dimension.

Problems in interpretation: Mapping of surficial deposits by photointerpretation alone presents a number of difficult problems, some of which can be resolved only through field checking. Problems that are especially difficult include:

(1) distinguishing terrace-shaped slump-type landslide deposits from alluvial terrace deposits where both are located adjacent to stream courses;
(2) recognizing bedrock cropping out beneath surficial deposits, especially where a creek or stream has cut down through the overlying surficial deposits to expose bedrock along the stream bed;
(3) determining boundaries between adjacent surficial deposits that laterally grade into or interfinger with one another without leaving any easily discernible topographic boundaries, e.g., the downstream gradation of alluvial terrace deposits into alluvial deposits;
(4) recognizing landslide deposit boundaries--whereas the upslope boundary is commonly defined by an easily recognized scarp, the toe or downslope boundary is seldom well defined and is difficult to locate exactly;
(5) recognizing stable masses of bedrock within landslide deposits, especially where the bedrock may appear only as a large block within the surrounding landslide deposit; and
(6) distinguishing between irregular or hummocky topography caused either by variations in the erosional resistance of bedrock or by the erosion of landslide deposits.

CHARACTERISTICS OF SURFICIAL DEPOSITS RELEVANT TO LAND-USE PLANNING

General background: The physical properties and engineering characteristics of the mapped surficial deposits can be inferred from knowledge of the geologic processes that formed them. Thus, with the information provided by this map, preliminary evaluations of the significance of the materials and processes with regard to land-use decisions can be made.

Landslide deposits: Landslides occur when the pull of gravity on earth materials overcomes their frictional resistance to downslope movement. Slope stability is affected by

(1) type of earth materials - unconsolidated, soft sediments or surficial deposits will move downslope easier than consolidated, hard bedrock;
(2) structural properties of earth materials - the orientation of the layering of some rocks and sediments relative to slope directions, as well as the extent and type of fracturing and crushing of the materials, will affect landslide potential;
(3) steepness of slopes - landslides occur more readily on steeper slopes;
(4) water - landsliding is generally more frequent in areas of seasonally high rainfall, because the addition of water to earth materials commonly decreases their resistance to sliding; water decreases internal friction between particles, decreases cohesive forces that bind clay minerals together, lubricates surfaces along which slippage may occur, adds weight to surficial deposits and bedrock, reacts with some clay

minerals, causing volume changes in the material, and mixes with fine-grained unconsolidated materials to produce wet, unstable slurries;

(5) ground shaking - strong shaking during earthquakes can jar and loosen bedrock and surficial materials, thus making them less stable;

(6) type of vegetation - trees with deep penetrating roots tend to hold bedrock and surficial deposits together, thereby increasing ground stability;

(7) proximity to areas undergoing active erosion - rapid undercutting and downcutting along stream courses and shorelines makes slopes in these areas particularly susceptible to landsliding.

All the natural factors that promote landsliding are present in the Bay region. In addition, man has at times decreased the potential for slope failures by leveling slopes, building retaining walls at the base of slopes, planting trees or seeding forests, as well as practicing soil conservation. However, other of his activities have increased the potential for slope failures, including increasing slope angles for road or building construction; adding water to marginally stable slopes by watering lawns, improperly handling rain-water runoff and choosing poor sites for septic tank drainfields; adding to the weight of marginally stable slopes by building structures as well as by adding fill for foundations; and removing natural vegetation. Thus, slope failure, a natural phenomenon that has occurred throughout the Bay region in the past, may be aggravated by improper land use.

The landslide deposits shown on the map may or may not be continuously or intermittently moving at the present time. The potential for continued movement varies greatly and depends on many factors, including the age of the deposits and their previous histories of activity. Some deposits may pose no problems for many types of development, while development on others may offer serious problems. Most landsliding takes place in areas where landsliding has occurred before, and old landslide deposits are commonly reactivated by either natural or artificial means. The materials that form landslide deposits may be so broken up and disturbed that landsliding may easily recur, especially if slope angles or moisture contents are changed. Landslide deposits are characterized by

(1) small isolated ponds, lakes, and other closed depressions;
(2) abundant natural springs;
(3) abrupt and irregular changes in slope and drainage pattern;
(4) hummocky irregular surfaces;
(5) smaller landslide deposits that are commonly younger and form within older and larger landslide deposits;
(6) steep, arcuate scarps at the upper edge of the deposit;
(7) irregular soil and vegetation patterns;
(8) disturbed vegetation; and
(9) abundant flat areas that might appear suitable as construction sites.

In general, fewer of these characteristics will be noted in the smaller deposits. Detailed ground studies, of course, are required for predicting the future behavior of landslide deposits under changing conditions.

SUGGESTIONS FOR MAP USERS

<u>Planning departments and developers:</u> The density of landslide deposits is a crude measure of the importance of slope failure as an erosional process and, therefore, a measure of the overall slope stability of an area. However, this map cannot be used to determine the probability of future landsliding, primarily because geologic and climatic changes during the past few hundred thousand years have altered slope stability and because the map does not provide detailed information regarding the composition and type of movement of individual landslide deposits. Therefore, the map should not be used as a substitute for detailed site investigations by engineering geologists and soils engineers; areas susceptible to landslide activity should be carefully studied before any development.

<u>Geologists and engineers:</u> This map has been prepared to provide a regional context for interpreting detailed site investigations and should be used in conjunction with slope maps, bedrock geology maps, soils maps, and other available information. It is not intended as a substitute for site investigations, and its limitations should be clear. Comments regarding its usefulness and accuracy would be appreciated.

Home buyers: Areas with relatively low densities of landslide deposits probably have good slope stability compared with areas with high densities of landslide deposits. However, landslide deposits less than 200 feet long have not been mapped, and the scale of this map is such that individual buildings cannot be precisely located. In fact, areas mapped as landslide deposits are not necessarily less stable than adjacent areas. The map, therefore, should not be used as a substitute for a report by an engineering geologist or soils engineer, because detailed site investigations are necessary for judgments about the slope stability of individual areas. In addition, other types of surficial deposits may pose construction problems and require investigation.

REFERENCES

Eckel, E.B., ed., 1958, Landslide and engineering practice: Highway Research Board Spec. Rept. 29, NAS/NRC 544, Washington, D.C., 232 p.

Flawn, P.T., 1970, Environmental geology; conservation, landuse planning, and resource management: New York, Harper & Row, 313 p.

Goldman, H. B., ed., 1969, Geologic and engineering aspects of San Francisco Bay fill:, California Div. Mines and Geology Spec. Rept. 97, 130 p.

Leighton, F.B., 1966, Landslides and hillside development, *in* Engineering geology in southern California: Assoc. Eng. Geologists, Los Angeles Section, Spec. Publ., p. 149-193.

Mitchell, J. K., 1963, Engineering properties and problems of the San Francisco Bay mud: California Div. Mines and Geology Spec. Rept. 82, p. 25-32.

Nichols, D. R., and Wright, N. A., 1971, Preliminary map of historic margins of marshland, San Francisco Bay, California: U.S. Geol. Survey open-file map, scale 1:125 000.

Sharpe, C.F.S., 1960, Landslides and related phenomena: Paterson, N.J., Pageant Books, 137 p.

Terzaghi, Karl, 1950, Mechanism of landslides, *in* Paige, S.M., chm., Application of geology to engineering practice (Berkey volume): New York, Geol. Soc. America, p. 83-123.

Trask, P.D., and Rolston, J.W., 1951, Engineering geology of San Francisco Bay, California: Geol. Soc. America Bull., v. 62, no. 9, p. 1079-1110.

Zaruba, Quido, and Mencl, Vojtech, 1969, Landslides and their control: Amsterdam, Elsevier, 205 p.

II.

DIGITAL COMPILATION

INTRODUCTION

We compiled the landslide-deposit database at a scale of 1:24,000 in version 7.1.1 of ARC/INFO, a commercial geographic information system, or GIS (Environmental Systems Research Institute [ESRI], Redlands, California), on a UNIX computer using the menu interface ALACARTE (versions 1 through 3.1: Fitzgibbon and Wentworth, 1991; Fitzgibbon, 1991; Wentworth and Fitzgibbon, 1991).

The digital compilation was derived from linework inked directly by T.H. Nilsen on 25 USGS Mylar greenline 7.5-minute (1:24,000-scale) quadrangles that cover Alameda County and were used to photographically reproduce the lines on his 1975 and 1976 maps. The linework for each greenline was scanned (400 dots per inch), converted from raster to vector form, imported into ARC/INFO, hand edited to remove all information save landslides, and combined into a single digital file. Landslide outlines were adjusted as needed to align across quadrangle boundaries. The base map for the landslide data comprises topography, drainage, and culture from 1:125,000-scale USGS Bay Region Topographic Sheets (Aitken 1997). A 1:62,500-scale map image was derived from the digital database.

The boundary of Alameda County (from Wentworth, 1997) was added to the database to delineate the county from the surrounding area. Landslides outside the county boundary are excluded from this database. The 25 constituent USGS quadrangles are: Richmond, Briones Valley, Oakland East, Las Trampas Ridge, Diablo, Tassajara, Byron Hot Springs, Clifton Court Forebay (formerly Bethany), San Leandro, Hayward, Dublin, Livermore, Altamont, Midway, Newark, Niles, La Costa Valley, Mendenhall Springs, Cedar Mountain, Lone Tree Creek, Milpitas, Calaveras Reservoir, Mt. Day, Eylar Mountain, and Mt. Boardman. Nilsen mapped no landslides in four additional quadrangles in western Alameda County—Oakland West, Hunters Point, Redwood Point, and Mountain View.

LANDSLIDE-DEPOSIT UNITS

In all quadrangles but one, landslides larger than 200 feet in maximum dimension are represented in the spatial database by polygons enclosing their approximate boundaries. In the La Costa Valley quadrangle, Nilsen denoted landslides 200-500 feet across by a small arrow. In the digital database, small landslides for that quadrangle are represented by an arrow; they are plotted on the landslide-deposit map from the Postscript and PDF plot files included with the database. The arrow points in the direction of downslope movement and is centered on the location of the deposit. Although smaller landslides in the La Costa Valley quadrangle range from 200 to 500 feet, all arrow symbols are the same size, about 200 feet long. The primary landslide identifier in the La Costa Valley quadrangle is a character string in the field PTYPE (polygon type) for the large landslide data layer and PTTYPE (point type) for the small landslide data layer.

Values in the PTYPE and PTTYPE fields give the two levels of certainty Nilsen ascribed to his interpretations. The values for this field are 'Landslide deposit' and 'Landslide deposit, identification uncertain'. Comparatively few deposits are 'uncertain'. In both the Postscript and PDF plot files, large landslide polygons are color coded accordingly; for the small landslides in the La Costa Valley quadrangle, the classification is printed at the head of each arrow as annotation.

Table 1. General PTYPE and PTTYPE Categories

Descriptions of landslide categories are modified from Landslide Map Annotation

ls	- landslide deposit
lsu	- landslide deposit, identification uncertain

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 physical constraint imposed by the scale of a paper map, the detail and accuracy inherent in map scale are also present in the digital data. Because this database was extracted from maps at a scale of 1:24,000 and compiled at that same scale, higher-resolution information is not present. Enlargement of the database to scales larger than 1:24,000 will not yield greater real detail, although it may reveal fine-scale irregularities below the intended resolution of the database. Similarly, where this database is used in combination with other data of higher resolution, the resolution of the combined output will be limited by the lower resolution of these data.

SPECIFICS OF THE LANDSLIDE-DEPOSIT DATABASE

The landslide-deposit spatial database itself consists of two different data layers each with the naming convention <pf>-extn. The prefix abbreviation <pf> is either <al> for Alameda County or <lc> for the La Costa Valley Quadrangle and the abbreviation <extn> is a data layer extension (suffix). The two data layers are described in Table 2 below. The map layer is stored in UTM projection (zone 10) (see Table 3), and projection files are included to convert between that and the state plane projection. Digital tics define a 7.5 minute grid of latitude and longitude (see 7.5 MINUTE QUADRANGLE GRID, below). The contents of the map database are described in terms of the lines, areas, and points that compose it. Terms in Table 4 describe the database fields.

Table 2. Data Layers

DATA LAYER NAME	DESCRIPTION
al-slid_um	polygons for landslides, internal quadrangle boundaries, and Alameda County boundary
lc-smls_um	point features for small landslides for the La Costa Valley Quadrangle

Table 3. Map Projection

Projection	UTM (universal transverse mercator)

Units	meters
Zone	10
Datum	NAD27
spheroid	Clarke 1866

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, N - ASCII floating point number, I - ASCII integer, C - ASCII character string
NDEC	number of decimal places maintained for floating point numbers

• Lines — Database lines (arcs) are recorded as strings of vectors with characteristics that are described in the arc attribute table (see Table 5). In the al-slid_um map layer they define the boundaries of the landslide units, the quadrangle boundaries, and the Alameda County Boundary. These distinctions are recorded in the LTYPE database field according to the line types listed in Table 6.

Table 5. Content of the Arc Attribute Table (AL-SLID.AAT)

ITEM NAME	WIDTH	OUTPUT	TYPE	N.DEC	DESCRIPTION
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
PF-SLID#	4	5	B	-	unique internal control number
PF-SLID-ID	4	5	B	-	unique identification number
LTYPE	35	35	C	-	line type

Table 6. Line Types Recorded in the LTYPE Field

LINE TYPE	DESCRIPTION
contact, certain	arcs delineating large landslide polygons
county boundary	Alameda County boundary
map boundary	quadrangle boundary

• <u>Areas</u> — Landslide units (except those smaller than 500 feet in the La Costa Valley quadrangle) are recorded as vector polygons with characteristics described in the polygon attribute table (see Table 7). The primary unit identifier is PTYPE.

Table 7. Content of the Polygon Attribute Table (AL-SLID.PAT)

ITEM NAME	WIDTH	OUTPUT	TYPE	N.DEC	DESCRIPTION
AREA	4	12	F	3	area of polygon in square meters
PERIMETER	4	12	F	3	length of perimeter in meters
AL-SLID#	4	5	B	-	unique internal control number
AL-SLID-ID	4	5	B	-	unique identification number
PTYPE	35	35	C	-	landslide category

• <u>Points</u> — Small landslide units in the La Costa Valley quadrangle (maximum dimension 200 to 500 feet) are recorded as point features in ARC/INFO. These features are plotted as arrows showing the direction of downslope movement and are centered on the location of the slide. Although the slides range in length from 200 to 500 feet, all arrows are about 200 feet long as plotted. In both Postscript and PDF plot files, the value for PTTYPE is printed as an annotation at the head of the landslide arrow for slides attributed as "questionable".

Table 8. Content of the Point Attribute Table (LC-SMLS.PAT)

ITEM NAME	WIDTH	OUTPUT	TYPE	N.DEC	DESCRIPTION
AREA	4	12	F	3	area of polygon in square meters
PERIMETER	4	12	F	3	length of perimeter in meters
PF-SMLS#	4	5	B	-	unique internal control number
PF-SLID-ID	4	5	B	-	unique identification number
PTTYPE	35	35	C	-	landslide category
STRIKE	3	3	I	-	direction of downslope movement, in degrees

REFERENCES CITED

Aitken, D.S., 1997, U.S. Geological Survey Bay Region topographic Sheets 1:125,000 1970: U.S. Geological Survey, Open-File Report 97-500.

Fitzgibbon, T.T., 1991, ALACARTE installation and system manual (version 1.0): U.S. Geological Survey, Open-File Report 91-587 B.

Fitzgibbon, T.T., and Wentworth, C.M., 1991, ALACARTE user interface - AML code and demonstration maps (version 1.0): U.S. Geological Survey, Open-File Report 91-587 A.

Wentworth, C.M., 1997, General Distribution of Geologic Materials in the San Francisco Bay

Region, California 1: 125,000. A Digital Map Database: U.S. Geological Survey, Open-File Report 97-744.

Wentworth, C. M., and Fitzgibbon, T.T., 1991, ALACARTE version 1 through 3.1: U.S. Geological Survey, Open-File Report 91-587 C.

III.
THE DIGITAL DATABASE

INTRODUCTION

This report consists of a 1:24,000-scale digital database, a 1:62,500-scale digital map image derived from it entitled "Landslides in Alameda County, California, a digital database extracted from preliminary photointerpretation maps of surficial deposits by T.H. Nilsen in USGS Open-file Report 75-277", and supporting files. The report is stored as several digital files, for the spatial data both ARC export (uncompressed) and ARCVIEW shape formats, and for the map image both Postscript and PDF formats. The exported ARC coverages lie in UTM zone 10 projection and the shape versions are coded in decimal degrees. This pamphlet, which only describes the content and character of the digital map database, is included as Postscript, PDF, and ASCII text files and is also available on paper as USGS Open-File Report 99-504. A plotted copy of the 1:62,500-scale map can be ordered from a USGS Earth Science Information Center or by phone at 1-800-USMAPS. Any or all of the digital files can be obtained over the Internet or by magnetic tape copy, as described at the end of this section.

The full versatility of the 1:24,000-scale spatial database is realized by importing the ARC export files into ARC/INFO or an equivalent GIS. Other GIS packages, including MapInfo and ARCVIEW, can use either the ARC export or shape files. The Postscript map image can be used for viewing or plotting in computer systems with sufficient capacity, and the considerably smaller PDF image files can be viewed or plotted in full or in part from Adobe ACROBAT software running on Macintosh, PC, or UNIX platforms. Please note that the PDF version contains two plot files (sheets 1 and 2) because of limits to the dimensions of PDF plots.

DATABASE CONTENTS

The eight sets of digital files comprising the database are encoded in more than one format. Names of the files are unique designators based on the report identifier, of99-504, followed by part numbers (i.e. 1 through 8 below) and an extension indicating file type. Some files have been bundled using the tar (UNIX Tape Archive) utility (.tar extension). All larger files have been compressed with the gzip utility, indicated by the .gz extension. The files and their identities are as follows:

1. **Revision List**: A list of the parts of the report and at what version number of the report each was last revised (if at all) followed by a chronological list that describes any revisions (see REVISIONS, below).

of99-504revs_1a.txt ASCII file

2. **Open File Text**: The open-file pamphlet (this text), which describes the database and how to obtain it.

of99-504_2a.txt	ASCII file
of99-504_2b.ps	Postscript file
of99-504_2c.pdf	PDF file

3. **Database for Landslide Deposits**: ARC export coverage containing both lines and polygons. Import aml will name this coverages al-slid_um.

of99-504_3.e00.gz Arc export coverage

4. **Database for Small Landslide Deposits**: ARC export coverage for La Costa Valley quadrangle containing points. Import aml will name this coverage lc-smls_um.

of99-504_4.e00.gz Arc export coverage

5. **Line and polygon ARCVIEW shape files bundled as one tar file**. When opened, the tar file yields:

-line files	al-arc.dbf	al-arc.shp	and al-arc.shx
-polygon files	al-poly.dbf	al-poly.shp	and al-poly.shx
-point files	lc-smls.dbf	lc-smls.shp	and lc-smls.shx

Note: Point files exist only for the La Costa Valley quadrangle.

of99-504_5.tar.gz ARCVIEW shape files

6. **Supporting files for ARC/INFO use, bundled as one tar file**.
When opened, the tar file yields:

utm2sp.prj and sp2utm.prj: These are projection files to convert between the UTM zone 10 projection of the database and state plane projection.

import.aml: This is an ASCII script written in Arc Macro Language for converting the ARC export files into usable coverages and INFO files that are assigned standard names (see IMPORTING THE ARC EXPORT FILES).

of99-504_6.tar

7. **Quadrangle Index Database**: The data files representing lines and polygons of the quadrangle index (ARC export and ARCVIEW shape format). The ARC version also includes quadrangle names as annotation.

of99-504_7a.e00.gz	ARC export coverage containing lines, polygons, and annotation. Import.aml will name this coverage al-index_um.
of99-504_7b.tar.gz	Line and polygon ARCVIEW shape files bundled as one tar file. When opened, the tar file yields:

line files:	grdlns.dbf,	grdlns.shp,	grdlns.shx
polygon files:	grdpys.dbf,	grdpys.shp,	grdpys.shx

8. **Plot Files for the Map**: Landslide Deposits in Alameda County, which measures 36 by 53 inches when plotted.

of99-504_8a.ps.gz	Postscript file (12 MB compressed to 3 MB)
of99-504_8b.pdf.gz	PDF file (4.5 MB)

Available on Adobe Acrobat Version 4.0 only

REVISIONS

Changes to any parts of the report (the numbered items described above and listed in the revision list of99-504revs_a.txt) may be made in the future if needed. These could involve, for example, fixing files that don't work, correcting or adding landslide details, or adding new file formats or other components. Major revision of the basic landslide information would result in a new report.

The report begins at version 1.00. Any revisions will be noted in the revision list and will result in the recording of a new version number for the report. Small changes will be indicated by decimal increments and larger changes by integer increments in the version number. Revisions will be announced and maintained on the Web page for this report on the Western Region Geologic Information Server (see next section).

OBTAINING THE DATA FILES

The database may be obtained in three ways.

1. The simplest way to obtain the database is to download it over the World Wide Web from the USGS Western Region Geologic Information Server:

   http://wrgis.wr.usgs.gov

   From the main page, click on 'Geologic map databases' under the heading 'Data On-line'; next click on 'California'. Scroll down to the listing for this database (Open File Report 99-504) and click on the Open-File button, which takes you to the page for this publication. You can also go directly to that final page at:

   http://wrgis.wr.usgs.gov/open-file/of99-504

   On this page, the several parts of the report in their different file types are separately available. Set your Web browser to save to a local disk and click on the appropriate links to download the desired files.

2. To download the files from the Internet via anonymous ftp:

   - ftp wrgis.wr.usgs.gov - make ftp connection with USGS computer wrgis.
   - Name: anonymous - enter "anonymous" as your user name.
   - Password: [your address] - enter your own email address as password.
   - pub/open-file/of99-504 - subdirectory where files from this report are stored

3. To obtain files from the database on magnetic tape, send a blank tape with your request specifying the desired files and your return address to:

   San Francisco Bay Geologic Materials Database
   c/o Database Coordinator
   U.S. Geological Survey
   345 Middlefield Road MS 975
   Menlo Park, CA 94025

   The specified files bundled in a compressed tar file will be returned to you on the tape. The acceptable tape types are: 2.3 or 5.0 GB, 8 mm Exabyte tape.

OPENING THE DATABASE FILES

Some of the files are packaged as tar files, and the larger files containing the databases and images have been compressed with gzip. Thus, gzip is required to uncompress the files, and a tar utility is required to open the tar files. The necessary utilities are available on-line:

Compressed Gzip Files

Files compressed with gzip (those with a .gz extension) can be uncompressed with gzip. The gzip utility converts the compressed file name.gz to its uncompressed equivalent name. The compressed file is replaced by the uncompressed file. This utility is free of charge over the Internet at:

http://w3.teaser.fr/*jlgailly/gzip

Tar Files (UNIX Tape Archive)

To extract the contents of a tar file, first uncompress it with gzip if the extension is .tar.gz. Once the tar extension is exposed, extract the contents with a tar utility. This utility is included in most UNIX systems. Tar utilities for PC and Macintosh can be obtained free of charge via the Internet from Internet Literacy's Common Internet File Formats Web Page:

http://www.matisse.net/files/formats.htm

WinZip

This commercial package runs on PCs and can deal with both gzip and tar files. An evaluation copy of WinZip for Windows 3.1, 95 and NT can be downloaded from:

http://www.winzip.com/winzip/:

IMPORTING THE ARC EXPORT FILES

The ARC export files with the extension .e00 can be converted to ARC/INFO vector maps (coverages) and INFO files by running the import.aml that is included in the database. This will import the export files and assign standard names (see below). Be sure to uncompress the of99-504_7a.e00.gz file with the gzip utility before running the import aml. Run import.aml from the ARC prompt in the directory containing the export files:

ARC: &run import.aml - run import.aml

Note that the arc coverages and separate INFO files will be given standard names:

of99-504_3.e00	(Landslide Deposit Database)	is named	al-slid_um
of99-504_4.e00	(Small Landslide Deposit Database for La Costa Valley quadrangle only)	is named	lc-smls_um
of99-504_7a.e00.gz	(Quadrangle Index Database)	is named	al-index_um