Final Technical Report

Computer-Based Earthquake Mapping

San Francisco Bay Area

Sponsored by U.S. Geological Survey
Contract No. 14-08-0001-17751

80-1147

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PROJECT COMPONENTS

1. Several data files that have not been available in ABAG's computer-based geographic data system have been developed, either by digitizing maps or by obtaining existing machine-readable data sets.

2. A series of earthquake hazard map files have been produced for the San Francisco Bay Area by combining the data files developed in the first task in various ways.

3. Various applications for these files have been explored.

4. Much effort is being made to ensure that this information is effectively communicated to city and county staff.

DISCUSSION OF RESEARCH

1. File Development

Several basic data map files that have not been available in BASIS* have been developed, either by digitizing maps or by obtaining existing machine-readable data sets. In those cases where regional coverage is either too general or too costly, subregional data sets have been developed for San Mateo County for experimental and demonstration purposes. San Mateo County was chosen because both ABAG and USGS have more information on that County than any other one in the Bay Area. Basic data map files developed include:

*BASIS - Bay Area Spatial Information System

OPEN FILE
80-1147

- a detailed geologic map of San Mateo County with hectare resolution**

- a revision of an existing map file of generalized geology to provide hectare resolution for the other eight counties**

- a flatland materials map of the Bay Area, with hectare resolution**

- the expansion of an existing fault file to include recent work for the entire region with hectare resolution

- a digital elevation model file of San Mateo County with hectare resolution

- a landslide map for San Mateo County with hectare resolution

- dam inundation maps with hectare resolution and regional coverage

- a tsunami inundation map with hectare resolution and regional coverage

- a land use file for San Mateo County with hectare resolution.

2. Reworking of Data Files

A series of earthquake hazard map files have been produced for the San Francisco Bay Area by combining the data files developed in the first task in various ways. Derivative files produced include:

- a map of maximum intensity of earthquake ground shaking for the Bay Area

- a series of four regional maps showing the risk of damage for three types of buildings and two sets of recurrence intervals for earthquakes

- liquefaction susceptibility and potential maps for the region

- maps of landslide susceptibility for San Mateo County from rainfall and earthquake-induced failures

- two sample composite maximum earthquake damage maps for San Mateo County (combining maps of maximum ground shaking intensity, faults, landslide and liquefaction susceptibility, and dam failure and tsunami inundation)

- a sample composite map showing risk of damage within San Mateo County from those earthquake hazards listed above.

The assumptions and data used in developing these maps have been documented in a series of working papers.

3. File Applications

These maps have been used:

**These three files were combined to create a new geology file.

- o to begin development of an automated regional environmental assessment document to serve as a background report for local Environmental Impact Reports (EIRs)
- o to compile sample composite maps of earthquake hazards
- o to compare the land affected by various earthquake hazards and to relate these hazards to their potential effects on both people and property

4. Communication of the Information

Much effort has been made to ensure that this information is effectively disseminated.

- o Key local staff have been involved in reviewing the working papers.
- o Potential users suggested that all map files should have hectare resolution. This suggestion has been implemented.
- o Targeted local staff and other users have been helpful in designing the three map applications described.
- o A user's manual, A Guide to ABAG's Earthquake Hazard Mapping Capability, has been developed and is being distributed.

RESEARCH CONCLUSIONS

This ABAG research has demonstrated that a computer-based geographic data system is a useful tool in examining earthquake-related hazards. The computer system enabled ABAG staff to use the entire Bay Area as a study area for developing most test products. It ensured that the information was consistent from one part of the region to another and enabled staff to easily expand projects developed in one part of the region to the entire nine county area. In addition, the map files are more adaptable to different uses than the more traditional map product. Maps can easily be produced at any scale for any area of interest. In addition, files can be manipulated to provide a listing of information for a given location and to produce an unlimited number of composite maps. Cross tabulations and statistical procedures can also be performed to compare files.

The methods used in developing the hazard maps were developed or modified as part of this project. The techniques and procedures, especially those related to mapping of risk of ground shaking damage and of liquefaction susceptibility and potential, make use of some valuable economic techniques. These techniques served to point out areas where more data and research is needed. The working papers, especially Paper #9 on composite maps, point out many of these needs.

This project focused on developing an operational earthquake hazard mapping capability and demonstrating some sample uses for researchers and local geologists and planners. ABAG has begun a project (USGS Contract No. 14-08-0001-19108) that will expand the area for which highly detailed topographic and geologic data is available as well as the types of applications. The study will focus on special products suited to the rapidly developing areas adjacent to Petaluma and the ridgelands of Santa Clara, Alameda and Contra Costa Counties.

TABLE OF CONTENTS

INTRODUCTION

In this project, ABAG used a computer-based geographic data system (BASIS)* to produce several types of earthquake maps for the Bay Area. These computer maps, or files, have been designed to be combined, cross-tabulated, and accessed for small areas. The results have been made available in a form useful to technical staff of local governments in the Bay Area.

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DISCUSSION OF RESEARCH

1. File Development

BASIS is structured around an array of grid cells, each representing a land area of one hectare. The original proposed work consisted of developing a series of data files with a mixture of 1/4 square kilometer (25 hectare) and hectare resolution. Conversations with city and county staff have shown the coarser resolution to be unacceptable for most applications. Therefore, all files developed have hectare resolution. More information on the basic data map files is available in the buff section of the user's guide (Appendix K).

A geology map of San Mateo County (scale - 1:62,500) was digitized. This map was prepared by Earl Brabb and Earl Pampeyan of USGS. It is unique in that the flatland and hillside materials have been combined into one map. Because the detail of the map is greater than any map ABAG had digitized previously, some new techniques were developed. For example, a photo enlargement was prepared to be used for recording information about the chains digitized. The original map, however, not the enlargement, was digitized to avoid any distortion that might occur in enlarging a map of this size (43 inches by 24 inches). The map will be published as an overlay of the original and a color plot of the BASIS map file.

ABAG's existing file of geologic information (generalized to include only six categories) was refined to have hectare resolution for the remaining eight Bay Area counties. More information on this file is contained in an ABAG report on an earlier earthquake mapping project (Perkins, 1978).

A map of flatland materials has been produced for the Bay Area at 1:125,000 (Helley, et al., 1979). Copies of these maps on stable materials were obtained from the USGS publications office to enable the file to have hectare resolution. In the process of digitizing the map, several inconsistencies were discovered and confirmed by the authors. Therefore, the BASIS file should be more accurate than the published version. This file was combined with the previous two files to create a new geology file.

ABAG's previous file of active faults consists of those included by the State Geologist in the Alquist-Priolo Special Studies Zone mapping program. Because of the activity of several other faults in the region and because the region can be affected by faults that are outside of its boundaries, several additional faults have been digitized and added to the existing file. Maps of all of these faults have been collected. They are mapped at various scales ranging from 1:24,000 to 1:250,000. The faults outside the region provided an interesting problem in computer-programming. BASIS has been developed to handle data for an area only slightly larger than the nine Bay Area counties. Some of the faults are outside of this area so that information about their location has been stored in a different framework.

Arrangements were made to obtain a digital elevation model file of topographic information for all of San Mateo County from the Topographic Division of USGS. The file consists of an elevation for each hectare in the county. This data has been manipulated to provide the slope information needed for producing the slope stability map. A file of slope length and slope aspect could be produced when needed. Local cities and counties are particularly interested in this file because of its possible application in local ordinances.

Landslides in San Mateo County were digitized using a map by Brabb and Pampeyan (1972). The larger landslides were digitized normally, while the smaller slides were digitized as point data so that the hectare cell corresponding to the center of the slide symbol would be tagged.

Dam failure inundation maps for the dams in all nine counties were collected from Bay Area counties. The maps have all been redrafted on sheets of mylar registered to USGS 7-1/2 minute quandrangles (scale-1:24,000) and these maps digitized. The file includes which areas will be inundated as well as by which dams.

A tsunami inundation map (scale-1:125,000) (Ritter and Dupre, 1972) was digitized and a hectare file compiled.

Level 3 and 4 land use information was digitized for San Mateo County (U.S. Geological Survey, 1978). Although the information is very detailed, the data was fairly easy to digitize because of the scale of the map (1:24,000).

2. Reworking of the Data Files

A series of earthquake hazard map files have been produced by combining the basic data map files in various ways. More information on these files is contained in the goldenrod section of the user's guide and a series of working papers developed to serve as documentation of the technical data and assumptions used in developing and using these files. The information contained in this technical report is intended to supplement that contained in the working papers and is more concerned with the procedures used.

Working Papers #1, #2, and #3 document the data and assumptions used to produce two types of ground shaking maps. A maximum ground shaking intensity map and four maps showing the expected risk of earthquake damage from ground shaking were produced simultaneously. Because the time required to make the distance calculation from each hectare to each fault is large, and because of the lack of space to store the distance, it was immediately, hectare by hectare, compared to the geology of that hectare and the results of the needed calculations (either intensity or present value of damage) stored in each of the five files. As the distance to each additional fault was calculated, the program called for one of two options:

- o to compare the intensity to that already stored in the cell and enter the larger (in the case of the maximum intensity map)
- o to add the additional present value of damage to that already in the cell (in the cases of the risk maps)

Next, two types of liquefaction maps were produced. Working Paper #4 documents the technical information used in this work. The susceptibility map was produced using a simple model that categorized the existing geology units, split the Bay mud category north and south of Coyote Point in San Mateo County, and added a category for an area of historic liquefaction. The potential map, however, again required calculations of distances from several faults. Because only one distance was critical for each fault, however, the program could calculate the distance for each square kilometer, rather than each hectare, test to see if the distance fell within a narrow band surrounding the critical distance, and only if it did, continue and revise the distance for each hectare. Again, distances were not stored. Rather, they were immediately compared to the susceptibility units and the results stored. This procedure was followed for each fault assumed to produce significant ground shaking with the results being added to those already in the potential file from the last fault.

The next two hazard files required a file of percent slope. This file was produced from the elevation information by calculating the maximum drop between each hectare and the eight surrounding it, correcting for the difference in distance for those hectares at the four diagonal corners. This slope file was then combined with the geology and landslide files in the two different ways described in Working Paper #5.

Working Papers #6 and #7 document the tsunami and dam inundation files that, while not produced by the reworking of earlier files, are types of earthquake hazards.

3. File Applications

Both the basic data map files and the earthquake hazard map files are used in three sample applications developed for this project. More information on these applications is contained in the green section of the user's guide, as well as in the final three working papers. Working Paper #8 discusses computer-assisted environmental assessment, #9 documents a method for producing various types of composite hazard maps, and #10 explains the way in which the various tabulations of earthquake effects on property and people can be developed. Obviously, maps can be used by themselves without any further manipulation. This use is not discussed in a working paper, however.

4. Communication of the Information

Many of the most detailed products of this project are only available for the San Mateo County. Therefore, ABAG researchers decided to focus on working with the staff of that County and the cities within it. A workshop was held in the City of San Mateo offices to explain this study to the planning, public works, and emergency services staffs of the jurisdictions in San Mateo County. Twenty-six people representing ten cities and three county departments were present. The City of Pacifica and the County Area Disaster Office agreed to be used as example agencies for special map applications. Meetings with the Pacifica staff showed that they are most interested in obtaining computer-generated environmental impact sheets for earthquake and related hazards. The Disaster Office was most interested in an atlas of hazard maps at 1:24,000 for some cities. Both of these types of products should be useful to other agencies. Extending these types of services to other local governments will be a major focus of a related ABAG project started in February 1980.

In order to encourage participation in the way the final products were developed, drafts of the working papers were forwarded to various city and county geologists. These papers have been discussed in the previous section on reworking of data files.

The research was compiled into the User's Manual. This document is being mailed to local planning, public works and building inspection departments, as well as to other interested individuals.

RESEARCH CONCLUSIONS

This ABAG research has demonstrated that a computer-based geographic data system is a useful tool in examining earthquake-related hazards. The computer system enabled ABAG staff to use the entire Bay Area as a study area for developing most test products. It ensured that the information was consistent from one part of the region to another and enabled staff to easily expand projects developed in one part of the region to the entire nine county area. In addition, the map files are more adaptable to different uses than the more traditional map product. Maps can easily be produced at any scale for any area of interest. In addition, files can be manipulated to provide a listing of information for a given location and to produce an unlimited number of composite maps. Cross tabulations and statistical procedures can also be performed to compare files.

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Brabb, E. E., 1979, personal communication regarding results of San Mateo County geologic mapping (U.S.G.S. Contract No. 9-9540-01618).

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

Perkins, J. B., 1978, Earthquake Intensity and Expected Cost in the San Francisco Bay Area: Association of Bay Area Governments, Berkeley, California, 12 p.

Ritter, J. R., and Dupre, W. R., 1972, Maps Showing Areas of Potential Inundation by Tsunamis in the San Francisco Bay Region, California: U.S. Geological Survey Miscellaneous Field Studies Map MF-480.

United States Geological Survey, 1978, Land Use and Land Cover 1976-77 for the eighteen 7-1/2 minute quandrangles in San Mateo County, California: U.S. Geological Survey Open File Maps 78-738 to 78-755.

APPENDIX A

EARTHQUAKE MAPPING PROJECT - WORKING PAPER #1
FAULTS AND GROUND SHAKING INTENSITY

INTRODUCTION

This paper, and the included tables, summarize the fault-related data used in producing the various ground shaking intensity maps for the ABAG/USGS earthquake mapping project. It is the first in a series of review papers documenting the data used and the assumptions made in that project.

Data are included on the following three factors needed to produce maps of maximum expected ground shaking intensity:

- those faults from which significant ground shaking can originate
- a method to calculate the maximum magnitude earthquake that could originate from a fault on the basis of length of that fault
- a method of calculating the maximum intensity experienced in a given magnitude earthquake.

All of the above information on faults, as well as recurrence intervals for various magnitude earthquakes on each fault, are necessary to produce maps of risk of damage from ground shaking. Therefore, some information on relative fault activity also is included.

Information on these four factors is very incomplete. Changes in information used on any one factor will change the way a final map appears. Therefore, five sample maps have been produced illustrating some of these variations. The maps are attached to Working Paper #3.

CHOOSING THE FAULTS

The major faults to be used as sources of ground shaking were selected and grouped after several published sources of active and potentially active faults were considered. The four most comprehensive lists are those compiled by:

- o the State Geologist to implement the Alquist-Priolo Special Studies Zones Act (Ref. 1),
- o the California Division of Mines and Geology in Geologic Data Map No. 1 (Ref. 2),
- o the U.S. Geological Survey in Bulletin 941-A (Ref. 3),
- o Herd and others of U.S.G.S. in several Miscellaneous Field Studies Maps and Open-File Reports (Ref. 4).

The four lists are given below in Table 1.

There is a great deal of similarity among the lists. However, the variety in the lists led to the decision to combine the faults into three groups for purposes of mapping and analysis. Group 1 consists of those faults appearing in all four compilations. Group 3 consists of all of the faults in Group 1 plus those faults listed in Ref. 4 or by all of the other three sources. Group 2 consists of all of the faults in Group 1 plus those faults in Group 3 of Holocene or younger age. The maps of maximum earthquake intensity and of expected cost include all three groups.

Most faults were mapped using the CDMG 1:24,000 maps prepared in compliance with the Alquist-Priolo Act. Those fault segments under water were extrapolated from CDMG maps when possible. The underwater segment of the northern San Andreas between the Bolinas and South San Francisco quadrangles was mapped using USGS 1:62,500 maps. Other faults were mapped using recent USGS publications. The sources for fault mapping are listed in Table 1.

TABLE 1: MAJOR ACTIVE AND POTENTIALLY ACTIVE FAULTS IN THE SAN FRANCISCO BAY AREA, CALIFORNIA

FAULT	SOURCE OF FAULT MAP	INCLUDED IN COMPILATIONS				AGE*** OF DISPLACEMENT IN OTHER REPORTS			AGE OF DISPLACEMENT USED
		STATE GEOLOGIST (Ref. 1)	CDMG (Ref. 2)	USGS 941-A (Ref. 3)	USGS HERD & OTHERS (Ref. 4)	CDMG (Ref. 2)	USGS 941-A (Ref. 3)	HERD & OTHERS (Ref. 4)	
GROUP 1									
San Andreas	Ref. 1	Yes	Yes	Yes	Yes(4a)	Historic	Historic	Historic	Historic
Calaveras-Paicines	Ref. 1	Yes	Yes	Yes	Yes(4e)	Historic	Historic	Historic(4e)	Historic
Calaveras-Sunol	Ref. 1	Yes	Yes	Yes	Yes(4e)	Historic	Historic	Historic(4e)	Historic
Pleasanton	Ref. 1	Yes	Yes	Yes	Yes(4d)	Quaternary	Historic*	Historic(4f)	Holocene
Concord	Ref. 1	Yes	Yes	Yes	Yes(4b)	Historic	Historic	Historic	Historic
Green Valley	Ref. 1	Yes	Yes	Yes	Yes(4b)	Quaternary	Historic	Historic	Historic
Antioch	Ref. 1	Yes	Yes	Yes	Yes(4b)	Historic	Historic	Historic(4b)	Historic
Hayward(incl. Crosley)	Ref. 1	Yes	Yes	Yes	Yes(4b)	Historic	Historic	Historic	Historic
Rodgers Creek	Ref. 1	Yes	Yes	Yes	Yes(4a)	Quaternary	Historic*	Holocene	Holocene
Maacama**	Ref. 1 and 4a	Yes	Yes	Yes	Yes(4a)	Quaternary	Holocene	Historic(4e)	Historic
San Gregorio	Ref. 1 and 6	Yes	Yes	Yes	Yes(4e)	Quaternary	Holocene	Holocene(4d)	Holocene
ADDED FOR GROUP 2									
Healdsburg/Rodgers Creek (Combined) (Replace)	Ref. 1	Yes	Yes	Yes	-	Quaternary	Historic	--	Historic
Verona	Ref. 4	-	Yes	Yes	Yes(4c)	Quaternary	Quaternary	Holocene(4d)	Holocene
Silver Creek	Ref. 1 and 5	Yes	Yes	Yes	-	Quaternary	Historic	--	Historic
Evergreen	Ref. 1	Yes	Yes	Yes	-	Quaternary	Historic	--	Historic

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		STATE GEOLOGIST (Ref. 1)	CDMG (Ref. 2)	USGS 941-A (Ref. 3)	USGS HERD & OTHERS (Ref. 4)	CDMG (Ref. 2)	USGS 941-A (Ref. 3)	HERD & OTHERS (Ref. 4)	
Dunnigan Hills	Ref. 4b	-	Yes	-	Yes(4b)	Quaternary	--	Holocene	Holocene
West Napa	Ref. 4b	-	Yes	Yes	Yes(4b)	Quaternary	Holocene	Holocene	Holocene
Cordelia	Ref. 4b	-	-	-	Yes(4b)	--	--	Holocene	Holocene
Calaveras (Combined) (Replace)	Ref. 1	Yes	Yes	Yes	-	Historic	Historic	Historic(4e)	Historic
Sargent	Ref. 5	-	Yes	Yes	Yes(4e)	Quaternary	Holocene	Historic(11)	Pleistocene
Concord/Green Valley (Combined) (Replace)	Ref. 1	Yes	Yes(12)	Yes	-	Quaternary	Historic	Historic	Historic
ADDED FOR GROUP 3									
Las Positas	Ref. 4c	-	Yes	Yes	Yes(4c)	Quaternary	Quaternary	Quaternary(4d)	Quaternary
Greenville	Ref. 4c	-	Yes	Yes	Yes(4c)	Quaternary	Quaternary	Pleistocene(4d)	Pleistocene
Faults Near Trenton	Ref. 4a	-	Yes	Yes	Yes(4a)	Quaternary	Quaternary	Pleistocene	Pleistocene
Tolay	Ref. 1	Yes	Yes	Yes	-	Quaternary	Quaternary	--	Quaternary
Faults East of Bennett Valley & Santa Rosa (Combined)	Ref. 4a and 4b	-	-	-	Yes(4a&b)	--	--	Pleistocene	Pleistocene
Zayante	Ref. 8	-	-	Yes	Yes(8)	--	Quaternary	Pleistocene	Pleistocene
Berrocal	Ref. 7	-	-	-	Yes(4e)	--	Quaternary	Pleistocene	Pleistocene
Midway	Ref. 2 and 4d	-	Yes	-	Yes(4d)	Quaternary	--	Pleistocene	Pleistocene
San Joaquin	Ref. 4d and e	-	-	-	Yes(4e)	--	--	Pleistocene	Pleistocene
Monte Vista	Ref. 5	-	Yes	-	Yes(4d)	Quaternary	--	Quaternary	Quaternary

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OTHERS NOT INCLUDED IN ANALYSIS									
Big Sulphur Creek	NOT APPLICABLE	-	-	Yes	-	NOT APPLICABLE			
Burdell Mountain		-	Yes	Yes	-				
San Geronimo Valley		-	-	Yes	-				
Unnamed (E of Napa)		-	Yes	-	-				
Pilarcitos		-	-	Yes	-				
Black Mountain****		-	-	Yes	-				
Shannon (Vasona)		-	Yes	Yes	-				
Rio Vista		-	Yes	Yes	-				
Montezuma Hills		-	Yes	Yes	-				
Unnamed (W of Lake Berryessa)		-	Yes	-	-				

* Based on microseismic activity - no evidence of historic displacement
** Including NE of Alexander Valley & Alexander Valley faults
*** Explanation:

Historic: 200 years
Quaternary: 200-2 million years
Holocene: 200-10,000 years
Pleistocene: 10,000-2 million years

**** Included in this analysis with the Monte Vista fault

ESTIMATING MAXIMUM MAGNITUDE AND INTENSITY ON THE FAULTS

The magnitude of the maximum probable earthquake can be related to the length of the rupture along the fault trace. The lengths of the various faults analyzed (obtained from two separate sources) and the associated maximum magnitudes are given in Table 2, below. The maximum magnitudes are calculated using the relationships used by Herd (Ref. 4e). Because the formula used depends on the character of the fault movement, the type of movement is also provided in Table 2. The formulas used to calculate maximum magnitude are as follows:

for strike-slip faults: $$(\text{Magnitude}) = 0.597 + 1.351 \log \left(\begin{matrix}\text{Fault rupture}\\ \text{length in meters}\end{matrix}\right)$$

for normal faults: $$(\text{Magnitude}) = 1.845 + 1.151 \log \left(\begin{matrix}\text{Fault rupture}\\ \text{length in meters}\end{matrix}\right)$$

for reverse and trust faults: $$(\text{Magnitude}) = 4.145 + 0.717 \log \left(\begin{matrix}\text{Fault rupture}\\ \text{length in meters}\end{matrix}\right)$$

The usual length of fault rupture chosen for use in the above formulas is one-half the total mapped length. However, because the assumption is not universally accepted, a second set of maximum magnitudes was calculated using the total mapped length.

The maximum intensity for any given magnitude of earthquake can be calculated using the following commonly used formulas:

$$\left(\begin{matrix}\text{Maximum}\\ \text{intensity}\end{matrix}\right) = 1.5\ (\text{Magnitude}) - 1.5.$$

(See, for example, Reference 9.)

The maximum intensities and the magnitudes calculated are listed in Table 2. The intensity maps have been produced using the maximum intensity and magnitude calculated assuming 1/2 the total mapped fault length represents the fault rupture length.

TABLE 2: LENGTH, MAXIMUM MAGNITUDES, AND ASSOCIATED MAXIMUM INTENSITIES OF MAJOR ACTIVE AND POTENTIALLY ACTIVE FAULTS IN THE SAN FRANCISCO BAY AREA, CALIFORNIA

FAULT	LENGTH USED IN OTHER REPORTS		LENGTH USED	CHARACTER OF MOTION	MAXIMUM MAGNITUDE		MAXIMUM INTENSITY	
	USGS 941-A (Ref. 3)	USGS Herd and Others (Ref. 4e unless otherwise noted)			(1/2 L) (used in analysis)	(1 L) (calculated for comparison)	(1/2 L) (used in analysis)	(1 L) (calculated for comparison)
San Andreas **	1200 km	- km	1200 km	Right-slip	8.4	8.8*	(11.1)/XI	(11.7)/ XII
Hollister-Bolinas	-	160	160	Right-slip	7.2	7.6	(9.3)/IX	(9.9)/X
Bolinas-Cape Mendocino	-	270	270	Right-slip	7.5	7.9	(9.75)/X	(10.4)/X
Calaveras **	115	-	170	Right-slip	7.3	7.7	(9.45)/IX	(10.1)/X
Calaveras-Paicines	-	100	100	Right-slip	6.9	7.4	(8.85)/IX	(9.6)/X
Calaveras-Sunol	-	70	70	Right-slip	6.7	7.1	(8.55)/IX	(9.15)/IX
Pleasanton	9	-	9	Right-slip	5.5	5.9	(6.75)/VII	(7.35)/VII
Concord/Green Valley	56	110	110	Right-slip	7.0	7.4	(9.0)/IX	(9.6)/X
Antioch	37	12 (4b)	37	Right-slip	6.4	6.8	(8.1)/VIII	(8.7)/IX
Hayward (incl. Crosley)	72	90	90	Right-slip	6.9	7.3	(8.85)/IX	(9.45)/IX
Healdsburg/Rodgers Creek	72	-	-	Right-slip	6.8	7.2	(8.7)/IX	(9.3)/IX
Maacama	35	140	140	Right-slip	7.1	7.5	(9.15)/IX	(9.75)/X
San Gregorio	200	140	140	Right-slip	7.1	7.5	(9.15)/IX	(9.75)/X

* Note that this number is impossibly high.
** The entire San Andreas and Calaveras faults will be used in the maximum intensity mapping. See the footnotes for Table 3.

FAULT	LENGTH USED IN OTHER REPORTS		LENGTH USED	CHARACTER OF MOTION	MAXIMUM MAGNITUDE		MAXIMUM INTENSITY	
	USGS 941-A (Ref. 3)	USGS Herd and Others (Ref. 4e unless noted)			(1/2 L) (used in analysis)	(1 L) (calculated for comparison)	(1/2 L) (used in analysis)	(1 L) (calculated for comparison)
Verona	-	10 (4d)	10	Thrust	6.8	7.0	(8.7)/IX	(9.0)/IX
Silver Creek	20	-	20	Thrust	7.0	7.2	(9.0)/IX	(9.3)/IX
Evergreen	-	-	12 (1)	Thrust	6.9	7.1	(8.85)/IX	(9.15)/IX
Dunnigan Hills	-	10 (4b)	10	Reverse	6.8	7.0	(8.7)/IX	(9.0)/IX
West Napa	17	28 (4b)	28	Right-slip	6.2	6.6	(7.8)/VIII	(8.4)/VIII
Cordelia	-	19 (4b)	19	Right-slip	5.9	6.4	(7.35)/VII	(8.1)/VIII
Sargent	55	60	60	Right-slip	6.6	7.1	(8.4)/VIII	(9.15)/IX
Las Positas	-	14 (4d)	14	Normal	6.3	6.6	(7.95)/VIII	(8.4)/VIII
Greenville	-	3 (4d)	3	Normal	5.5	5.8	(6.75)/VII	(7.2)/VII
Faults Near Trenton	27	9 (4a)	27	Right-slip	6.2	6.6	(7.8)/VIII	(8.4)/VIII
Tolay	11	-	11	Right-slip	5.7	6.1	(7.05)/VII	(7.65)/VIII
Faults East of Bennett Valley & Santa Rosa	-	10 (4a & 4b combined)	10	Right-slip	5.6	6.0	(6.9)/VII	(7.5)/VIII
Zayante	82	82 (8)	82	Right-slip	6.8	7.2	(8.7)/IX	(9.3)/IX
Berrocal	33	60 (4d)	60	Thrust	7.4	7.6	(9.6)/X	(9.9)/X
Midway	-	10 (2)	10	Reverse	6.8	7.0	(8.7)/IX	(9.0)/IX
San Joaquin	-	120	120	Normal	7.3	7.8	(9.45)/IX	(10.2)/X
Monte Vista	-	-	25(5)	Thrust	7.1	7.3	(9.15)/IX	(9.45)/IX

ESTIMATING RELATIVE FAULT ACTIVITY

In order to produce maps of the expected cost of damage from earthquakes originating on any fault in the region, one needs information on the recurrence intervals for various magnitude earthquakes on each fault of concern. Given a constant slip rate, one can calculate the recurrence of a given magnitude event. However, this formula:

$$\left(\begin{array}{l}\text{Recurrence interval}\\ \text{in years}\end{array}\right) = \frac{10^x}{\text{Slip rate (in meters)}} \quad \text{where } x = \frac{\text{Magnitude} - 6.717}{1.214}$$

assumes that all earthquakes are of a single specified magnitude. One can adjust the recurrence intervals by reducing the slip rate by a percentage assumed to be released by aseismic creep. This refinement does nothing toward providing a breakdown of the distribution of large and moderate sized earthquakes, however. Such a breakdown is essential. As one can see from Table 4, the annual cost of damage for buildings next to a fault is much greater for moderate events (magnitude 5.3 to 6) than for lower or higher magnitude events. In order to avoid this problem some researchers (see, for example, Reference 9) have used the historic record, which now approaches 200 years in California. The usefulness of this procedure can be debated given recurrence intervals of the size implied by Table 3.

A more direct approach would be to use slip rate as the critical measure of seismicity. Relatively speaking, a fault with a slip rate of 1.5 cm/year would cause twice as much damage to adjacent homes than one with a slip rate of 0.75 cm/year regardless of the maximum expected magnitude and the distribution of smaller events.

Because of the need to graphically depict the effects of these changes in assumptions, two test maps have been produced displaying average annual damage for small wood-frame buildings. The first uses the assumption that all events are of the maximum magnitude given assuming 1/2 L in Table 3 and the second uses the assumption that only magnitude 5.5 events (with a maximum intensity of D) can occur. The slip rates used in the analysis are given in Table 3, below, and are from Reference 4e.

These recurrence intervals are not synonymous with the number of earthquakes anticipated in the Bay Area since one needs to enter the information on fault rupture length into the formula. For example, for the San Andreas there would be two magnitude 8.4 events with ruptures 600 km long in 1000 years or 70,000 magnitude 5.3 events with ruptures 4.26 km long in 1000 years.

TABLE 3: INFORMATION ON RELATIVE ACTIVITY AND RECURRENCE INTERVALS FOR MAJOR EARTHQUAKES ON THE PRINCIPLE ACTIVE AND POTENTIALLY ACTIVE FAULTS IN THE SAN FRANCISCO BAY AREA, CALIFORNIA

FAULT	LONG TERM SLIP RATE (Ref. 4e) (cm/year)	RECURRENCE INTERVAL FOR MAX. EVENT (yrs.)* 1/2 L	1 L	FOR MAGNITUDE 5.5 EVENT
San Andreas***	2.5 (ave.)	1000	2000	4
Holister-Bolinas	2.0	100	300	5
Bolinas-Cape Mendocino	3.0	100	300	3
Calaveras***	1.0 (ave.)	300	600	10
Calaveras-Paicines	1.5	100	200	7
Calaveras-Sunol	.75	100	300	10
Pleasanton	N/A**	-	-	-
Concord/Green Valley	.75	200	500	10
Antioch	N/A**	-	-	-
Hayward (incl. Crosley)	.75	200	400	10
Healdsburg/Rodgers Creek	.75	200	300	10
Maacama	.75	300	600	10
San Gregorio	1.0	200	400	10

FAULT	LONG TERM SLIP RATE (Ref. 4e) (cm/year)	RECURRENCE INTERVAL FOR MAX. EVENT (yrs.)* 1/2 L	1 L	FOR MAG. 5.5 EVENT
Verona	N/A**	-	-	-
Silver Creek	N/A**	-	-	-
Evergreen	N/A**	-	-	-
Dunnigan Hills	N/A**	-	-	-
West Napa	N/A**	-	-	-
Cordelia	N/A**	-	-	-
Sargent	0.3 (11)	300	700	30
Las Positas	N/A**	-	-	-
Greenville	N/A**	-	-	-
Faults Near Trenton	N/A**	-	-	-
Tolay	N/A**	-	-	-
Faults E of Bennett Valley & Santa Rosa	N/A**	-	-	-
Zayante	N/A**	-	-	-
Berrocal	N/A**	-	-	-
Midway	N/A**	-	-	-
San Joaquin	.03(4d)	10,000	30,000	300
Monte Vista	N/A**	-	-	-

* Years are rounded to one significant figure.

** N/A = Not available; slip rate assumed very low in all cases to yield recurrence intervals for even moderate earthquakes of tens of thousands of years.

***One major problem with using a calculated recurrence interval based on slip rate is that that the interval for large magnitude earthquakes on long faults (such as the San Andreas) becomes too large to agree with historic data. In order to lessen this problem for these two long faults, the recurrence intervals to be used for earthquakes on the faults will be for the shorter fault segments.

TABLE 4: ANNUALIZED COST OF EARTHQUAKE DAMAGE FOR A SERIES OF EARTHQUAKES OF THE LISTED MAGNITUDE FOR SMALL WOOD FRAME BUILDINGS NEAR THE FAULT FOR A SLIP RATE OF 0.75 cm/year*

MAGNITUDE	RECURRENCE INTERVAL (yrs.)	MAXIMUM INTENSITY	DAMAGE FOR MAX. INTENSITY (percent)	ANNUALIZED COST (percent)
<5	<5	<6 / VI	0	0
5.0	5	6.0 / VI	.1	.016%
5.3	9	6.45 / VI	.5	.056%
5.5	13	6.75 / VII	1.2	.091%
5.6	16	6.90 / VII	1.6	.100%
5.7	19	7.05 / VII	2	.105%
5.8	23	7.2 / VII	2.3	.100%
5.9	28	7.35 / VII	2.5	.089%
6.0	34	7.5 / VIII	3.1	.091%
6.2	50	7.8 / VIII	4.2	.084%
6.5	88	8.25 / VIII	5.7	.065%
6.7	129	8.55 / IX	6.4	.050%
6.9	189	8.85 / IX	7.6	.040%
7.1	276	9.15 / IX	8.8	.032%
7.3	403	9.45 / IX	9.5	.022%
8.0	1520	10.5 / XI	15	.010%

* With 1.5 cm/year slip rate, the annualized cost column is doubled.
If 1/3 of the slip rate is released as creep, the .75 becomes .50 for the annualized cost is reduced 1/3 and becomes 2/3 of the amount in the above cost column.

** The following % damages are assumed for each intensity: II - 0.1, VII - 2, VIII - 5, IX - 8, X - 12, XI - XII - 20 (See Reference 10).

OTHER DATA FOR GROUND SHAKING INTENSITY MAPS

The various maps described cannot be produced until after the necessary information is obtained on:

- o the attenuation of intensity with distance from faults
- o a table showing groups geologic materials with similar earthquake intensity characteristics, along with the intensity increments to be added to the intensity derived from the distance relationship listed above for each group
- o intensity/damage relationships

Working Papers #2 and #3 discuss these factors. The maps described are attached to Working Paper #3.

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APPENDIX B

EARTHQUAKE MAPPING PROJECT - WORKING PAPER #2
ATTENUATION, GEOLOGIC MATERIALS AND GROUND SHAKING

INTRODUCTION

This paper summarizes the information on geologic materials used in producing the ground shaking intensity maps. It is the second in a series of review papers documenting the data used and the assumptions made in the ABAG/USGS earthquake mapping project.

Data are included on:

- o an attenuation relationship between intensity and distance from faults for a standard geologic material (Franciscan assemblage);
- o combining geologic materials into groups with similar responses to earthquake ground shaking;
- o intensity increments to be added to the standard intensity for each of the seismically distinct groups of geologic materials.

Unlike the first working paper on fault-related information, much of this data has been obtained directly from U.S.G.S. staff working in this field. Earl Brabb, Roger Borcherdt, Jim Gibbs and Tom Fumal have been most helpful in providing information prior to its publication.

ESTABLISHING AN INTENSITY-DISTANCE ATTENUATION RELATIONSHIP

In order to predict the intensity of ground shaking, one needs a basic formula relating expected intensity and distance from faults for a standard geologic material. The formula currently being used for work in this region relates San Francisco intensity to distance for the Franciscan assemblage. The formula, developed by Borcherdt, Gibbs and Lajoie (Reference 1) is:

Predicted San Francisco intensity (where intensity ranges from 4-0 to represent A-E) = 2.69 - 1.9 log (distance in km)

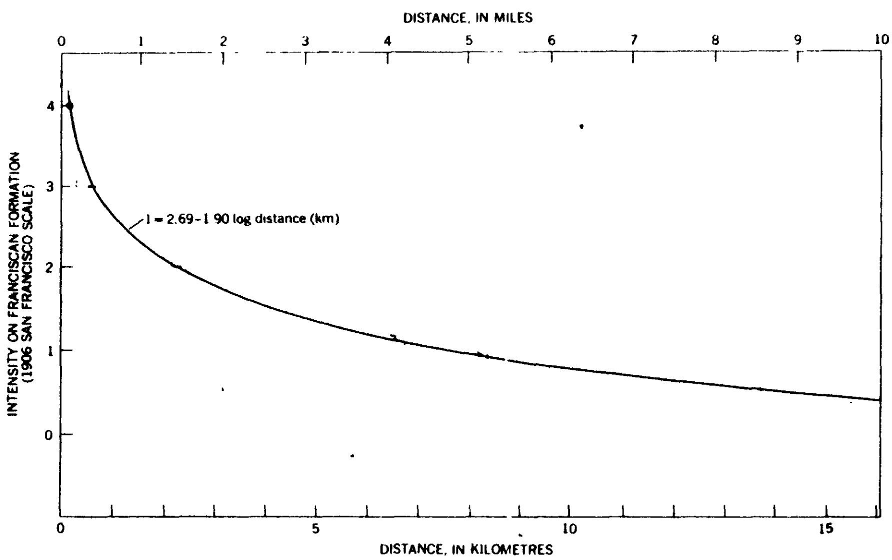
This formula is illustrated in Figure 1, below. Table 1 illustrates the relationship between the San Francisco intensity scale and the more commonly used modified Mercalli intensity scale. A new attenuation formula using modified Mercalli intensity is being developed by Bob Nason at USGS and may be available by the end of 1980. New maps could be produced after the new formula is finalized.

TABLE 1: APPROXIMATE RELATIONSHIPS BETWEEN INTENSITY SCALES
(Modified from Borcherdt, Gibbs, and Lajoie, 1975)

San Francisco scale*	Modified Mercalli scale
	XII
A	
	XI
	X
B	
	IX
	VIII
C	
D	VII
	VI
E	

*San Francisco Intensity A: Very Violent
B: Violent
C: Very Strong
D: Strong
E: Weak

FIGURE 1: INTENSITY DISTANCE ATTENUATION CURVE
(Modified from Borcherdt, Gibbs, and Lajoie, 1975)



CORRECTING THE GENERAL FORMULA FOR GEOLOGY

Different intensities tend to occur at sites which are located the same distance from a fault but are on different types of geologic materials. Working with information on seismic wave velocities, Fumal (Reference 2) has developed a series of seismically distinct units. For the unconsolidated to semiconsolidated sediments, he used texture, standard penetration resistance and depth to define six units. For the bedrock materials, he used fracture spacing and hardness to define seven more units. These 13 seismically distinct units are listed in Table 2, below.

The problem then becomes one of relating these units to those used on existing geologic maps. More detailed mapping has been used in San Mateo County than in the remainder of the region. For that County, Brabb and Pampeyan have combined the map of flatlands deposits (Reference 3) with the preliminary geologic map (Reference 4) to provide a more refined geologic map of the area (Reference 5). This new map has been used in this project. In the remainder of the Bay Area, the flatlands map (Reference 3) has been combined with a generalized geologic map of the region prepared by ABAG for earlier intensity maps (see Reference 7) based on the units established by Borcherdt, Gibbs and Lajoie (Reference 1). The relationship between the seismically distinct units and the various geologic units have been provided by Gibbs, Fumal and Borcherdt (Reference 6) and appear in Table 3. Note that some formations contain several materials with different physical properties and therefore fall into several different seismically distinct units.

To correct the general formula for intensity on Franciscan assemblage to apply to these other units, an intensity increment must be added to the derived Franciscan intensity for any given distance. These intensity increments also have been provided by Gibbs, Fumal, and Borcherdt (Reference 6) for each of the thirteen seismically distinct units and appear in Table 2. An average intensity increments for each of the geology units then was obtained by adding the intensity increments for all the materials contained in each geology unit and dividing by the number of intensity increments. This averaging technique is obviously very imprecise. If the precise percentage of each rock type in each formation were known, the average could be weighted accordingly. In addition, if the units on the geologic maps corresponded more closely with the seismically distinct units, further refinements could be made in assigning intensity increments. The range and average intensity increments are listed in Table 3.

Correcting the formula for geology, or even rock type, does not result in a totally accurate representation of intensity. For example, very deep alluvium may have a minor effect on intensity. Insufficient data is available on these other factors at this time to allow for any further refinement in the procedure. Various degrees of saturation do not significantly effect intensity, however (Reference 6).

TABLE 2: SEISMICALLY DISTINCT UNITS AND PREDICTED INTENSITY INCREMENT

SEISMIC UNIT	MATERIAL PROPERTIES			PREDICTED INTENSITY INCREMENT
SEDIMENTS				
I	Clay-silty clay, very soft to soft			2.86
II	Clay-silty clay, medium to hard			1.84
III	Sand, loose to dense			1.71
IV	Sandy clay-silt loam, interbedded coarse and fine sediment			1.36
V	Sand, dense to very dense			0.93
VI	Gravel			0.37
BEDROCK	ROCK TYPE	HARDNESS	FRACTURE SPACING	
I	Sandstone	Firm to soft	Moderate and wider	0.67
II	Igneous, Sedimentary	Hard to soft	Close to very close	0.31
III	Igenous, Sandstone Shale	Hard to firm	Close	-0.05
IV	Igneous, Sandstone	Hard to firm	Close to moderate	-0.33
V	Sandstone, Conglomerate	Firm to hard	Moderate to wider	-0.54
VI	Sandstone	Hard to quite firm	Moderate & wider	-0.75
VII	Igneous	Hard	Close to moderate	-1.13

TABLE 3: AVERAGE PREDICTED INTENSITY INCREMENTS FOR THE GEOLOGIC UNITS

Map Symbol***	Geologic Unit	Seismic Unit Range	Range of Predicted Intensity Increment	Average Predicted Intensity Increment
Qm, Qhbm*	Bay mud	I	2.9	2.9
Qb	Younger basin deposits	II	1.8	1.8
Qhaf*, Qhafs*	Fine-grained alluvium			
Qyfo	Fine-grained younger alluvial fan deposits	III	1.7	1.7
Qham*	Medium-grained alluvium			
Qob	Fine-grained older alluvial fan and basin deposits	II, IV	1.4-1.8	1.6
Qaf	Artificial fill	II, III, V	.9-1.8	1.5
Qs, Qhs*	Beach deposits and windblown sand	III, V	.9-1.7	1.3
Qcl	Colluvium			
Qps*	Merrit Sand			
Qal	Quaternery alluvium			
Qhsc*	Stream channels			
Qu*	Undivided Quaternary deposits	II-VI	.4-1.8	1.2
Qyf	Coarse-grained younger alluvial fan deposits	V	.9	.9
Qhac*	Coarse-grained alluvium			
Qmt, Qpmt*	Marine terrace deposits			
Qc, Qpmc*	Colma Formation			
QTm	Merced Formation			
Tp	Purisima Formation, undivided			
Tptu	Tunitas Sandstone Member			
Tpsg	San Gregorio Sandstone Member			
Tpt	Tahana Sandstone and Siltstone Member			

TABLE 3: (Continued)

Map Symbol***	Geologic Unit	Seismic Unit Range	Range of Predicted Intensity Increment	Average Predicted Intensity Increment
Tpl	Purisima Formation, Lobitos Mudstone Member	I	.7	.7
Tsm	Santa Margarita Sandstone			
Tus	Unnamed sandstone			
Tsl	San Lorenzo Formation, undivided			
Tsr	Rices Mudstone Member			
Tst	Twobar Shale Member			
Tls	Lambert Shale and San Lorenzo Formation			
Tb?	Butano (?) Sandstone			
Tbs	Shale in the Butano sandstone			
Ksh	Unnamed shale			
Qof	Coarse-grained older alluvial fan & stream terrace deposits	V, VI	.4- .9	.6
Qpea*	Early Pleistocene alluvium			
Qpa*	Late Pleistocene alluvium			
QT und**	Quaternary-Tertiary undivided	V, VI, V	.9- -.5	.3
Tpp	Purisima Fm., Pomponio Siltstone Member	II, III	.3- -.1	.1
Tsc	Santa Cruz Mudstone of Clark			
Tm	Monterey Shale			
Tla	Lambert Shale			
fc	Franciscan chert	III	-.1	-.1
QTs	Santa Clara Formation	VI, V	.4- -.5	-.1
TK und**	Most Tertiary and older deposits	I, VI	.7- -.8	-.1

TABLE 3: (Continued)

Map Symbol***	Geologic Unit	Seismic Unit Range	Range of Predicted Intensity Increment	Average Predicted Intensity Increment
Tb	Butano Sandstone	II-VI	-.3- -.8	-.3
sp	Serpentine			
fsr	Franciscan sheared rock			
Tss	Unnamed sandstone, shale & conglomerate	IV	-.3	-.3
Tvq	Vaqueros Sandstone	III, VI	-.1- -.8	-.4
fs	Franciscan graywacke			
fcg	Franciscan conglomerate			
KJf	Franciscan Assemblage			
KJf und**	Franciscan, undivided	II, VII	.3- -1.1	-.4
Tpm	Page Mill Basalt	III-VII	-.1- -1.1	-.6
Tmb	Mindego Basalt & related volcanic rocks			
KJv	Unnamed volcanic rocks			
Tuv	Unnamed volcanic rocks			
Kpp	Pigeon Point Formation	V, VI	-.5- -.8	-.6
KJs	Unnamed sandstone			
Tlo	Lompico Sandstone			
fl	Franciscan limestone	IV-VII	-.3- -1.1	-.7
m	Marble and hornfels			
fg	Franciscan greenstone	VII	-1.1	-1.1
fm	Franciscan metamorphic rocks			
Kgr	Granitic rocks of Montara Mountain			
gr und**	Granitic rocks, undivided			

All units are from the San Mateo County map except:

*Flatlands deposits map
**Generalized geology map

CALCULATING INTENSITIES BASED ON DISTANCE AND GEOLOGY

By using the attenuation formula and correcting the results using the average intensity increments for each seismically distinct group of geologic units, one can calculate the range of distances from a fault trace for each intensity and each geologic unit. The outer limits of these intensity ranges are given in Table 5, below.

It is important to realize the uncertainty involved in the intensity increments (as much as plus or minus one-half an intensity increment) results in a very high uncertainty in the distance calculations. This uncertainty is higher for greater distances. The relationship is illustrated in Table 4, below, which lists distances for sample intensity increments. Distances in both Tables 4 and 5 are provided to two significant figures. This level of accuracy was chosen as a compromise between geographic precision and scientific knowledge. Any potential user of these maps should realize these limitations. When dealing with any individual location, soils and geologic information on that site would enable the user to assign the material to a single seismically distinct unit with a much more precise intensity increment. Hand calculations of distance could then be used to yield more precise predictions of intensity.

In making the distance calculations for some faults, it has been necessary to calculate the distance from the edges of the Special Studies Zones delineated by the State Geologist rather than from fault traces. This procedure eliminates the need to enter the actual location of the fault trace within the zone in the computer. The cost involved in entering the additional data is not warranted due to the other uncertainties in the distance calculations. In these cases, the fault traces have been assumed to be 0.2 km inside the study zone boundary. This distance has been subtracted from all values in Table 5, but no distance has been assigned to be less than zero.

ADJUSTING THE INTENSITY

The intensities need to be adjusted to account for events smaller than that of 1906. The maximum intensities (those nearest the faults) have been related to maximum magnitude in Working Paper #1. The remainder of the intensities are assumed to have the same pattern as those for a 1906 event, but adjusted downward. Therefore, for an earthquake with a maximum intensity of B, the zone closest to the fault (shown as A on Table 5) would become B. The next zone, shown as B, would become C, and so on. The intensity maps are attached to Working Paper #3.

TABLE 4: MAXIMUM DISTANCE (in kilometers) FROM FAULT TO EACH INTENSITY THRESHOLD FOR INTENSITY INCREMENTS (SELECTED TO ILLUSTRATE UNCERTAINTY IN DISTANCE CALCULATIONS)

Intensity Increment	San Francisco Intensity A	B	C	D	E
3.0	7.8	26	88	290	990
2.9	6.9	23	78	260	880
2.0	2.3	7.8	26	88	290
1.9	2.0	6.9	23	78	260
1.5	1.3	4.2	14	48	160
1.4	1.1	3.7	13	42	140
1.0	.7	2.3	7.8	26	88
.9	.6	2.0	6.9	23	78
.5	.3	1.3	4.2	14	48
.4	.3	1.1	3.7	13	42
0	.2	.7	2.3	7.8	26
-.1	.2	.6	2.0	6.9	23
-.5	.1	.3	1.3	4.2	14
-.6	.1	.3	1.1	3.7	13
- 1.0	.1	.2	.7	2.3	7.8
- 1.1	.1	.2	.6	2.0	6.9

TABLE 5: MAXIMUM DISTANCE (in kilometers) FROM FAULT TO EACH INTENSITY THRESHOLD FOR VARIOUS GROUPINGS OF GEOLOGIC UNITS

Geologic Units	San Franciscan Intensity A	B	C	E	E
Qm,Qhbm	6.9	23	78	260	880
Qb, Qhaf, Qhafs	1.8	6.1	20	69	230
Qyfo, Qham	1.6	5.4	18	61	200
Qob	1.4	4.8	16	54	180
Qaf	1.3	4.2	14	48	160
Qs, Qhs, Qcl, Qps, Qal, Qhsc	1.0	3.3	11	38	130
Qu	.8	2.9	9.9	33	110
Qyf, Qhac, Qmt, Qpmt Qc, Qpmc, QTm, Tp, Tptu, Tpsg, Tpt	.6	2.0	6.9	23	78
Tpl, Tsm, Tus, Tsl, Tsr, Tst, Tls, Tb?, Tbs, Ksh	.5	1.6	5.4	18	61
Qof, Qpea, Qpa	.4	1.4	4.8	16	54
QT und.	.3	1.0	3.3	11	38
Tpp, Tsc, Tm, Tla	.2	.8	2.6	8.8	29
fc, QTs, TK und.	.2	.6	2.0	6.9	23
Tb, sp, fsr, Tss	.1	.5	1.6	5.4	18
Tvq, fs, fcg, KJf, KJf und.	.1	.4	1.4	4.8	16
Tpm, Tmb, KJv, Kpp, KJs, Tlo, Tuv	.1	.3	1.1	3.7	13
fl, m	.1	.3	1.0	3.3	11
fg, fm, Kgr, gr und.	.1	.2	.6	2.0	6.9

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APPENDIX C

EARTHQUAKE MAPPING PROJECT - WORKING PAPER #3
DAMAGE AND GROUND SHAKING INTENSITY

INTRODUCTION

Balancing the risk of earthquake losses against the cost of mitigation measures requires some estimate of the amount of damage to be expected both in any particular earthquake and over the longer term. Experience from past earthquakes can be used to estimate the damage different types of buildings would experience when subjected to various intensities of ground shaking. This information, when combined with the intensity maps and recurrence interval information (described in Working Papers #1 and #2), have been used to produce maps showing the geographic distribution of the present value of damage for wood frame dwellings and other types of buildings from earthquake ground shaking. These maps differ in appearance and use from a maximum intensity map.

This working paper describes the types of damage information and how general damage cost factors are used in the ABAG/USGS earthquake mapping project. It is the third in a series of review papers documenting the data used and the assumptions made in that project and the last of those dealing with mapping ground shaking intensity. Therefore, the sample intensity maps produced are described and shown in Figures 3-7.

DEVELOPMENT OF DAMAGE INFORMATION

The Basic Data

Detailed surveys of damage, <u>and lack of damage</u>, to buildings throughout the general area experiencing an earthquake have not been a part of earthquake studies until recent years. Most studies have concentrated on areas of major damage, neglecting to identify areas where little or no damage occurred. However, some damage statistics have been collected in recent years from nuclear tests (References 1 and 2) and from moderate earthquakes in San Fernando (References 3 and 4) and Santa Rosa (Reference 5), for example. Although damage data have been collected after major earthquakes occurring outside the United States, these statistics are difficult to translate into possible damage in the U.S. because of the differences in construction practices.

Damages by General Building Type

Of course, once such damage statistics are collected for particular earthquakes, the data need to be generalized to apply to future hypothetical events. This generalized data can be supplied as an approximate average cost factor for each intensity level. This cost factor is defined as the cost of repairing a building divided by the cost of replacing that building. It can be viewed as percent loss and expressed in percent. Page and others (Reference 6) developed a table of approximate average damage cost factors for buildings in the United States. (See Table 1, below).

TABLE 1: APPROXIMATE AVERAGE DAMAGE COST FACTORS FOR BUILDING BUILT TODAY (from Page and Others, 1975)

Modified Mercalli Intensity	Damage Cost Factor (%) for Wood Frame Dwellings	Damage Cost Factor (%) for Other Buildings
VI	<0.2	<1
VII	2	5
VIII	5	15
IX	8	35
X	12	>50

Grouping the damage data into cost factors for only two types of buildings is quite simplified. The following sections present attempts at refining the data.

Refinements for Wood Frame Dwellings

Algermissen, Steinbrugge and their associates have made several refinements for wood frame dwellings (See References 7 - 11). In some recent work, Rinehart, Algermissen, and Gibbons (Reference 11) have separated wood frame dwellings into three categories: (1) pre-1940; (2) 1940-1949; (3) post-1950. In addition, their estimates of damage apply to three building components: (1) finish; (2) structure; (3) chimneys. These refinements of damage keyed to more building components, such as used in the earlier U.S. Coast and Geodetic Survey works (References 7-9) are not of great significance to this project. The equivalent to the average damage cost factor of Page and others can be derived from the work of Rinehart, Algermissen and Gibbons by multiplying their damage factors (incidence of each type of damage) by their damage ratios (fraction of value lost for each type of damage) and summing these products for finish, structural and chimney damage. The resulting values, for wood frame buildings built since 1950, are presented in Table 2, below.

TABLE 2: APPROXIMATE DAMAGE COST FACTORS FOR WOOD FRAME BUILDINGS BUILT SINCE 1950 BY BUILDING COMPONENT (from Rinehart, Algermissen and Gibbons, 1976)

Modified Mercalli Intensity	Damage Cost Factor (%) for Wood Frame Buildings				
	Finish Components	Structural Components	Chimneys*	Total**	Page and Others**
IV	0	0.10	0	0.10	-
V	0	0.25		0.25	-
VI	0	2.11	0.0025	2.11	<0.2
VII	0.03	4.44	0.0725	4.54	2
VIII	0.60	6.28	0.1825	7.06	5
IX	1.62	8.50	0.3050	10.42	8
IIX	-	-	-	-	12

*Factor is multiplied by % of homes assumed to have chimneys, in this case 25%.

**Values in these two columns can be compared. The second column is from Table 1.

These composite damage cost factors are larger than the average cost factors of Page and others. The factors for older buildings are even larger. Table 3, below, illustrates how the values vary with age of construction. The main reason for the discrepancy between the values of Page and others and these composite values is probably that these values are derived largely from a single earthquake, the event in San Fernando, where the abnormally high duration of the earthquake resulted in higher than average damages.

TABLE 3: APPROXIMATE AVERAGE DAMAGE COST FACTORS FOR WOOD FRAME BUILDINGS OF VARIOUS AGES (from Rinehart, Algermissen and Gibbons, 1976)

Modified Mercalli Intensity	Damage Cost Factor (%) for Wood Frame Buildings				
	Built Since 1950	Percent Change*	Built From 1940-1949	Percent Change*	Built Prior to 1940
IV	0.10	0	0.1	0	0.10
V	0.25	0	0.25	0	0.25
VI	2.11	1	2.14	79.	3.76
VII	4.54	17	5.34	58.	7.20
VIII	7.06	8	7.66	47.	10.44
IX	10.42	9	11.42	51.	15.74

*Percent increase (to nearest percent) from factor for "Built Since 1950" provided in these two columns.

Refinements for Other Buildings

Further refinements of damage estimates for other types of buildings become even more complex. Algermissen and Steinbrugge avoided these buildings when making the damage estimates published earlier (References 7-11). However, in a recent article (Reference 12) they made such estimates for several classes of buildings. The classes of buildings they considered are shown in Table 4, while the percent losses (damage cost factors) for each modified Mercalli intensity are illustrated in Figure 1.

TYPE OF DAMAGE INFORMATION USED IN THIS PROJECT

As can be seen by a comparison of Tables 1 and 2, the development of damage cost factors by intensity level is indeed an inexact science. The discrepancies are partially the result of limited data points, and are partially the result of the imprecise and subjective nature of the intensity scale. More research obviously is needed. The expected damage maps for wood frame dwellings use the general damage cost factors (percent loss values) of Page and others (Reference 6), but extrapolated and converted to San Francisco intensity, as shown in Table 5, below. Category 4D, and the group of classes 3B, 3D, 4C, and 5C from Reference 12 are used instead of the general category, "other buildings", of Page and others (Reference 6) to illustrate the differences in risk maps. Again, the values will be extrapolated and converted to San Francisco intensity.

TABLE 5: DAMAGE COST FACTORS FOR BUILDINGS ASSOCIATED WITH SELECTED INTENSITIES

		Damage Cost Factors (%) for		
Estimated San Francisco Intensity	Modified Mercalli Intensity	Wood Frame Dwellings (Class 1A)	Ordinary Concrete Block & Steel Frame Buildings Some Reinforced Concrete Buildings (Classes 3B, 3D, 4C, 5C)	Ordinary Tilt-Up Concrete Buildings Class 4D
E	VI	0.2	1.5	4
D	VII	2	7	12
C	IX	5	12	21
B	X	12	22*	35*
A	XI-XII	16*	30*	35*

*Values obtained by extrapolation; estimates probably low.

TABLE 4: BUILDING CLASSIFICATION
(from Algermissen and Steinbrugge, 1978)

Notation used in loss tables 3 and 4	Brief description of subclasses of five broad building classes
1A	Wood-frame and frame-stucco dwellings.
1B	Wood-frame and frame-stucco buildings not qualifying under 1A (usually large-area nonhabitational units); (not considered in this study).
2A	One story, all metal; floor area less than 20,000 feet^2.
2B	All metal buildings not considered under 2A.
3LA	Steel frame, superior damage-control features; less than four stories.
3LB	Steel frame; ordinary damage-control features; less than four stories.
3LC	Steel frame; intermediate damage-control features (between 3LA and 3LB); less than four stories.
3LD	Floors and roofs not concrete; less than four stories.
3HA, 3HB, 3HC, 3HD	Descriptions are the same as for 3LA, 3LB, 3LC, and 3LD except that buildings have four or more stories.
4LA	Reinforced concrete; superior damage-control features; less than four stories.
4LB	Reinforced concrete; ordinary damage-control features; less than four stories.
4LC	Reinforced concrete; intermediate damage-control features (between 4LA and 4LB); less than four stories.
4LD	Precast reinforced concrete, lift slab, less than four stories.
4LE	Floors and roofs not concrete, less than four stories.
4HA, 4HB, 4HC, 4HD, 4HE	Descriptions are the same as for 4LA, 4LB, 4LC, 4LD, and 4LE except that buildings have four or more stories.
5A	Dwellings, not over two stories in height, constructed of (a) poured-in-place reinforced concrete, with roofs and second floors of wood frame or (b) adequately reinforced brick or hollow-concrete-block masonry, with roofs and floors of wood (not considered in this study).
5B	One-story buildings having superior earthquake damage-control features, including exterior walls of (a) poured-in-place reinforced concrete, and (or) (b) precast reinforced concrete, and (or) (c) reinforced brick masonry or reinforced-concrete brick masonry, and (or) (d) reinforced hollow-concrete-block masonry. Roofs and supported floors are of wood or metal-diaphragm assemblies. Interior bearing walls are of wood frame or any one, or a combination, of the aforementioned wall materials.
5C	One-story buildings having construction materials listed for Class 5B, but with ordinary earthquake damage-control features.
5D	Buildings having reinforced concrete load-bearing walls and floors and roofs of wood, but not qualifying for Class 4E; and buildings of any height having Class 5B materials of construction, including wall reinforcement; also included are buildings with roofs and supported floors of reinforced concrete (precast or otherwise) not qualifying for Class 4.
5E	Buildings having unreinforced solid-unit masonry of unreinforced brick, unreinforced concrete brick, unreinforced stone, or unreinforced concrete, where the loads are carried in whole or in part by the walls and partitions. Interior partitions may be wood frame or any of the aforementioned materials. Roofs and floors may be of any material. Not qualifying are buildings having nonreinforced load walls of hollow tile or other hollow-unit-masonry, adobe, or cavity construction.
5F	Buildings having load-carrying walls of hollow tile or other hollow-unit-masonry construction, adobe, and cavity-wall construction, and any building not covered by any other class (not considered in this study).

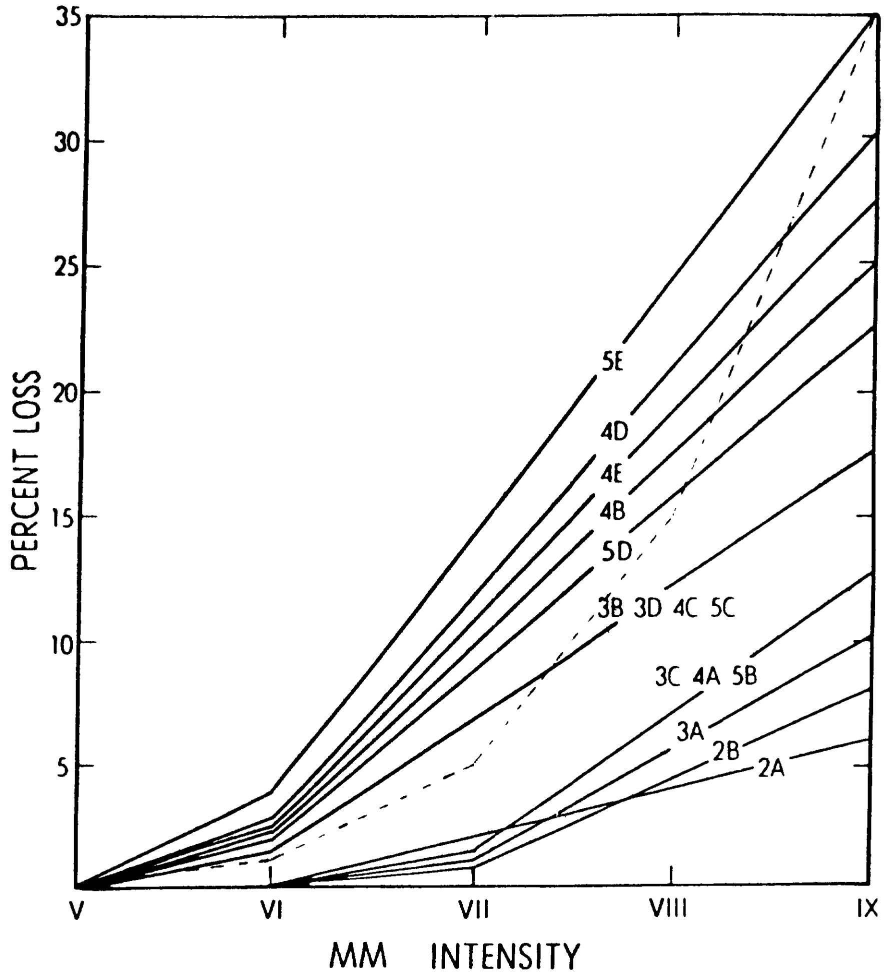


FIGURE 1: MODIFIED MERCALLI INTENSITY - PERCENT LOSS BY CLASS OF CONSTRUCTION

(from Algermissen and Steinbrugge, 1978 -- Descriptions of the various classes may be found in Table 4. High-(H) and low-(L)rise subclasses of class 3 and class 4 have been combined. The percent loss for <u>Other Buildings</u> developed by Page and others (Reference 6) is included for comparison and shown by a dashed line.)

COMBINING DAMAGE INFORMATION FOR SEVERAL EVENTS

Discount rates and present values are difficult concepts to understand, but they must be used to provide information on future rare events. "Discounting" may be defined as the act of reducing the value of some future dollar amount to its present value by a given amount to cover interest. The expected value of all future costs (losses) discounted back to the present is chosen in order to compare losses that occur at different times in the future. Obviously, the losses that would occur as the result of another 1906 San Francisco earthquake 3 hours from now are more important than those that would occur in such an earthquake 100 years from now. Actually one doesn't know when in the next 100 years such an earthquake will occur, and it is equally likely to occur in any year during that time. Discounting all three losses to their present value enables one to compare the three cases. This concept is illustrated in Figure 2, below.

To calculate the total expected percent loss for all future earthquakes, the factors obtained from Table 5, above, are divided by the recurrence intervals of various events (found in Working Paper #1) and these amounts are discounted to their present values. If a discount rate of 10%* is used, and if the term over which the costs are discounted is assumed to be forever, the present values of those percent losses can be estimated by dividing the amounts calculated above by the discount rate (0.10).

*This rate is commonly used in cost-benefit analysis.

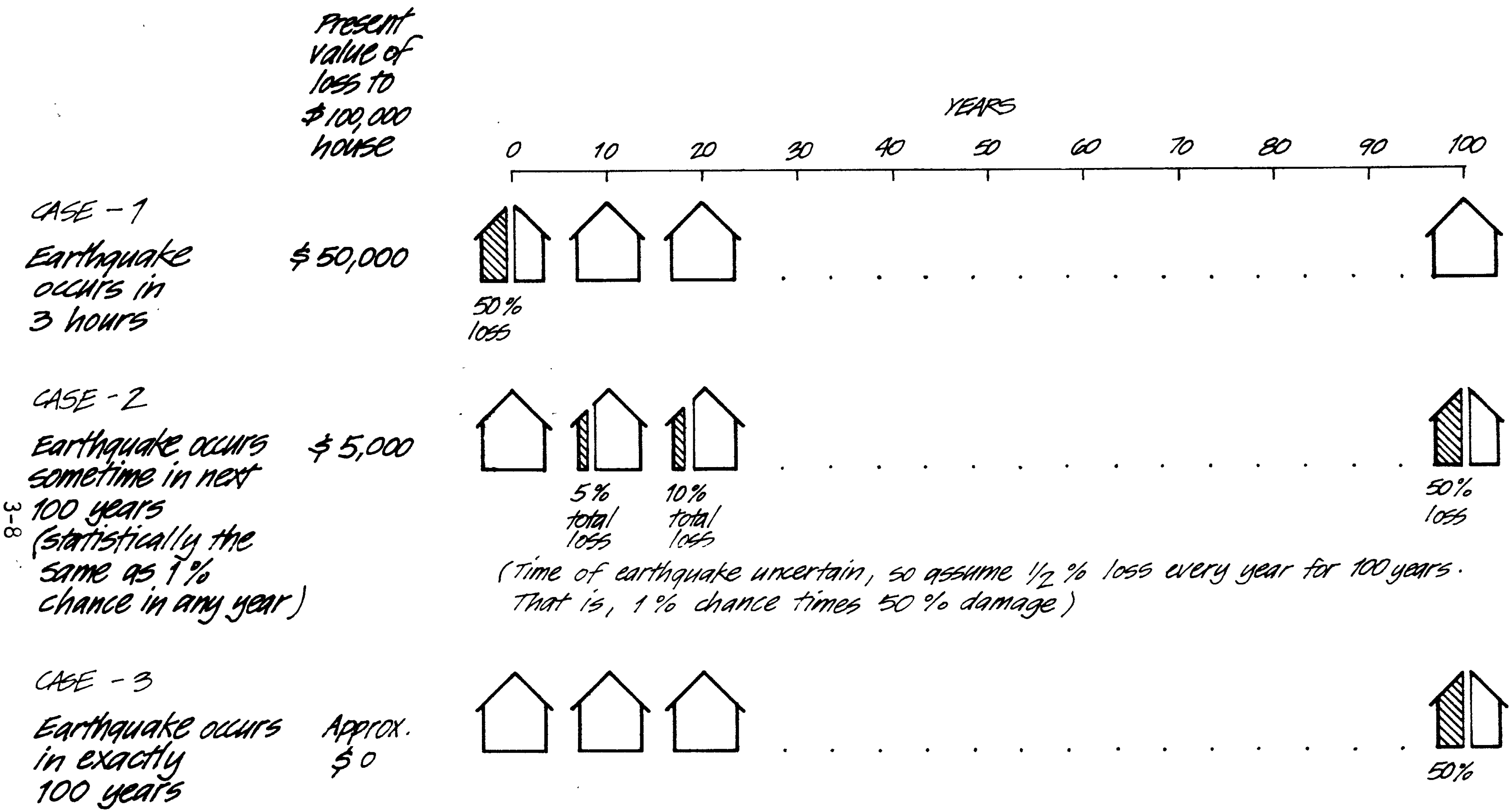


Figure - 2

PRESENT VALUE OF LOSS FOR SELECTED HYPOTHETICAL CASES

MAPPING EARTHQUAKE INTENSITY AND RISK

By using the information on faults, attenuation, geology and damage provided in this working paper and the previous two papers, it is possible to create intensity maps for earthquakes on individual faults and then to combine those maps in the two different ways already discussed:

- o by taking the highest intensity appearing in an area from any of the faults to create a new map showing the maximum intensity regardless of fault source;
- o by weighting the intensity maps for individual faults using recurrence interval and damage data to create maps of the present (discounted) value of that cumulative damage.

The maximum intensity map is shown in Figure 3. Because damages vary by type of construction, three expected damage or risk maps have been produced for three different building types:

- o Wood frame dwellings (Figure 4);
- o Ordinary concrete block and steel frame buildings with some reinforced concrete buildings (Figure 5);
- o Ordinary tilt-up concrete buildings (Figure 6).

In addition, because the recurrence interval data is so essential, two different maps of risk of wood frame dwelling assumptions about recurrence intervals, that:

- o only the maximum magnitude events occur;
- o the slip occurs through many 5.5 magnitude earthquakes.

The former assumption is much more accurate, but the latter illustrates the importance of recurrence interval data on the distribution of large and small events. The sample map assuming all small events is Figure 7. The patterns associated with the present value of damage are the same on Figures 4 through 7 so that the effects of changing building types and recurrence interval information are best illustrated.

These two types of maps have different uses. The maximum intensity map can be used with information on existing buildings to forecast locations of maximum damage for use in planning emergency response measures and for designating areas of critical concern. The risk maps show the present value of the cumulative damage of many earthquakes over time. They may be used in evaluating the relative costs due to earthquakes for new buildings and for designating areas where special precautions may be needed. However, the damage information is not a sufficient basis for engineering decisions at a specific site, for these decisions require specific knowledge of the process causing damage.

None of these maps use any information on the location of specific buildings. They are meant to indicate the intensity or risk inherent in a particular location should a building or specific type of building be located there. Land use data could be used with this type of information, however. This application is discussed in Working Paper #10.

EXPLANATION FOR FIGURE 3

MAXIMUM GROUND SHAKING INTENSITY

SHADE PATTERN	SAN FRANCISCO INTENSITY
	A - Very Violent
	B - Violent
	C - Very Strong
	D - Strong
	E - Weak
	E - Negligible

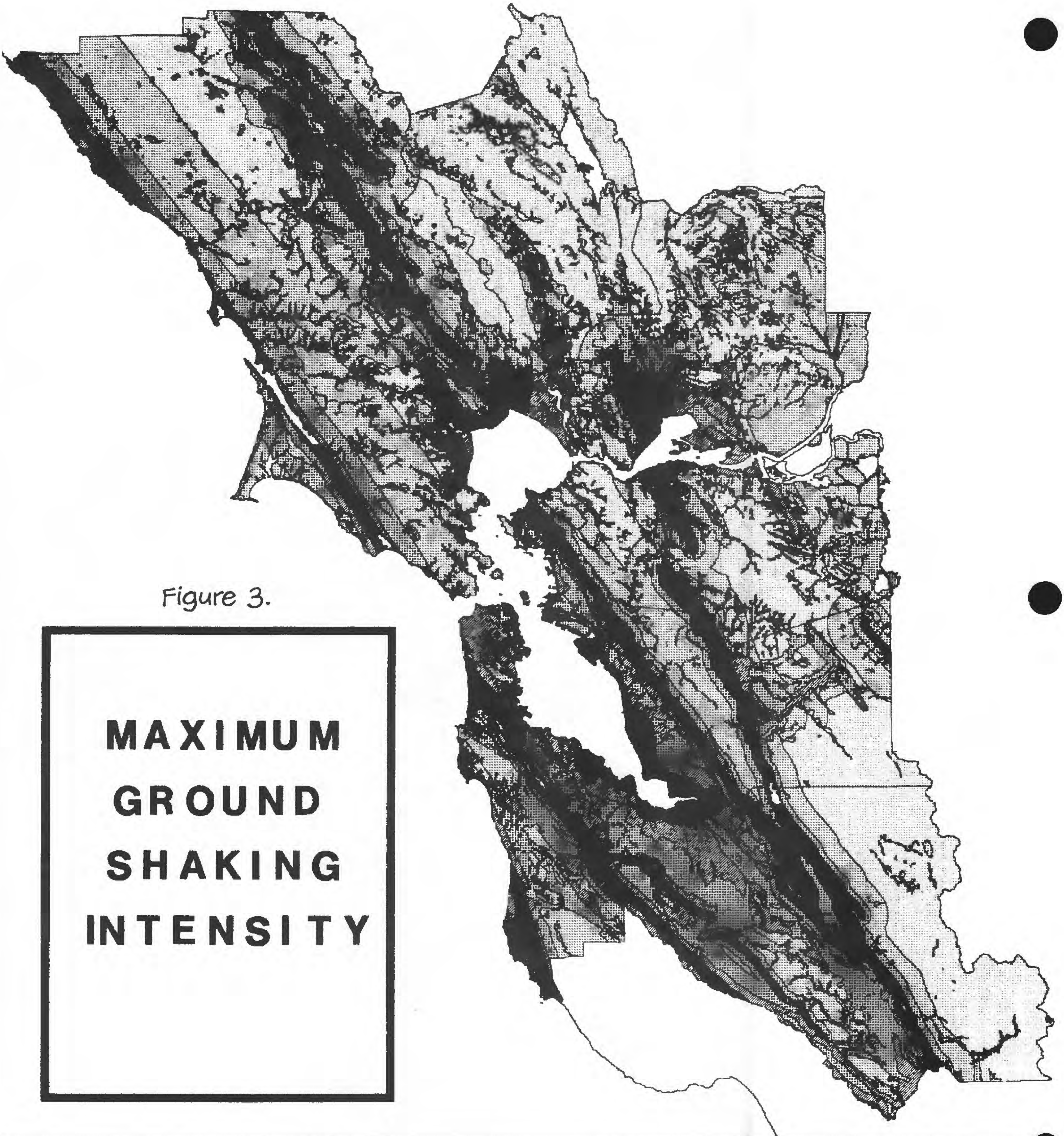


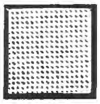
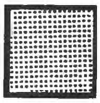
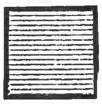
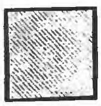
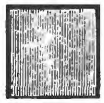
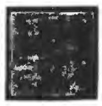
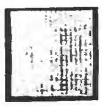
Figure 3.

MAXIMUM GROUND SHAKING INTENSITY

BASIS BAY AREA SPATIAL INFORMATION SYSTEM

EXPLANATION FOR FIGURES 4 - 7

RISK OF GROUND SHAKING DAMAGE

SHADE PATTERN	EXPECTED DAMAGE DISCOUNTED TO PRESENT VALUE*
	0 - .2 %
	.3 - .5 %
	.6 - 1.0 %
	1.1 - 1.5 %
	1.6 - 2.0 %
	2.1 - 2.5 %
	2.6 - 3.0 %
	3.1 - 3.5 %
	3.6 - 4.0 %
	4.1 - 4.5 %
	4.6 - 5.0 %
	5.1 - 5.5 %
	5.6 - 6.0 %
	6.1 - 6.5 %
	6.6 + %

* Estimate based on statistical procedures using data on recurrence intervals and average building damage

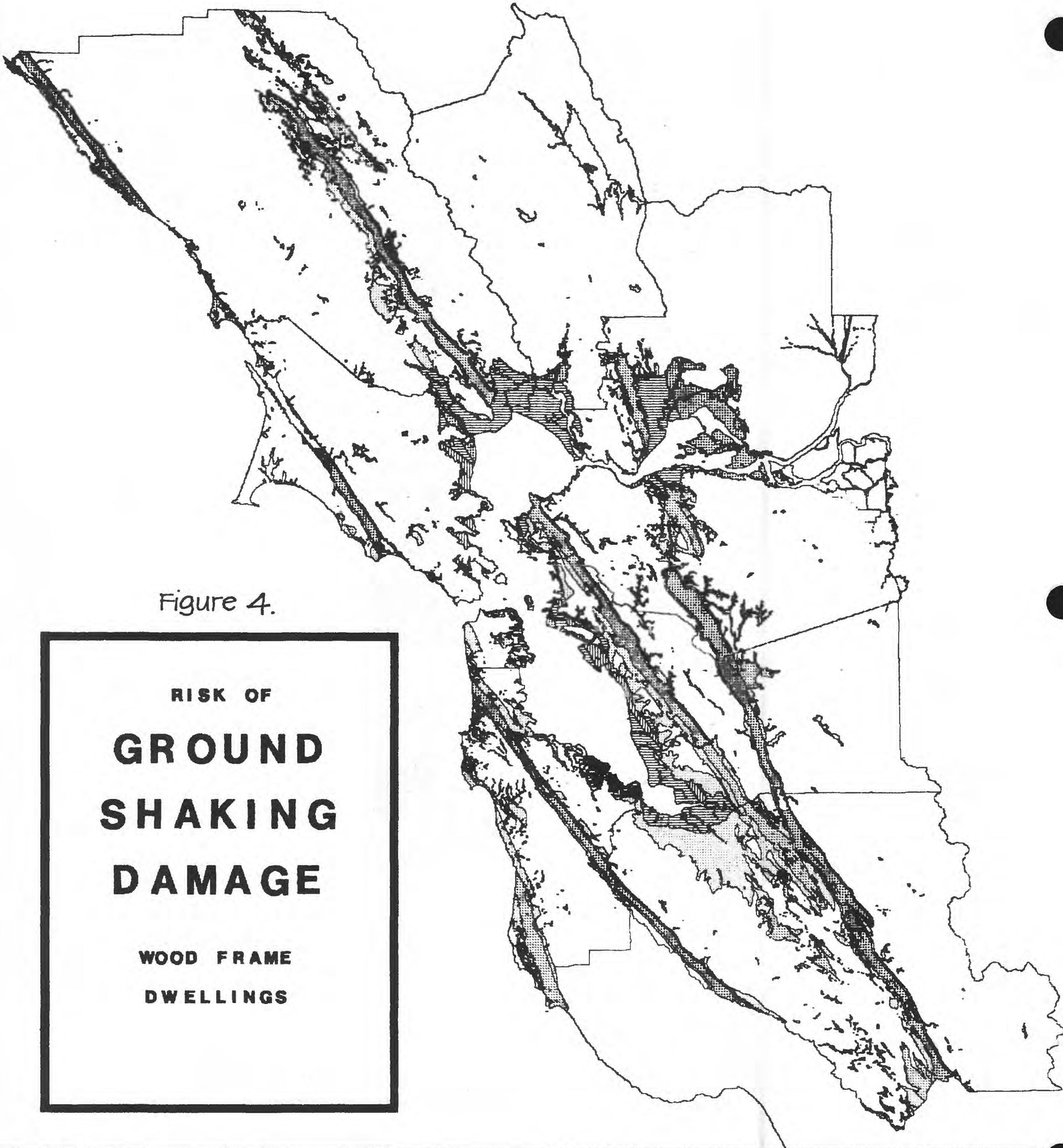


Figure 4.

RISK OF

GROUND SHAKING DAMAGE

WOOD FRAME DWELLINGS

BASIS BAY AREA SPATIAL INFORMATION SYSTEM

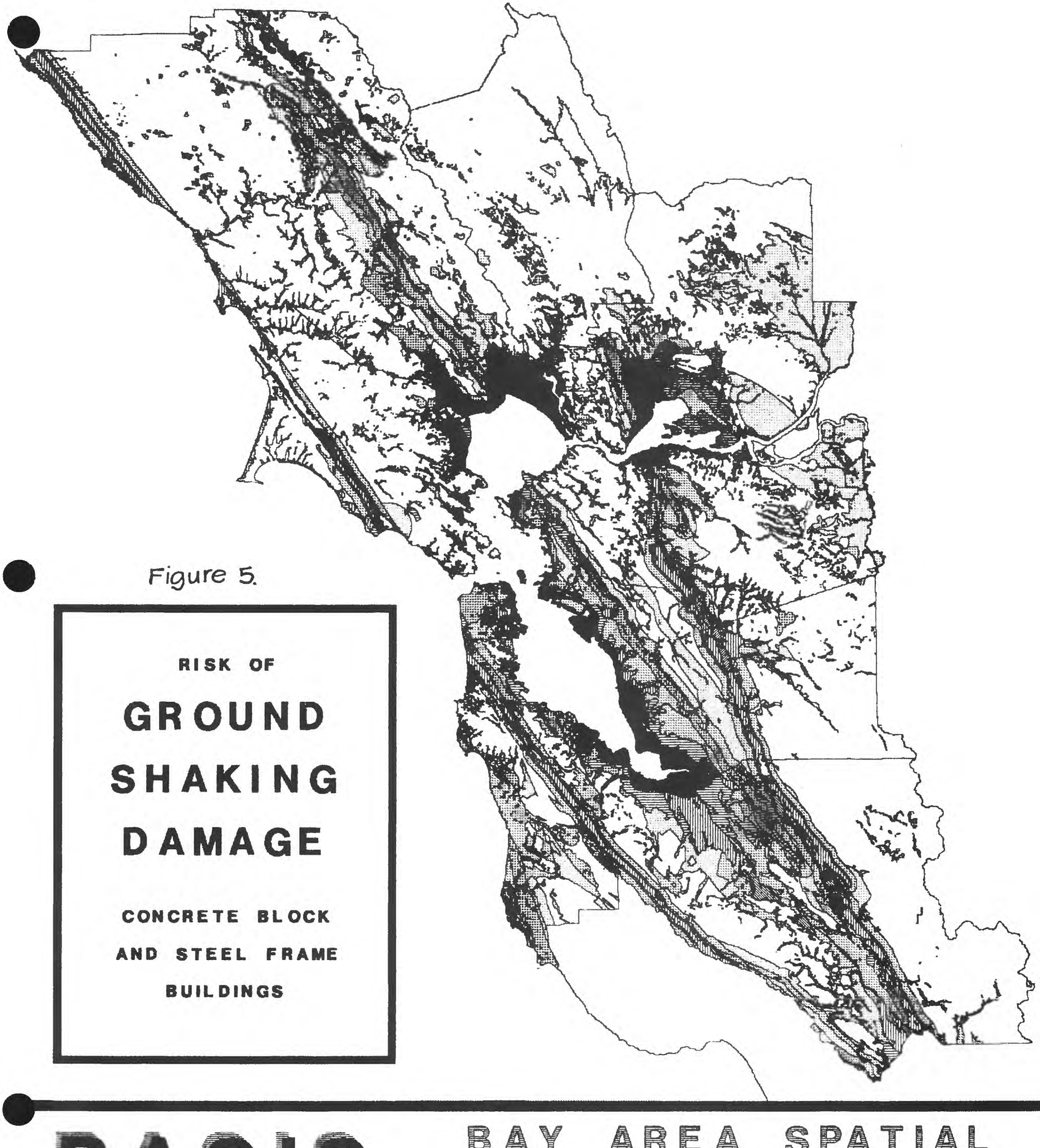


Figure 5.

RISK OF

GROUND SHAKING DAMAGE

CONCRETE BLOCK AND STEEL FRAME BUILDINGS

BASIS BAY AREA SPATIAL INFORMATION SYSTEM

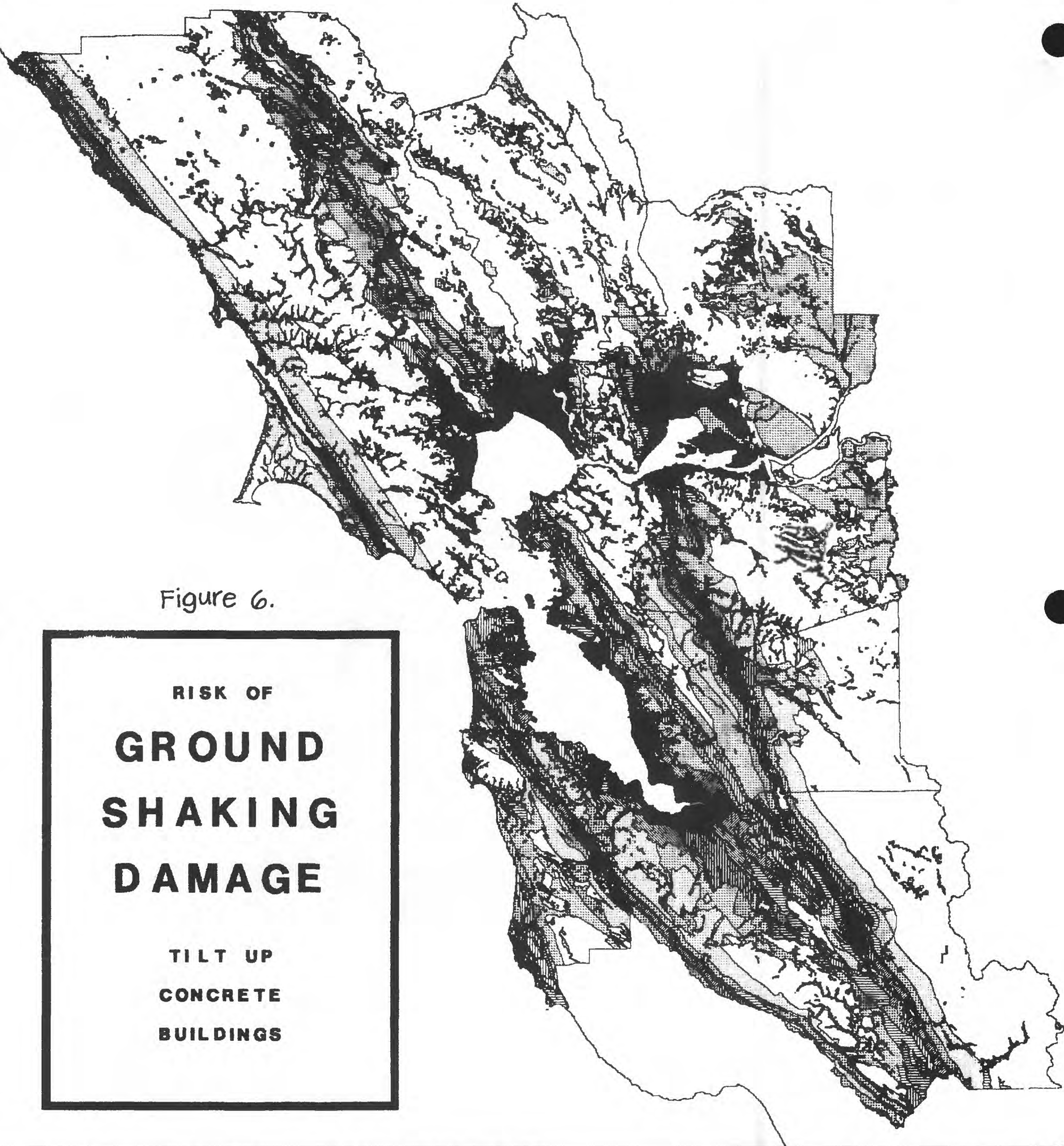


Figure 6.

BASIS

BAY AREA SPATIAL INFORMATION SYSTEM

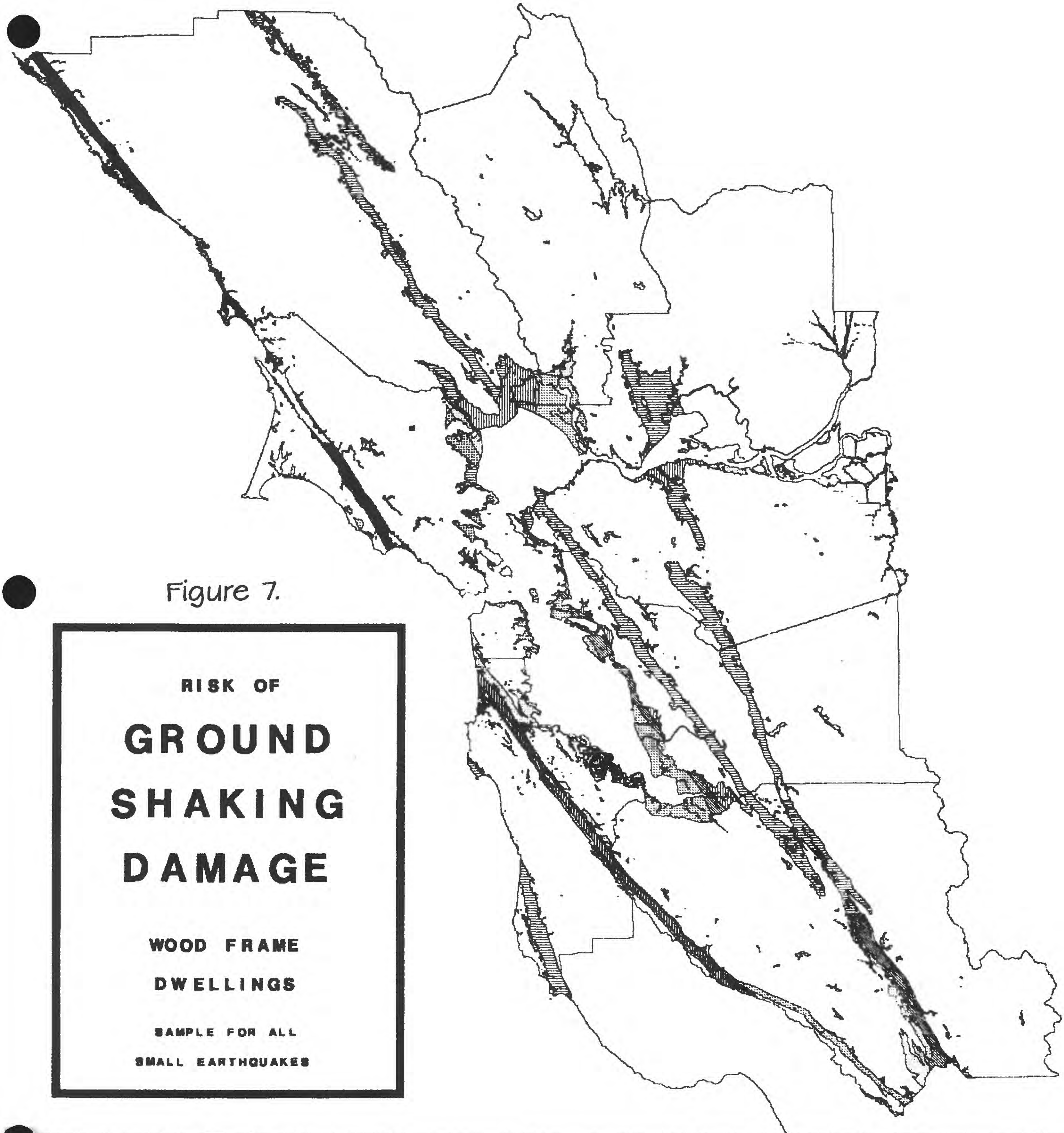


Figure 7.

BASIS BAY AREA SPATIAL INFORMATION SYSTEM

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APPENDIX D

EARTHQUAKE MAPPING PROJECT - WORKING PAPER #4
LIQUEFACTION POTENTIAL MAPPING

INTRODUCTION

This paper describes the technique used in compiling liquefaction potential maps for the region. It is the fourth in a series of review papers documenting the data used and the assumptions made in the ABAG/USGS earthquake mapping project.

The production of the liquefaction maps has been based primarily upon the method described in an article by Youd and Perkins of the U.S. Geological Survey, "Mapping Liquefaction Induced Ground Failure Potential" (Reference 1). The method consists of the combining of two preliminary maps (one of liquefaction susceptibility and a second of liquefaction opportunity) into a single liquefaction potential map.

LIQUEFACTION SUSCEPTIBILITY

As a first step in this technique, a liquefaction susceptibility map (Figure 1) has been compiled by assigning a relative liquefaction susceptibility to each of several units of geologic or soils materials. These units have been derived from those of the flatlands units of U.S. Geological Survey Professional Paper 944 (Reference 2) and from the geologic units in San Mateo County (described in Working Paper No. 2) complied by Brabb and Pampeyan (Reference 3) as shown in Table 1, below. In addition, two of the units in San Mateo County have been further subdivided. The bay muds have been divided into those of the Colma Valley area (north of Coyote Point) and those south of Coyote Point.* An additional area of historic failure along Colma Creek is mapped separately. There is not sufficient data to subdivide areas of artificial fill for this project.

As shown in Table 1, overall susceptibility can be expressed as the product of three fractions:

- o the likelihood of finding cohesionless sediments within a map unit
- o the likelihood that those sediments (when saturated) would be susceptible to liquefaction
- o the likelihood of finding the sediments saturated (based on groundwater elevations)

*Based on the relative number of sand deposits mapped by Nichols and Wright (Reference 4).

The susceptibility map shows 5 categories of materials, based on the final column of Table 1. Susceptibility ratings are assigned as follows:

- o 10% or greater as very high;
- o less than 10% to 1% as high;
- o less than 1% to .1% as moderate;
- o less than .1% to .01% as low;
- o less than .01% (about 0) as very low.

TABLE 1: RELATIVE SUSCEPTIBILITY OF GEOLOGIC UNITS TO LIQUEFACTION

Type of Deposit	Age of Deposit	Symbol on Geologic Map of San Mateo Co. (Ref. 3)	Symbol on Map of Flatlands Deposits (Ref. 2)	Likelihood of Finding Cohesionless Sediment Under Area Mapped as This Unit (1)	Likelihood that Cohesionless Sediment (When Saturated) Would Be Susceptible to Liquefaction (5)	Likelihood that Cohesionless Sediment Would Be Saturated	Overall Relative Susceptibility (11)
Undivided	Quaternary	--(2)	Qu	Widespread (6) (~25%)	Low to Moderate (6) 22%-high 33%-moderate 45%-low (~22%)	Only in Rainy Season (~20%)	Moderate (~.1%)
Stream Channel	Holocene	Qal	Qhsc	Widespread But Locally Variable (~50%)	Moderate to High 42%-High 42%-Moderate 16%-Low (~42%)	Very High (~100%)	High (~2.1%)
Alluvial Fan and Plain	Holocene				Low to Moderate 22%-High 33%-Moderate 45%-Low (~22%)		Moderate
Medium- to Coarse-Grained		Qyfo, Qyf	Qham, Qhac	Widespread (~50%)		Only in Rainy Season (~20%)	(~.2%)
Fine-Grained		Qb	Qhaf, Qhafs (Yellow)	Locally Variable (~5%)		Very High (~100%)	(~.1%)
Bay Mud	Holocene	Qm	Qhbm	Variable (4)	Moderate to High	Very High (~100%)	Low to Moderate
In General (Most Bay Area Counties)				Within (~9%) Below (~35%)	Within 73%-High 21%-Moderate 6%-Low (~73%)		Within (.6%) Below (1.2%) Overall (~1.8)
North of Coyote Pt. (San Mateo County)				Within (~12%) Below (~45%)			Within (.9%) Below (1.5%) Overall (~2.4%)
South of Coyote Pt. (San Mateo County)				Within (~7%) Below (~27%)	Below 33%-High 28%-Moderate 39%-Low (~33%)		Within (.5%) Below (.9%) Overall (~1.4%)
Colluvium	Holocene	Qcl	--(3)	Variable (<1%)	Low to Moderate (6) 22%-High 33%-Moderate 45%-Low (~22%)	Only in Rainy Season (~20%)	Very Low (~0%)
Beach and Dune Sand	Holocene	Qs	Qhs	Widespread (~100%)	Moderate to High (8) 42%-high 42%-moderate 16%-low (~42%)	Variable, Depending on Location (~50%)	High (~2.1%)

TABLE 1: Continued

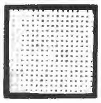
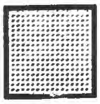
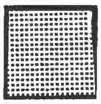
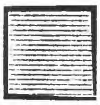
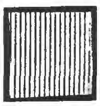
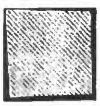
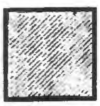
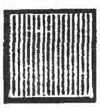
Type of Deposit	Age of Deposit	Symbol on Geologic Map of San Mateo Co. (Ref. 3)	Symbol on Map of Flatlands Deposits (Ref. 2)	Likelihood of Finding Cohesionless Sediment Under Area Mapped as This Unit (1)	Likelihood that Cohesionless Sediment (When Saturated) Would Be Susceptible to Liquefaction (5)	Likelihood that Cohesionless Sediment Would Be Saturated	Overall Relative Susceptibility (11)
Artificial Fill	Historic	Qaf	Qhaf (purple)	Variable		Variable, Depending on Location (~50%)	Overall - Moderately Low (~.1%)
Compacted				(<1%)	(<1%)		(Assuming 80% of fill in Bay Area is compacted; 20% is uncompacted)
Uncompacted				(~9-35%) (9)	Moderate to High (9) (~73-33%)		
Alluvial Fan and Plain	Pleistocene	Qof, Qob	Qpa, Qpea	Widespread (~25%)	Low 11%-High 29%-Moderate 60%-Low (~11%)	Only in Rainy Season (~20%)	Low (<.1%)
Marine Terraces and Plains	Pleistocene	Qmt	Qpmt	Widespread (~25%)	Low (10) 11%-High 29%-Moderate 60%-Low (~11%)	Only in Rainy Season (~20%)	Low (<.1%)
Beach and Dune	Pleistocene	Qc	Qpmc, Qps	Widespread (~100%)	Low (10) 11%-High 29%-Moderate 60%-Low (~11%)	Only in Rainy Season (~20%)	Moderate (~.2%)
All	Pre-Pleistocene	Varies	br	Variable (<1%)	Very Low 0%-High 0%-Moderate 100%-Low (~0%)	Only in Rainy Season (~20%)	Very Low (~0%)
Areas of Historic Liquefaction	—	Varies	Varies	(100%)	High-100%	100%	Very High (10%)

NOTES:

(1) Column adapted from Ref. 1, Table 2 in conjunction with Ref. 5.
(2) Not mapped as a separate unit.
(3) Included with Qham and Qhac.
(4) Based on data on the relative number of bore holes hitting sand within and below Bay mud (Ref. 4).
(5) Based on data from Ref. 6, Table 5, page A72 unless otherwise indicated. Overall percent was obtained by assuming all "high" sediments liquefy whenever provided the opportunity, while none of the "moderate" sediments liquefy and none of the "low" sediments liquefy.
(6) No data; assumed similar to Holocene alluvial fan and plain.
(7) Based on data from the Salinas River and Coyote Creek (Ref. 5).
(8) No data; assumed similar to Holocene stream channel deposits.
(9) No data; values assumed similar to those for Bay Mud.
(10) No data; assumed similar to Pleistocene alluvial fan and plain.
(11) The numbers in this column have been reduced to 10% of the product of the previous three columns to more closely reflect experiences in the 1906 San Francisco earthquake. Reasons for the discrepancy include conservative estimates of susceptibility and the many small pockets of sand which liquefy without causing surface deformation.

EXPLANATION FOR FIGURE 1

LIQUEFACTION SUSCEPTIBILITY

SHADE PATTERN	LIKELIHOOD OF LIQUEFACTION*	
	0 %	Very Low
	<.1%	Low
	.1%	Moderate
	.2%	Moderate
	1.4%	High
	1.8%	High
	2.1%	High
	2.4%	High
	10.0%	Very High

*Numbers indicate work accurate relationships to each other than to absolute values

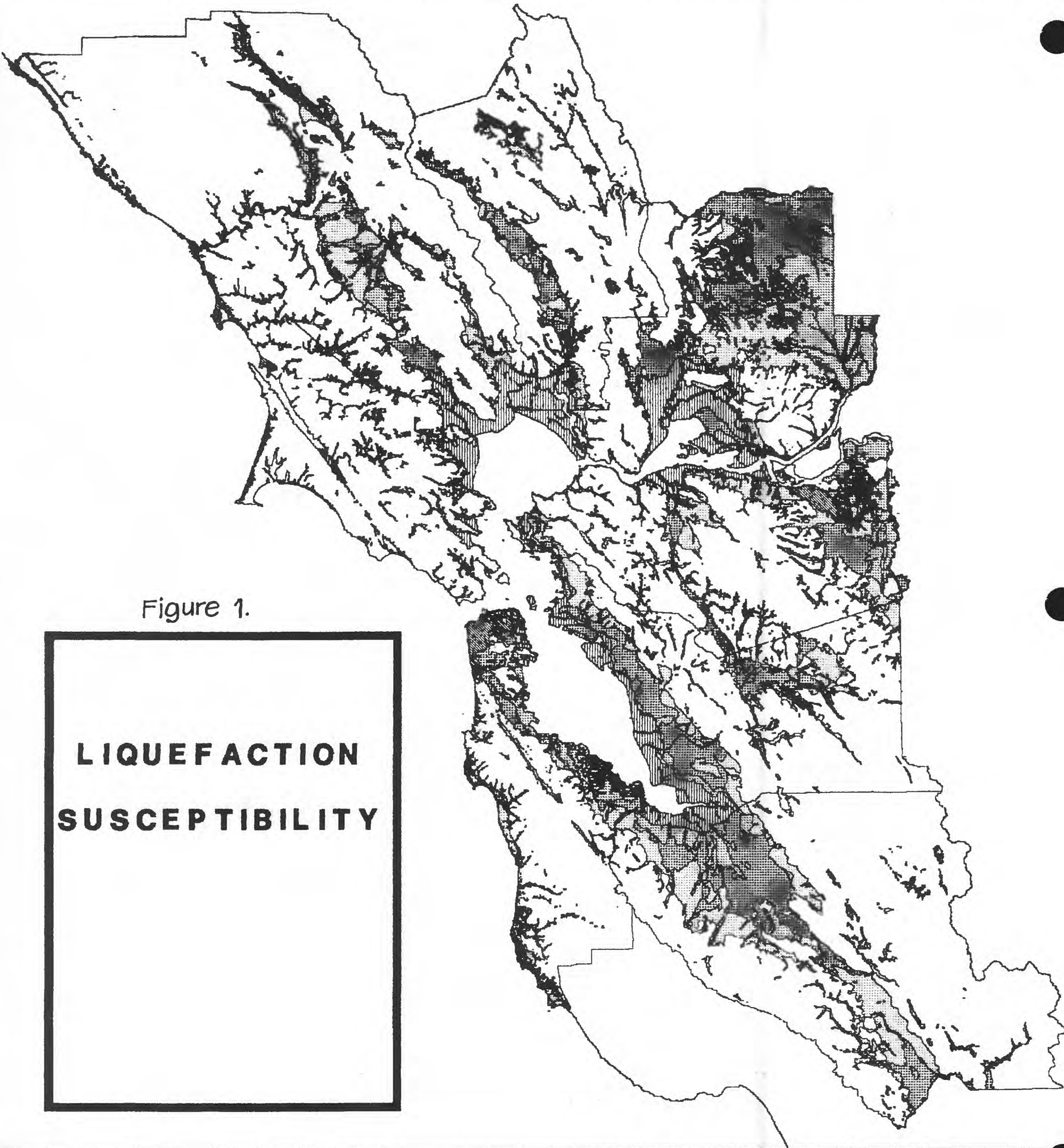


Figure 1.

LIQUEFACTION SUSCEPTIBILITY

BASIS

BAY AREA SPATIAL INFORMATION SYSTEM

LIQUEFACTION OPPORTUNTY

After the relative susceptibility of the various units is established, a method is required to estimate the relative frequency of occurence of ground shaking sufficent to produce liquefaction, or liquefaction opportunity. The method used is based on earthquake magnitude, recurrence intervals and distance of areas from active faults. Although the method is similar to that developed by Algermissen and Perkins (Reference 7) and used by Youd et al. in a study for the San Fernando Valley Area (Reference 8), it is different in two ways:

- o the distances from the fault sources of the earthquakes are more closely approximated (since they are assumed to originate on several faults rather thn just the San Andreas fault); and
- o the recurrence of earthquakes are estimated from long-term slip rate (instead of from a statistical analysis of historic activity) for each source.

The recurrence intervals used for various magnitude earthquakes are discussed in Working Paper #1. The maximum distances from faults at which liquefaction can occur for these various earthquake magnitudes is derived using this formula from Reference 2:

Magnitude = 5 + 1.15log (distance from fault for liquefaction in kilometers)

with 150 kilometers as a maximum. Information on magnitude, recurrence intervals, and distances is provided in Table 2, below.

Note that recurrence interval information is provided for two different hypothetical cases of liquefaction opportunity. Those two cases are the same as those used to produce maps of risk of ground shaking damage. The first case assumes that only the largest magnitude earthquake that can occur will occur (maximum magnitude being derived from one half the length of a fault)*. The second case assumes that only magnitude 5.5 earthquakes can occur and results in liquefaction only being a problem up to 3 km away from a fault, an obviously incorrect assumption. Thus, Case 1 has been used to calculate opportunity. Each maps cell in the Bay Area accumulated an opportunity based on multiplying (1 + frequency of earthquakes on fault A) by (1 + frequency of earthquakes on fault B)...for those earthquakes originating on faults close enough to generate ground shaking great enough to cause liquefaction.

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*One major problem with using a calculated series of recurrence intervals from a slip rate is that the interval for large magnitude earthquakes on long faults (such as the San Andreas) becomes too large to agree with historic data. In order to lessen this problem for the San Andreas, the recurrence intervals used for earthquakes on that fault will be for the Hollister to Bolinas segment and the Bolinas to Cape Mendocino segment, rather than for the entire length of the fault.

TABLE 2: LIQUEFACTION OPPORTUNITY FOR TWO SAMPLE CASES

	CASE 1			CASE 2		
Fault	Max. Magnitude (1/2 L)	Recurrence Interval (2)	Max. Distance from Fault at Which Liquefaction Can Occur (in km) (3)	Max. Magnitude (all 5.5)	Recurrence Interval (2)	Max. Distance from Fault at Which Liquefaction Can Occur (in km) (3)
San Andreas	8.4	1000	150	5.5	4	3
Hollister-Bolinas	7.2	100	82	5.5	5	3
Bolinas-Cape Mendocino	7.5	100	150	5.5	3	3
Calaveras	7.3	300	100	5.5	10	3
Calaveras-Paicines	6.9	100	45	5.5	7	3
Calaveras-Sunol	6.7	100	30	5.5	10	3
Pleasanton	5.5	N/A (1)	3	5.5	N/A (1)	3
Concord/Green Valley	7.0	200	55	5.5	10	3
Antioch	6.4	N/A	16	5.5	N/A	3
Hayward	6.9	200	45	5.5	10	3
Healdsburg/ Rodgers Creek	6.8	200	37	5.5	10	3
Maacama	7.1	300	67	5.5	10	3
San Gregorio	7.1	200	67	5.5	10	3
Verona	6.8	N/A	37	5.5	N/A	3
Silver Creek	7.0	N/A	55	5.5	N/A	3
Evergreen	6.9	N/A	45	5.5	N/A	3
Dunnigan Hills	6.8	N/A	37	5.5	N/A	3
West Napa	6.2	N/A	11	5.5	N/A	3
Cordelia	5.9	N/A	6	5.5	N/A	3
Sargent	6.6	300	25	5.5	30	3
Las Positas	6.3	N/A	14	5.5	N/A	3
Greenville	5.5	N/A	3	5.5	N/A	3
Faults near Trenton	6.2	N/A	11	5.5	N/A	3
Tolay	5.7	N/A	4	5.5	N/A	3
Faults East of Bennett Valley & Santa Rosa	5.6	N/A	3	5.5	N/A	3
Zayante	6.8	N/A	37	5.5	N/A	3
Berrocal	7.4	N/A	120	5.5	N/A	3
Midway	6.8	N/A	37	5.5	N/A	3
San Joaquin	7.3	10,000	100	5.5	300	3
Monte Vista	7.1	N/A	67	5.5	N/A	3

NOTES:

(1) N/A = Not Available
(2) All recurrence intervals are rounded to one significant figure.
(3) All distances are rounded to two significant figures.

LIQUEFACTION POTENTIAL

After maps of liquefaction susceptibility and data on opportunity have been compiled, the information can be combined in a number of ways. One simple way is to overlay two maps and assign a different color or pattern to each new polygon, as was done by Youd, et al. in the San Fernando project (Reference 8). For the purpose of compiling composite maximum damage maps, the entire Bay Area has the opportunity for failure, thus the susceptibility map will have the same lines as the maximum liquefaction potential map.

The maps also can be combined quantitatively, however. As has been done with expected damage from earthquake ground shaking, (see Working Paper #1-#3), two liquefaction potential maps could have been produced based upon two different assumptions about liquefaction opportunity to illustrate the technique. Because of the problems with the second case, however, a liquefaction potential map (Figure 2) has been produced for the first case, one that is far closer to reality.

For these maps, the susceptibility maps and the opportunity maps have been combined for each map cell by multiplying two fractions:

- o the relative susceptibility--the last column in Table 1
- o the liquefaction opportunity--the frequency of earthquakes from Table 2

DAMAGE RESULTING FROM LIQUEFACTION-INDUCED GROUND FAILURE

Many problems occur when trying to estimate the extent of damage associated with each liquefaction potential unit. For example, the problem with trying to estimate percentages from historic information in San Mateo County (see Reference 9) is that the areas where liquefaction did not occur are not well defined (Reference 5). In addition, according to Youd (Reference 10):

> ...every major pipeline break in the city of San Francisco during the 1906 earthquake occurred in areas of lateral spreading [a type of failure caused by liquefaction]. These pipeline breaks severely hampered efforts to fight the large fire that ignited during the earthquake. Thus, rather inconspicuous ground-failure movements of a few feet were in large part responsible for the devastating damage to that city.

This type of information becomes necessary when trying to combine ground shaking maps, liquefaction maps and other hazard maps into the type of composite earthquake hazard maps described in Working Paper #9.

EXPLANATION FOR FIGURE 2

LIQUEFACTION POTENTIAL

SHADE PATTERN	RELATIVE LIQUEFACTION POTENTIAL*
	0 - .009 %
	.010 - .025 %
	.026 - .045 %
	.046 - .070 %
	.071 - .094 %
	.095 - .114 %
	.115 - .140 %
	.141 - .160 %
	.161 - .185 %
	.186 - .205 %
	.206 - .230 %
	.231 - .250 %
	.251 - .275 %
	.276 - .299 %
	.300 + %

* Liquefaction potential is the product of liquefaction susceptibility and liquefaction opportunity. Numbers indicate more accurate relationships to each other than to absolute values.

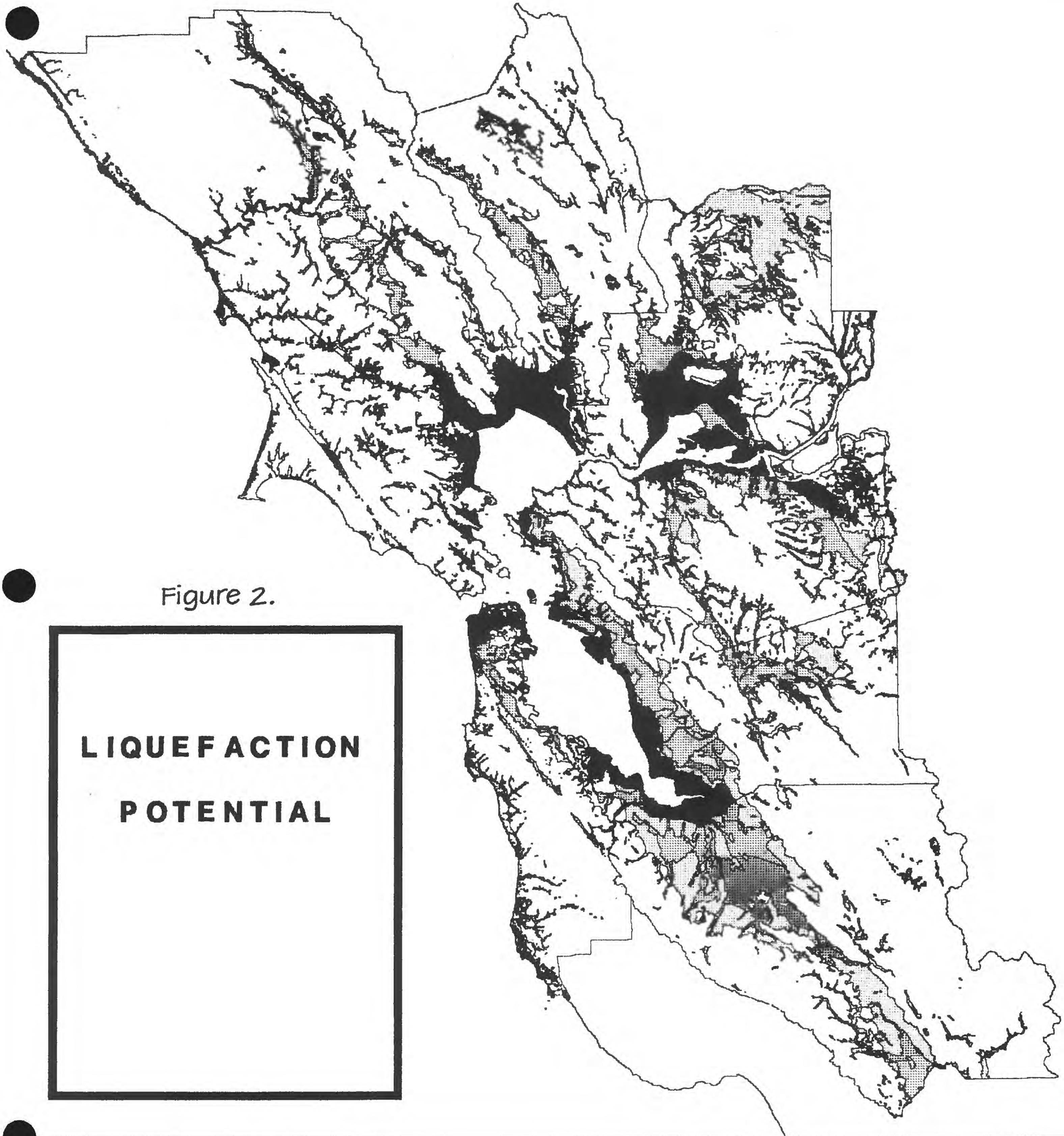

Figure 2.

LIQUEFACTION POTENTIAL

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10. Youd, T. L., 1978, Major Cause of Earthquake Damage is Ground Failure in Civil Engineering - ASCE, April, pp. 47-51.

APPENDIX E

EARTHQUAKE MAPPING PROJECT - WORKING PAPER #5
SLOPE STABILITY MAPPING

INTRODUCTION

Information on the amount of slope of hillsides, on geologic materials, and on landslides has been used to estimate the relative stability of a hillside. The way in which these three factors interact to yield relative slope stability is different during an earthquake than during other times when landslides are usually the result of winter rains.

This working paper describes the sources of the information on slope, geology and existing landslides and explains how this information has been combined to produce maps of rainfall-induced and earthquake-induced landslide susceptibility. It is the fifth in a series of working papers documenting the data used and the assumptions made in the ABAG/USGS earthquake mapping project.

THE BASIC INFORMATION

Slope

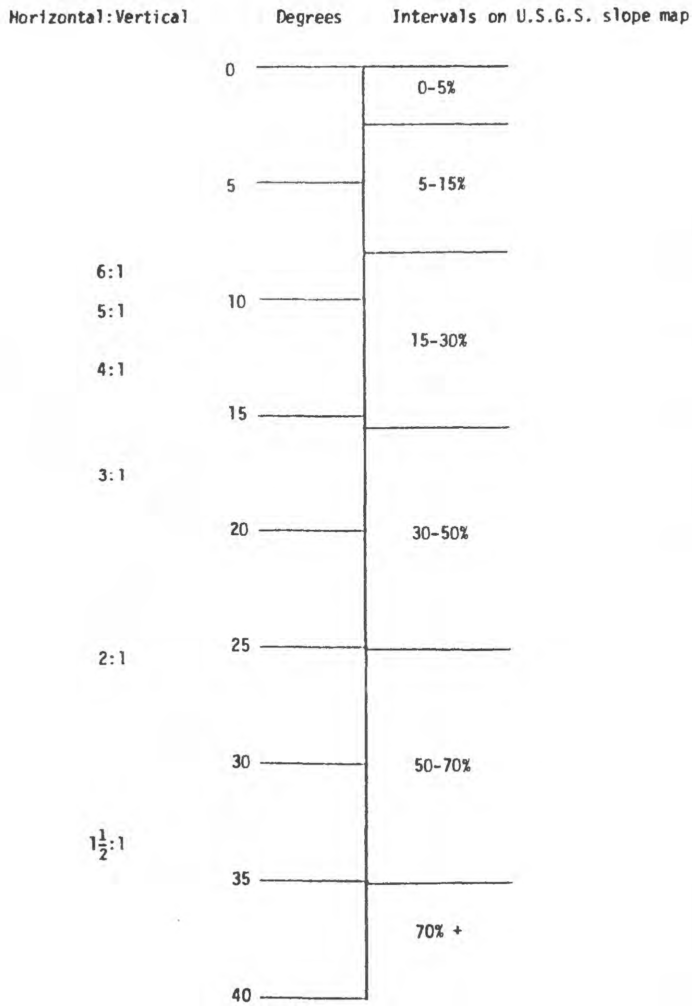
Information on the amount of slope of hillsides has been obtained from a digital file of elevation records for San Mateo County developed by the U.S. Geological Survey Topographic Division. Elevation data for points on a 100 meter grid has been converted to slope data by a program developed by ABAG staff. Because of the expense in developing this information, the file covers only San Mateo County. Consequently, all slope stability mapping for this project covers only that county. The file will be expanded as slope data for other areas becomes available.

The slope data is expressed in percent slope. The relationship of this method of expressing slope to two other methods, degrees and ratios, is illustrated in Table 1, below.

Geologic Materials

Information on the geologic units for San Mateo County has been obtained from a new map compiled by Brabb and Pampeyan of U.S.G.S. (Reference 1). This map also has been used in the ground shaking intensity mapping.

TABLE 1: SCOPE INTERVALS
(from Brabb and Pampeyan, Ref. 3).



Existing Landslides

Brabb and Pampeyan have compiled a map of landslides in San Mateo County (Reference 2). The map delineates large landslides and marks small landslides (50 to 500 feet) with a symbol. Large landslides are shown as active, definite, probable, and questionable, as well as whether they have been mapped from aerial photos or from field work. The source of the smaller landslides is shown as being mapped from aerial photos, field work, public agencies or private consultants' files. The map was published in 1972 and therefore lacks data on landslides from consultants reports prepared since then. Collecting that data from the numerous reports is beyond the scope of this project, but the file developed at ABAG is capable of handling the new data if time and money become available.

RAINFALL-INDUCED LANDSLIDE SUSCEPTIBILITY

Categories of landslide susceptibility have been mapped and are shown in Figure 1. The table of criteria developed by Brabb and others (Reference 3) was used and is presented in Table 2. This table shows the relationship between the various geologic units and seven relative landslide susceptibility units based on the percent of area in failure. Table 2 also relates these seven units to six categories of percent slope. The susceptibility unit has been decreased for some combinations based on the experience of Brabb and Pampeyan and data on percent slope prior to failure. The seven susceptibility units are defined in Table 3.

Although this method of mapping slope stability depends on only three variables (slope, geology, and existing landslides), other research notes that other variables may be almost as basic. The factors include land use, precipitation, vegetation type, slope aspect, and the bedding dip of the geologic materials. Although modifying the method for predicting slope stability based on non-USGS work is beyond the scope of this project, some additional work will be possible in the near future. It is reasonably easy to perform cross-tabulations between any two variables in ABAG's computer-based data system. Since land use, average annual precipitation, peak hourly precipitation, vegetation type, and slope aspect all will be in the system, cross tabulations calculating the area of landslides in the various categories on the maps of these other variables will be feasible when time and money become available.

TABLE 2: LANDSLIDE FAILURE RECORD FOR ROCK UNITS IN SAN MATEO COUNTY WITH CORRESPONDING RELATIVE SUSCEPTIBILITY NUMBERS

(modified from Brabb and Pampeyan, Ref. 3)

Surface extent of the rock unit that has failed by landsliding		Rock unit on geologic map by Brabb and Pampeyan (Ref. 1), in order of increasing proportion of surface having failed by landsliding	Map symbol	Approx. area in County (sq mi)	Approx. area that has failed (sq mi)	Relative suscepti-bility numbers	Susceptibility numbers in each slope interval					
							0-5	5-15	15-30	30-50	50-70	> 70
Little of the rock unit has failed	Percent											
	0-1	(No data for alluvium, Qal; coarse-grained younger alluvial fan deposits, Qyf; fine-grained younger alluvial fan deposits, Qyfo; younger basin deposits, Qb; beach deposits and windblown sand, Qs; San Francisco Bay mud, Qm; artifical fill, Qaf; coarse-grained older alluvial fan and stream terrace deposits, Qof; fine-grained older alluvial fan deposits, Qob; marine terrace deposits, Qmt; Page Mill Basalt, Tpm; unnamed volcanic rocks, KJv & Tuv; marble, m; shale near Palo Alto, Ksh; conglomerate, fcg; or metamorphic rocks, fm, but extent of landsliding probably small)				I						
		Limestone	fl	.30	.00		I	I	I	I	I	I
		Colma Formation	Qc	11.11	.01		I	I	I	I	I	I
	2-8	Sandstone at San Bruno Mountain	KJs	4.77	.10	II	I	I	I	I	I	II
		Butano(?) Sandstone	Tb?	10.56	.19		I	I	II	II	II	II
		Unnamed sandstone	Tus	1.81	.04		I	I	I	I	I	II
		Granitic rocks	Kgr	24.61	.90		I	I	I	I	I	II
		Serpentine	sp	4.76	.09		I	I	I	II	II	II
		Sandstone of Franciscan assemblage (incl. KJf)	fs	22.19	.74		I	I	I	II	II	II
		Slope wash and ravine fill	Qcl	4.51	.18		I	I	I	II	II	II
		Greenstone of Franciscan assemblage	fg	11.70	.61		I	I	I	II	II	II
		Chert of Franciscan assemblage	fc	1.43	.10		I	I	I	II	II	II
		Lompico Sandstone of Clark (1966)	Tlo	.40	.03		I	I	I	I	I	II
	9-25	Sheared rocks of Franciscan assemblage	fsr	9.99	.83	III	I	I	II	III	III	III
		Pigeon Point Formation	Kpp	7.77	.84		I	I	II	II	III	III
		San Lorenzo Formation, undivided	Tsl	1.00	.11		I	I	I	II	II	III
		Merced Formation	QTm	7.91	1.01		I	I	II	II	III	III
		Sandstone, shale and conglomerate	Tss	3.34	.51		I	I	I	I	II	III
		Butano Sandstone, Skylonda area (incl. Tbs)	Tb	22.55	4.33		I	I	II	III	III	III
	26-42	Santa Clara Formation	QTs	6.97	1.85	IV	I	I	III	IV	IV	IV
		Rices Mudstone Member of San Lorenzo Formation of Brabb (1964)	Tsr	1.37	.43		I	I	II	III	IV	IV
		Vaqueros Sandstone	Tvq	7.60	2.41		I	I	II	III	III	IV
		Monterey Shale	Tm	5.11	1.76		I	I	II	IV	IV	IV
		Purisima Formation, undivided	Tp	23.06	7.81		I	II	III	IV	IV	IV
		Lambert Shale	Tla	19.95	7.25		I	I	II	III	III	IV
		Mindego Basalt and other volcanic rocks	Tmb	10.80	4.01		I	I	II	III	III	IV
		Butano Sandstone along Butano Ridge	Tb	20.18	7.66		I	I	II	III	IV	IV
		Santa Cruz Mudstone of Clark (1966)	Tsc	19.25	7.98		I	I	I	III	IV	IV
	43-53	San Gregorio Sandstone Member of Purisima Formation of Cummings and others (1962)	Tpsg	2.41	1.06	V	I	I	I	IV	V	V
		Tunitas Sandstone Member of Purisima Formation of Cummings and others (1962)	Tptu	2.76	1.24		I	I	III	V	V	V
		Tahana Member of Purisima Formation of Cummings and others (1962)	Tpt	33.46	16.08		I	II	III	V	V	V
		Pomponio Member of Purisima Formation of Cummings and others (1962)	Tpp	11.97	5.76		I	I	II	V	V	V
		Twobar Shale Member of San Lorenzo Formation of Brabb (1964)	Tst	.80	.42		I	I	II	III	IV	V
Most of the rock unit has failed	54-70	Santa Margarita Sandstone	Tsm	.65	.41	VI	I	I	I	III	III	VI
		San Lorenzo Formation and Lambert Shale, undivided	Tls	6.83	4.56		I	I	III	V	VI	VI
		Lobitos Mudstone Member of Purisima Formation of Cummings and others (1962)	Tpl	3.71	2.57		I	II	II	VI	VI	VI
	100	Landslide deposits	Qls	83.88	83.88	L	L	L	L	L	L	L

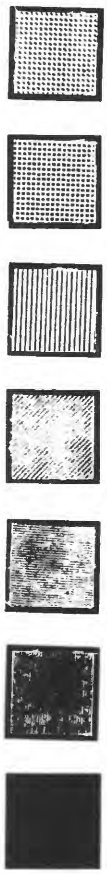
TABLE 3: EXPLANATION OF RELATIVE SUSCEPTIBILITY NUMBERS (from Brabb and Pampeyan, Ref. 3)

Susceptibility	Number	Explanation
Least	I	Areas least susceptible to landsliding. Very few small landslides have formed in these areas. Formation of large landslides is possible but unlikely, except during earthquakes. Slopes generally less than 15%, but may include small areas of steep slopes that could have higher susceptibility. Includes some areas with 30% to more than 70% slopes that seem to be underlain by stable rock units. Additional slope stability problems; some of the areas may be more susceptible to landsliding if they are overlain by thick deposits of soil, slopewash, or ravine fill. Rockfalls may also occur on steep slopes. Also includes areas along creeks, rivers, sloughs, and lakes that may fail by landsliding during earthquakes. If area is adjacent to area with higher susceptibility, a landslide may encroach into the area, or the area may fail if a landslide undercuts it, such as the flat area adjacent to sea cliffs.
↓	II	Low susceptibility to landsliding. Several small landslides have formed in these areas and some of these have caused extensive damage to homes and roads. A few large landslides may occur. Slopes vary from 5-15% for unstable rock units to more than 70% for rock units that seem to be stable. The statements about additional slope stability problems mentioned in I above also apply in this category.
↓	III	Moderate susceptibility to landsliding. Many small landslides have formed in these areas and several of these have caused extensive damage to homes and roads. Some large landslides likely. Slopes generally greater than 30% but includes some slopes 15-30% in areas underlain by unstable rock units. See I for additional slope stability problems.
↓	IV	Moderately high susceptibility to landsliding. Slopes all grater than 30%. These areas are mostly in undeveloped parts of the County. Several large landslides likely. See I for additional slope stability problems.
↓	V	High susceptibility to landsliding. Slopes all greater than 30%. Many large and small landslides may form. These areas are mostly in undeveloped parts of the County. See I for additional slope stability problems.
↓	VI	Very high susceptibility to landsliding. Slopes all greater than 30%. Development of many large and small landslides is likely. Slopes all greater than 30%. The areas are mainly in undeveloped parts of the County. See I for additional slope stability problems.
Most	L	Highest susceptibility to landsliding. Consists of landslide and possible landslide deposits. No small landslide deposits are shown. Some of these areas may be relatively stable and suitable for development, whereas others are active and causing damage to roads, houses and other cultural features.

Definitions: Large landslide - more than 500 feet in maximum dimension
Small landslide - 50 to 500 feet in maximum dimension

EXPLANATION FOR FIGURE 1

RAINFALL-INDUCED LANDSLIDE SUSCEPTIBILITY

SHADE PATTERN	RELATIVE SUSCEPTIBILITY
	
	I Low
	II
	III
	IV
	V
	VI
	VII High

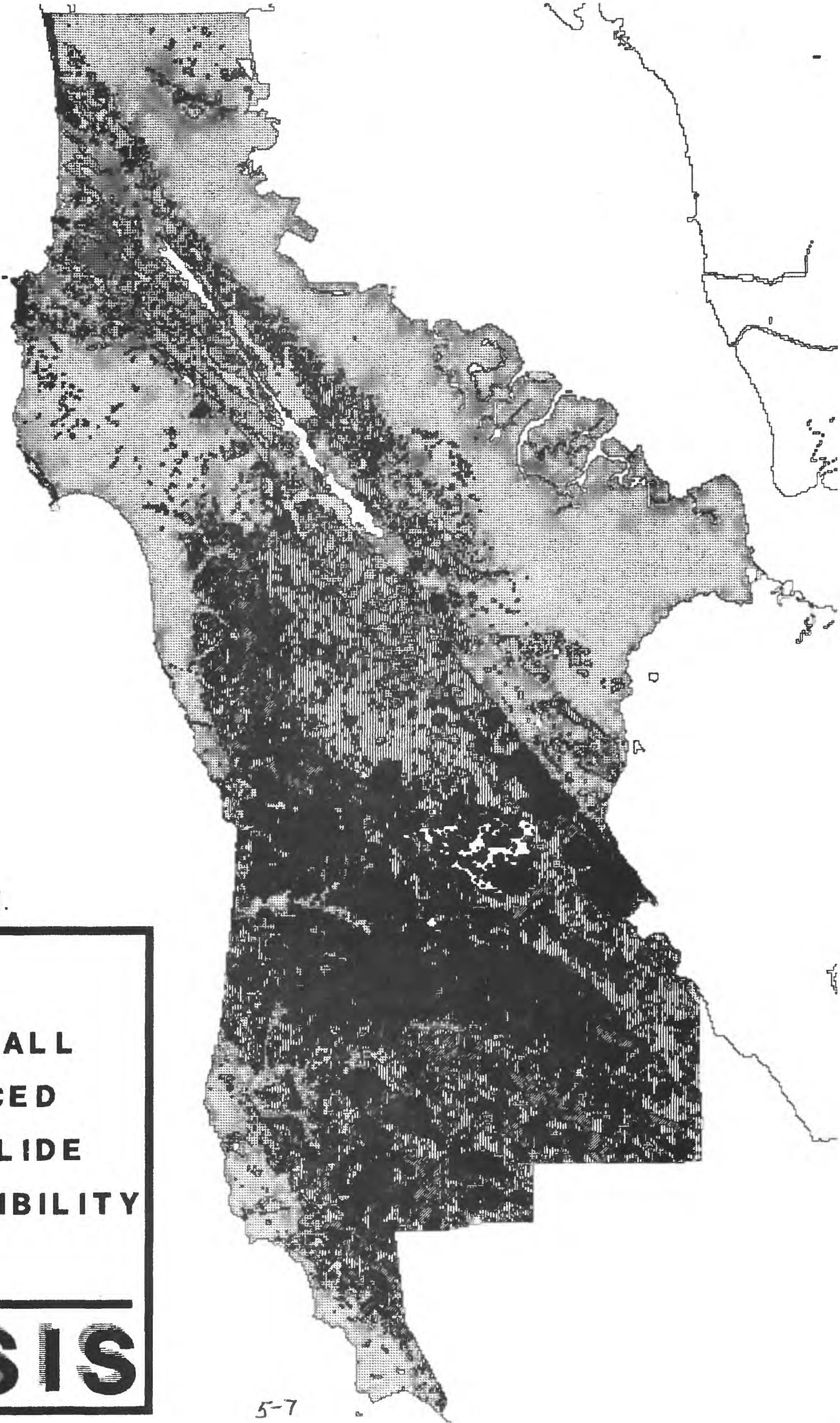


Figure 1.

RAINFALL
INDUCED
LANDSLIDE
SUSCEPTIBILITY

BASIS

EARTHQUAKE-INDUCED LANDSLIDE SUSCEPTIBILITY

Categories of earthquake-induced landslide susceptibility have been mapped using a series of criteria tables supplied by Gerry Wieczorek of the U.S. Geological Survey (Reference 4) and are shown in Figure 2. Table 4 shows the grouping of the various geologic units into three categories based on physical properties related to landslide susceptibility. These three categories include relatively cohesive units (A), units that are relatively cohesionless (B), and the clay-rich rocks (C). Table 5 relates these three groups to seven categories of percent slope and assigns one of four susceptibility ratings to each combination. The four susceptibility ratings are defined in Table 6. Whereas all types of landslides have been considered in defining rainfall-induced landslide susceptibility, questionable landslides mapped from aerial photo interpretation have been omitted from consideration on this derived map.

TABLE 4: RELATIVE SUSCEPTIBILITY CATEGORIES FOR GEOLOGIC UNITS FOR EARTHQUAKE-INDUCED LANDSLIDES

Susceptibility Category	Rock Unit on Geologic Map	Map Symbol
A	Mindego Basalt & other rocks	Tmb
	Butano Sandstone	Tb
	Tunitas Sandstone of Tp	Tptu
	Lompico Sandstone of Clark	Tlo
	Vaqueros Sandstone	Tvq
	Granitic rocks	Kgr
	Page Mill Basalt	Tpm
	Sandstone at San Bruno Mt.	KJs
	Greenstone of KJf	fg
	Metamorphic Rocks of KJf	fm
	Limestone of KJf	fl
	Conglomerate of KJf	fcg
	Marble	m
	Pigeon Point Formation	Kpp
	Unnamed volcanic rocks	KJv
	Sandstone of KJf	fs
	Unnamed volcanic rocks	Tuv
B	San Gregorio Sandstone of Tp	Tpsg
	Unnamed Sandstone	Tus
	Younger fan deposits	Qyf
	Marine terrace deposits	Qmt
	Sandstone, shale & conglomerate	Tss
	Santa Margarita Sandstone	Tsm
	Older fan deposits	Qof
	Colma Formation	Qc
	Beach & sand deposits	Qs
	Butano (?) Sandstone	Tb?

Susceptibility Category	Rock Unit on Geologic Map	Map Symbol
C	San Lorenzo & Lambert Fms.	Tls
	San Lorenzo Formation	Tsl
	Lambert Shale	Tla
	Monterey Shale	Tm
	Twobar Shale of Tsl	Tst
	Rices Mudstone of Tsl	Tsr
	Purisima Formation	Tp
	Lobitos Mudstone of Tp	Tpl
	Pomponio Member of Tp	Tpp
	Tahana Member of Tp	Tpt
	Shale in Butano Sandstone	Tbs
	Franciscan Assemblage	KJf
	Santa Cruz Mudstone	Tsc
	Merced Formation	QTm
	Santa Clara Formation	QTs
	Slope wash & ravine fill	Qcl
	S. F. Bay Mud	Qm
	Artificial fill	Qaf
	Sheared rocks of KJf	fsr
	Chert of KJf	fc
	Serpentine	Sp
	Shale near Palo Alto	Ksh
	Younger disected fans	Qyfo
	Basin deposits	Qb
	Alluvium	Qal
	Older basin deposits	Qob
	Landslides	On Ref. 2

TABLE 5: RELATIVE SUSCEPTIBILITY OF ROCK UNITS TO SEISMICALLY-INDUCED LANDSLIDES

Stability Category	0-5%	5-15%	15-30%	30-50%	50-70%	70-100%	100+%
A	1	1	1	1	2	3	4
B	1	1	2	3	4	4	4
C	1	2	3	4	4	4	4

TABLE 6: EXPLANATION OF RELATIVE SUSCEPTIBILITY NUMBERS FOR SEISMICALLY-INDUCED LANDSLIDES

Category 1: Stable all year

2: Stable insummer; of intermediate stability in winter

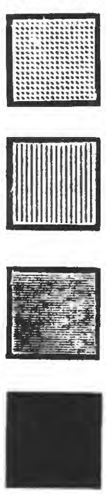
3: Of intermediate stability in summer; unstable in winter

4: Unstable all year

EXPLANATION FOR FIGURE 2

EARTHQUAKE-INDUCED LANDSLIDE SUSCEPTIBILITY

SHADE PATTERN



RELATIVE SUSCEPTIBILITY

1 Low

2

3

4 High

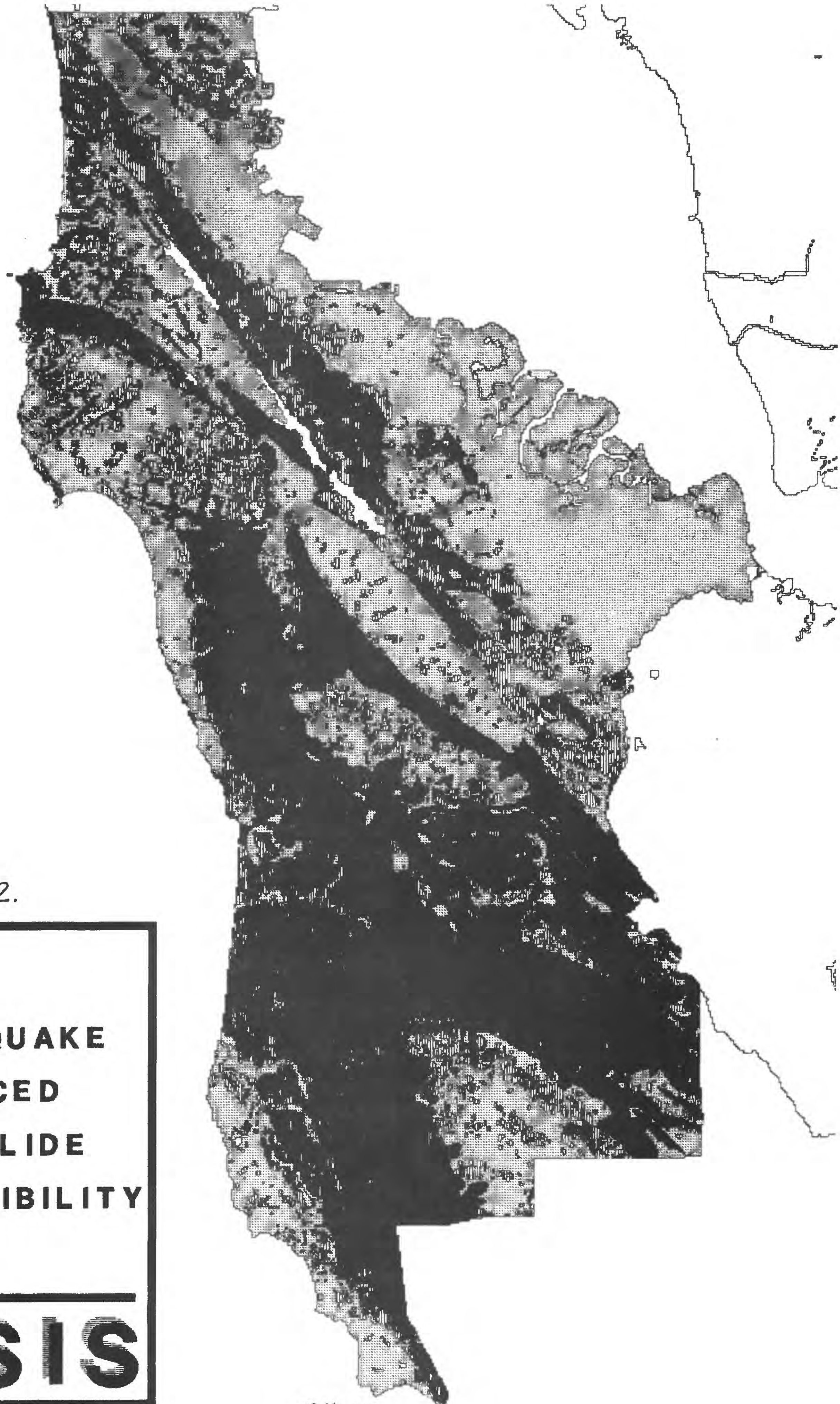


Figure 2.

EARTHQUAKE INDUCED LANDSLIDE SUSCEPTIBILITY

BASIS

LANDSLIDE OPPORTUNITY AND POTENTIAL

In order to produce a map of earthquake-induced landslide potential, landslide susceptibility can be combined with landslide opportunity in much the same way as with liquefaction potential (See Working Paper #4).

Landslide Opportunity

Landslide opportunity is a measure of the relative frequency of occurence of ground shaking intense enough to cause failure. It depends on both the recurrence intervals of faults and the distances from faults at which failure can occur for various magnitudes of earthquakes. The recurrence intervals that would be used are discussed in Working Papers #1 and #4. At the present time, no data is available for calculating distances from faults for failure. The formula probably would be similar to that used in calculating liquefaction opportunity. This analogy is not inappropriate because both are types of shaking-induced ground failure. The formula would be of the form:

Magnitude = a + b log (distance from fault for landsliding in kilometers)

Landslide Potential

For the purposes of compiling composite maximum damage maps, the entire Bay Area has the opportunity for failure, thus the susceptibility map will have the same lines as the landslide potential map.

As with the expected damage maps for earthquake ground shaking and for liquefaction potential, two landslide potential maps could be produced based on two different assumptions about landslide opportunity. For these maps, the susceptibility map and the opportunity maps would be combined to yield average annual damage. That damage would be obtained by multiplying two fractions:

- the landslide opportunity
- the likelihood of earthquake-induced failure for each susceptibility unit

A map of landslide potential is currently beyond the state-of-the-art for two reasons:

- a lack of information on opportunity
- no data on the percent of areas in each of the susceptibility categories that would fail in any single earthquake

In addition, an estimate of the extent of damage associated with each landslide potential unit becomes necessary when trying to combine ground shaking maps, landslide potential maps and other hazard maps into the type of earthquake hazard maps described in Working Paper #9.

REFERENCES

1. Brabb, E.E., personal communications in June 1979 (unpublished mapping).

2. Brabb, E.E., and Pampeyan, E.H., 1972, Preliminary Map of Landslide Deposits in San Mateo County, California, U.S. Geological Survey Miscellaneous Field Studies Map MF-344.

3. Brabb, E.E., Pampeyan, E.H., and Bonilla, M.G., 1972, Landslide Susceptibility in San Mateo County, California, U.S. Geological Survey Miscellaneous Field Studies Map MF-360.

4. Wieczorek, G., personel communication in October 1979, (Tables 4-6).

APPENDIX F

EARTHQUAKE MAPPING PROJECT - WORKING PAPER #6
TSUNAMI INUNDATION AREAS

The areas to be inundated by a tsunami were defined using the most complete source available as of March 1980, a U.S.G.S. miscellaneous field studies map (Reference 1). The other possible sources of this type of information, the Corps of Engineers and the HUD National Flood Insurance Program, currently do not have a more complete or usuable map. The series of detailed maps prepared by the Corps (Reference 2) have two major problems:

- o the maps cover those areas adjacent to San Francisco Bay and do not include those areas adjacent to the Pacific Ocean

- o the maps provide elevations of run-up only and no topographic maps or data with resolution of the detail needed (± 2 feet) are available to translate the elevations into map form.

By early 1981, better mapping should be completed and the possibility of replacing the tsunami inundation map reexamined.

Tsunami inundation areas can be assumed to be of approximately the same severity as San Francisco ground shaking intensity "A" for purposes of producing a composite maximum earthquake intensity map described in Working Paper #9. For purposes of compiling a composite map of risk of damage of earthquakes, one-fifth of the HUD/NFIP flood insurance rate for a comparable category can be used. That category, "V", is defined as "special flood hazard areas inundated by the 100-year flood as determined by approximate methods and that have additional hazards due to velocity (wave action)." One-fifth the rate can be used to account for the flood insurance rate being based on a 100-year flood and the tsunami map being based on a 500-year event.

Figure 1 illustrates this map file.

* * * * * * * * * * * * * *

REFERENCES

1. Ritter, J.R., and Dupre, W.R., 1972, Map Showing Areas of Potential Inundation by Tsunamis in the San Francisco Bay Region, California, U.S. Geological Survey Miscellaneous Field Studies Map MF-480.

2. Garcia, A.W., and Houston, J.R., 1975, Type 16 Flood Insurance Study: Tsunami Predictions for Monterey and San Francisco Bays and Puget Sound, Federal Insurance Administration Technical Report H-75-17, 19 pp. and maps.

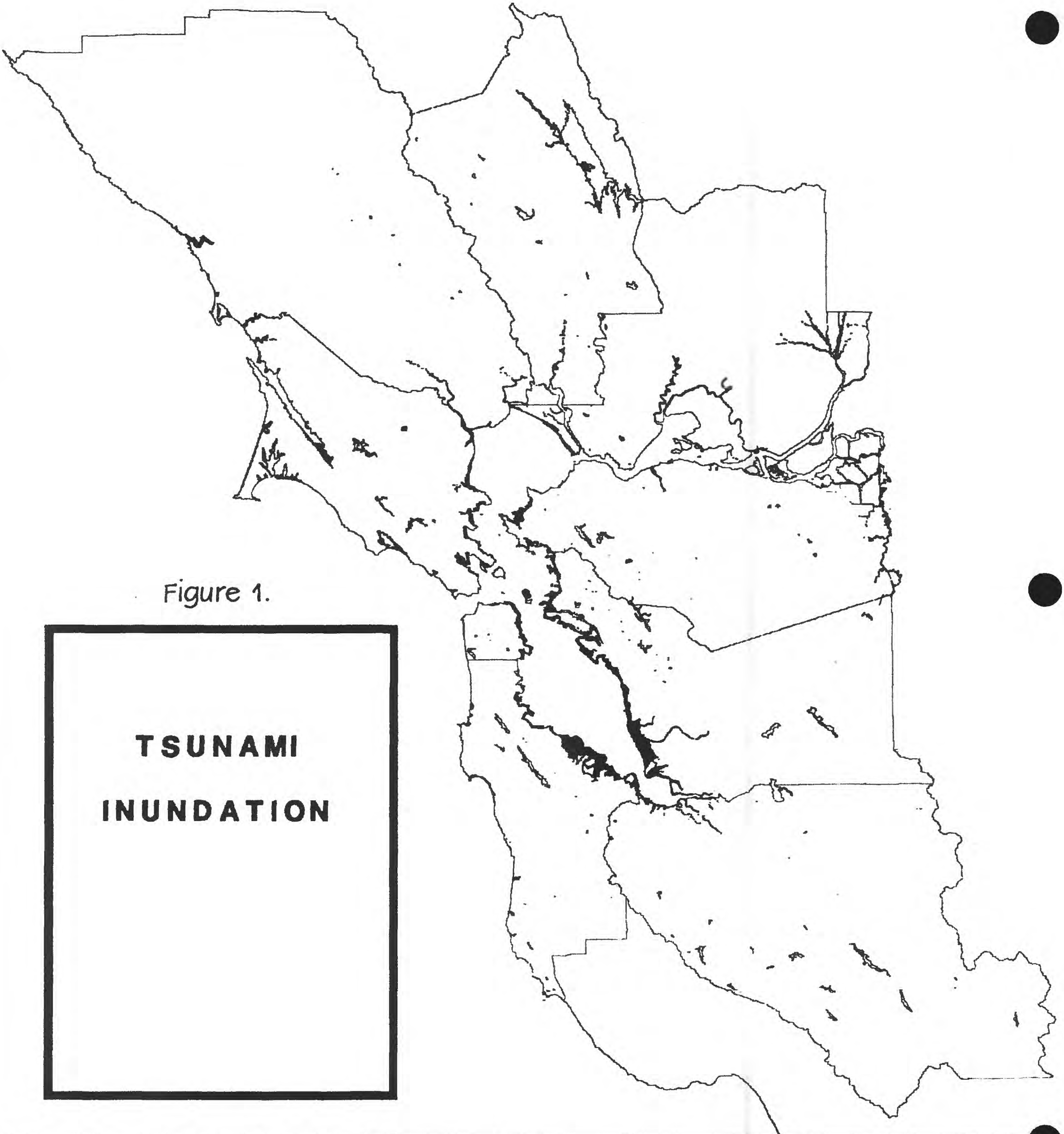


Figure 1.

BASIS BAY AREA SPATIAL INFORMATION SYSTEM

APPENDIX G

EARTHQUAKE MAPPING PROJECT - WORKING PAPER #7
DAM INUNDATION AREAS

INTRODUCTION

This paper documents the way in which dam inundation maps and associated data have been used in the ABAG/USGS earthquake mapping project.

SOURCE OF MAPS

The California Dam Safety Act (Section 8589.5 of the Government Code) requires dam owners to submit inundation maps to the California Office of Emergency Services (OES) for those dams or reservoirs whose total failure would cause injury or loss of life. The State Department of Water Resources established the criteria used for producing these maps and reviewed the completed maps for compliance with the criteria. These maps have been collected for the 134 dams and reservoirs affecting people in the region and digitized to produce a computer file. In the digitizing process, the dam or dams inundating any given area were recorded in addition to whether or not a particular area would be inundated.

Table 1, below, lists the various dams and reservoirs in the region by county and Figure 1 illustrates the file.

WAYS IN WHICH DATA ARE USED

Various tabulations can be run to provide information on the amount of area to be inundated by each failure, (both by census tract and jurisdiction) for the region. In addition, an attempt can be made to disaggregate census-derived population data using land use data to provide the population affected by each dam for San Mateo County only. See Working Paper #10.

Because the effects of dam failure overshadow other earthquake concerns and because the probability of failure is so low, the dam inundation maps cannot be a part of any final composite maps produced. However, a hypothetical maximum intensity map has been produced that includes dam inundation areas for comparative purposes. See Working Paper #9 for more information.

TABLE 1: DAMS AND RESERVOIRS WHOSE FAILURE WOULD

AFFECT PEOPLE IN THE SAN FRANCISCO BAY REGION, CALIFORNIA

Alameda County

Almond	Claremont	James H. Turner	Seneca	Upper San Leandro
Berryman	Cull Creek	Lake Temescal	South	U.S.L. Clrwell. #1
Bethany Forebay	Del Valle	Lower Edwards	Summit	U.S.L. Clrwell. #2
Calaveras	Dingee	Patterson	39th Avenue	Ward Creek
Central	Dunsmuir	Piedmont	Three J Ranch	
Chabot	Estates	San Lorenzo Creek	Upper Edwards	

TOTAL = 28

Contra Costa County

Antioch Res.	Clifton Court FB	Lafayette	Martinez	San Pablo Clrwell.
Argyle No. 2	Contra Loma	Lake Orinda	Moraga	Sobrante Clrwell.
Briones	Danville	Leland	North	Walnut Creek Clrwell.
C.L. Tilden Park	Deer Creek	Maloney	Pine Creek	Schapiro
(Lake Anza)	Dry Creek	Marsh Creek	San Pablo	Fay Hill

with

Summit (Alameda Co.)
Bethany Forebay (Alameda Co.)

TOTAL = 24 + 2

Table 1 - (Continued)

Marin County

Nicasio	Novato Creek	Peters	Phoenix Lake

TOTAL = 4

Napa County

Bell Canyon	Kimball Creek	Lake Marie	Orville (Silverado)
Conn Creek	Lake Camille	Milliken	Rector Creek
Deer Lake (Silverado)	Lake Curry	Monticello	St. Helene Lower
Henne (Silverado)	Lake Cynthia	Newton (Silverado)	St. Helena Upper

with

Summit Res. (Solano Co.)

TOTAL = 16 + 1

San Francisco

Stanford Heights	Sunset S. Basin	Univ. Mound N
Sunset N Basin	Sutro Reservoir	Univ. Mound S

TOTAL = 6

San Mateo

Bear Gulch	Emerald Lake Lower	Notre Dame	San Andreas
Burlingame	Laurel Creek	Pilarcitos	Searsville
Crocker	Lower Crystal Spr.	Rickey & West	

with

Felt Lake (Santa Clara Co.)

TOTAL = 11 + 1

Table 1 (Continued)

Santa Clara County

Almaden	Columbine	Guadalupe	Lower Howell	Upper Howell
Almaden Valley	Coyote (on Anderson)	Kelly Cabin Can.	Murry	Uvas
Austrian	Coyote Percol.	Lagunita	North Fork	Vasona Percol.
Calero	Ed R. Levin	Lake Ranch	Rinconada Res.	Williams
Cherry Flat	Elmer J. Chesbro	Leroy Anderson	San Felipe Ranch	
Coit	Felt Lake	Lexington	Stevens Creek	

with

James H. Turner (Alameda Co.)

TOTAL = 28 + 1

Solano County

Fleming Hill No. 2	Lake Frey	Lake Madigan	Pine Lake	Swanzy Lake
Lake Chabot	Lake Herman	Pennsylvania Creek	Summit Reservoir	

with

Lake Curry (Napa Co.)
Monticello (Napa Co.)

TOTAL = 9 + 2

Sonoma County

Fern Lake	Lagunita	Matanzas Creek	Suttenfield
Fountaingrove	Lake Ralphine	Refvem No. 1	

with

Coyote (Mendocino Co.)

TOTAL = 7 + 1

GRAND TOTAL

TOTAL = 133 + 1 = 134

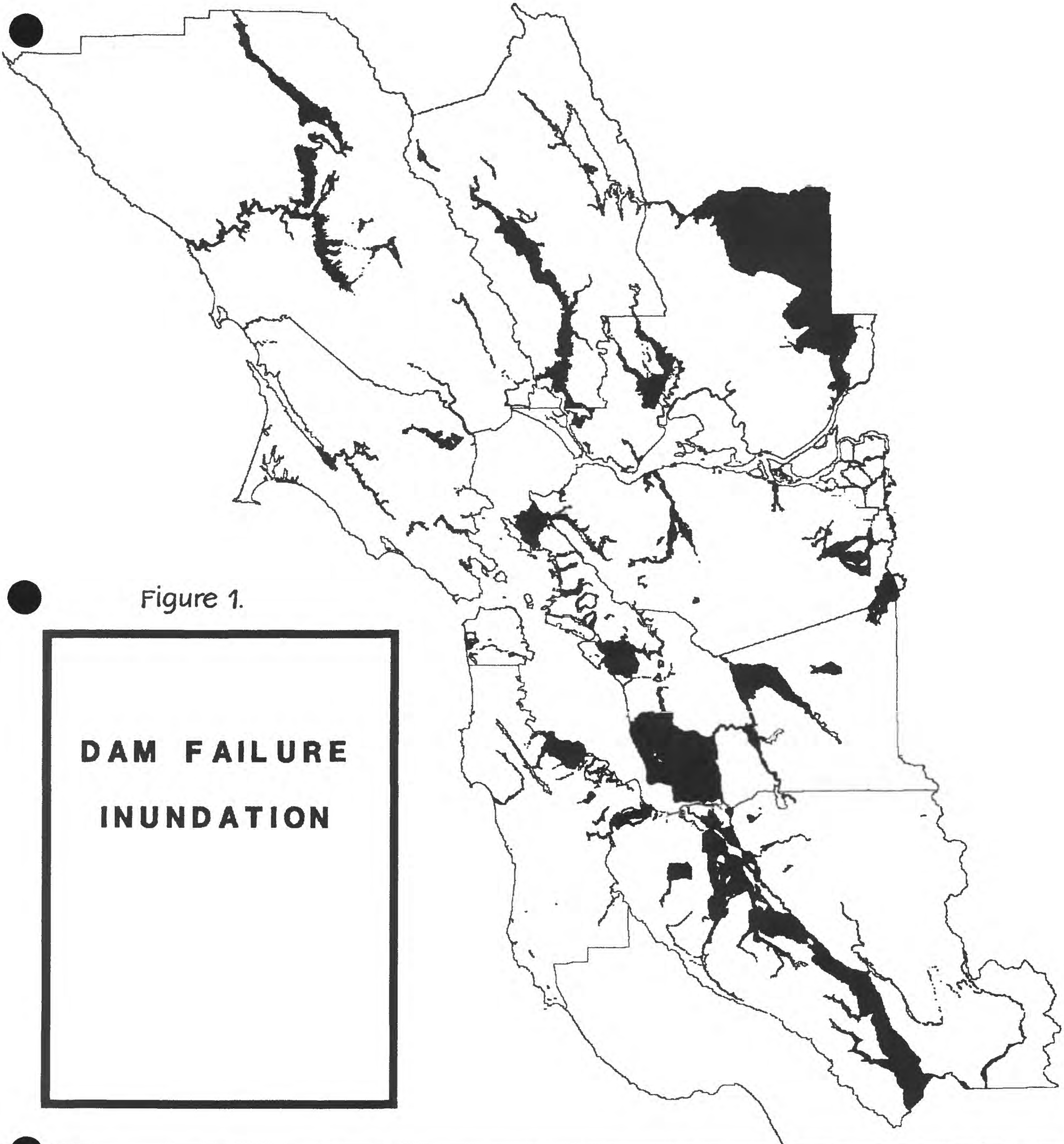


Figure 1.

DAM FAILURE INUNDATION

BASIS BAY AREA SPATIAL INFORMATION SYSTEM

APPENDIX H

EARTHQUAKE MAPPING PROJECT - WORKING PAPER #8

EARTHQUAKE MAP APPLICATIONS FOR AUTOMATED ENVIRONMENTAL IMPACT ASSESSMENT

INTRODUCTION

Large fiscal constraints on cities and counties have been present since the passage of California's Proposition 13 and are uncertain for the future due to the Gann Initiative. These constraints have led to a growing emphasis in planning through dealing with individual projects rather than by producing or updating the local general plan.

Therefore, a pressing need exists to make the earthquake map information in this project easily and cheaply accessible as background information on individual projects, even if only to flag when further study should be required.

In addition, ABAG programs are currently working together to create an Automated Regional Environmental Assessment (AREA) capability. Consequently, it is appropriate for the uses of earthquake information in this system to be explored.

This working paper describes possible earthquake map applications for automated environmental impact assessment. It is the eighth in a series of working papers being prepared on the ABAG/USGS earthquake mapping project and the first of three working papers focusing on map applications.

OVERVIEW

AREA will produce a background document for development proposals that can be incorporated into the Environment Impact Report (EIR). This document, as currently envisioned, will have ten parts, each focusing on a different environmental concern. The section dealing with earthquakes is entitled "Geology and Soils -- Hazards and Resources". Other parts are concerned with hydrology and flooding, noise, fire, and other issues. Each part, including the one on geology and soils, contains three sections -- setting, impacts, and mitigation.

Most of the information in the sections on settings and impacts will be displayed in the form of lists or tables rather than as text. Advantages of this format include the use of less space, ease in production by a computer, and ease in access to information by users. The mitigation section, however, contain a list of conditions that a city or county require of the developer.

The AREA display has at least one obvious limitation. The type of geologic and soils maps in the system are often not adequate for site-specific analysis. Therefore, the display and mitigation measures should serve as background information. Requests for further geotechnical and engineering study may be common conditions specified in the mitigation section.

The remainder of this paper will examine the contents of each of these three sections.

SETTING SECTION

The setting section contains information on five data items:

- o topography - elevation and slope
- o faults - study zones and distances to faults
- o landslides - mapped from air photos and identified in the field or from local government files
- o geologic materials - area of each type
- o soil associations - area of each type and four commonly used characteristics

Map files of all of these data items except soils were compiled (at least for San Mateo County) as part of this project. The display is provided as Table 1-A.

Topography

The topography file in BASIS covers San Mateo County at the present time, but will cover 15 additional quadrangles by the end of 1980. It was obtained in tape form from a digital terrain model produced by the U.S. Geological Survey. The model generates elevation data directly from aerial photographs; it does not use standard topographic maps as an intermediate step. For San Mateo County, the model produced data on a 30 meter grid which was then averaged to produce data to be stored on BASIS's 100-meter grid. The ABAG program used to produce slope calculates the maximum slope by using the maximum change in elevation between any given cell and the eight surrounding cells, allowing for the longer distance between the cell and those at the four diagonal corners. Other ways of producing slope files could be produced at the request of potential users.

The elevation data supplied in the display consists of:

- o the maximum elevation value (in meters) assigned to any hectare in the study area (itself an average of the elevation in the hectare cell);
- o the minimum elevation value (in meters); and

TABLE 1-A

****

* AUTOMATED REGIONAL ENVIRONMENTAL ASSESSMENT *

****

GEOLOGY AND SOILS - HAZARDS AND RESOURCES

SETTING

TOPOGRAPHY

ELEVATION (IN METERS)	
MAXIMUM	-----
MINIMUM	-----
AVERAGE	-----

PERCENT SLOPE	
MAXIMUM	-----
MINIMUM	-----
AREA (IN HECTARES)	
0-5%	-----
5-15%	-----
15-30%	-----
30-50%	-----
50-70%	-----
70-100%	-----
100%+	-----

FAULTS

FAULT STUDY ZONE?	-----
AVE. DISTANCE (IN KM) TO	
MAJOR ACTIVE FAULTS	
SAN ANDREAS	-----
CALAVERAS	-----
SAN GREGORIO	-----
HAYWARD	-----
CONCORD/GRN VAL.	-----
HEALDSBURG/ROD. CR.	-----
MAACAMA	-----

LANDSLIDES

AREA (IN HECTARES)	
ON AIR PHOTOS	-----
FROM FIELD	-----
FROM LOCAL FILES	-----
TOTAL OF ABOVE	-----

GEOLOGIC MATERIALS

AREA (IN HECTARES)

XXXXXXXXXXXXXX	-----	XXXXXXXXXXXXXX	-----	XXXXXXXXXXXXXX	-----
XXXXXXXXXXXXXX	-----	XXXXXXXXXXXXXX	-----	XXXXXXXXXXXXXX	-----
XXXXXXXXXXXXXX	-----	XXXXXXXXXXXXXX	-----	XXXXXXXXXXXXXX	-----
XXXXXXXXXXXXXX	-----	XXXXXXXXXXXXXX	-----	XXXXXXXXXXXXXX	-----

SOIL ASSOCIATIONS

AREA (HECTARES)	TYPE	SHRINK/ SWELL	PERMEA- BILITY	EROSION POTENTIAL	PRIME AG LAND
-----	XXXXXXXXXXXXXX	X	X	X	X
-----	XXXXXXXXXXXXXX	X	X	X	X
-----	XXXXXXXXXXXXXX	X	X	X	X
-----	XXXXXXXXXXXXXX	X	X	X	X
-----	XXXXXXXXXXXXXX	X	X	X	X
-----	XXXXXXXXXXXXXX	X	X	X	X

o an average elevation (in meters) calculated by adding the elevation values for all the cells in the study area and then dividing by the number of those cells.

The percent slope data consists of similar maximum and minimum values. In addition, instead of providing an average value, the slope values in the cells are grouped into seven categories and the area in each category calculated by summing the number of cells falling in each of those categories. The slope categories may be changed or reduced in number to suit different users.

Faults

The region-wide fault file in BASIS was obtained in large part by digitizing the 7-1/2-minute quadrangles of Special Studies Zones produced by the State Geologist in compliance with the Alquist-Priolo Special Studies Zones Act. Fault traces have been included for additional faults that are not included in the Special Studies Zones program. For additional information, refer to Working Paper #1.

The display shows the reviewer whether or not the study area falls within an Alquist-Priolo Study Zone. Additional local study zones may be added; those used by Santa Clara County are included.

Information is then provided on the distance from the centroid of the site to seven major fault systems in the Bay Area. The straight-line distance is calculated to the nearest tenth of a kilometer and assumes the fault trace is 0.2 kilometers (approximately 1/8 mile) within the study zone.

Landslides

The data in the landslide file currently covers only San Mateo County. As with the topography information, it will cover 15 additional 7-1/2-minute quadrangles by the end of 1980. It was obtained by digitizing a map of San Mateo County landslides at a scale of 1:62,500 (Reference 1). This U.S. Geological Survey compilation for San Mateo County contains data on landslides based on aerial photographs, field observations, and local files of soil and geologic studies for development projects and of road maintenance records. When a hectare cell has been mapped as being a landslide by more than one source, the most specific reference is cited. Therefore, the information that a landslide has been mapped from local files takes precedence over the information that it was observed in the field, which in turn takes precedence over the information that it was observed as an anomaly on an aerial photograph. This categorization should enable local data to be added to the landslide file with a minimum of difficulty.

The display shows the total number of cells falling in each of these three landslide categories and the total number of cells depicted as landslides, regardless of category. No information on degree of activity of the landslides is provided, although those observed in the field or from local files can be assumed to have moved historically.

Geologic Materials

The region-wide geology file in BASIS is a composite of three interim files, or maps:

- o a geologic map of San Mateo County prepared in 1979 by Earl Brabb and Earl Pampeyan of the U.S. Geological Survey but not published (Reference 2)
- o the flatlands deposits map of the nine Bay Area counties (Reference 3)
- o other geologic mapping for the Bay Area outside of San Mateo County, largely at a scale of 1:62,500 prepared by USGS and generalized to four bedrock units that was digitized for an earlier ABAG project (see References of Reference 4 for more information).

The file was compiled by using the information in the following order of priority:

- o in San Mateo County, the map from Reference 1 was used;
- o in the other eight counties, the flatlands maps from Reference 2 were used except when noted as "bedrock";
- o in these "bedrock" areas, the generalized geologic mapping cited in Reference 4 were used.

Further information on each of the 66 geologic units is contained on the original digitized maps (References 2-4).

The AREA display lists each of the map categories that appear in the study area and the total number of hectare grid cells associated with each. The sheet has room for displaying twelve geology categories.

Soil Associations

The BASIS soils file, although complete for all nine counties, is based on a compilation of county soil surveys prepared in 1965 as part of a joint ABAG/U.S. Soil Conservation Service project. As with the county surveys, soil types are correlated with several engineering and planning properties, including shrink/swell behavior, permeability, erosion potential, and extent of prime agricultural land. However, the original maps were generalized and soils with relatively similar properties combined into soils associations. The data on this file, although suitable for general planning purposes, should not be relied upon for special ordinance enforcement or implementation. Jurisdictions requiring more detailed soils data will need to upgrade this file within their area of interest.

The display sheet lists information from the soils file in table form. It lists all soils occuring within the study area and the total number of hectare cells within each category. In addition, the four most commonly used properties are listed for each soil as defined by SCS:

o shrink/swell -- low (L), moderate (M), and high (H)

o permeability -- very rapid or rapid (H), moderately rapid, moderate or moderately slow (M), slow (L), and very slow (VL)

o erosion potential -- none (VL), slight (L), moderate (M), severe (H), and very severe (VH);

o prime agricultural land -- Class I or II soils (YES), and Class III or larger soils (NO). (Other prime agricultural soils data may be available from the State of California within two to three years.)

IMPACTS SECTION

This section to contains information on:

o rainfall-induced landslide susceptibility

o earthquake-induced landslide susceptibility

o liquefaction potential

o tsunami inundation areas

o dam failure inundation areas

o maximum earthquake intensities

o earthquake intensity damage and risk

The display is provided as Table 1-B. All of the map files that provide this information were compiled as part of this project.

Rainfall-Induced Landslide Susceptibility

This BASIS file was compiled by combining the files of geology, landslides, and slope described in the previous section. The criteria used for combining these maps are explained in Working Paper #5. Because computer files on landslides and slope currently are available only for San Mateo County, this composite file also is available only for that County. However, data may be available for 15 additional 7-1/2-minute quadrangles by early 1981 if the method for preparing a susceptibility map developed for San Mateo County proves to be applicable or if another suitable method is developed.

TABLE 1-B

GEOLOGY AND SOILS - HAZARDS AND RESOURCES

IMPACTS

SLOPE STABILITY

RAINFALL-INDUCED LANDSLIDE SUSCEPTIBILITY AREA (IN HECTARES)

STABLE	-----
*	-----
*	-----
TO	-----
*	-----
*	-----
UNSTABLE	-----

EARTHQUAKE-INDUCED LANDSLIDE SUSCEPTIBILITY AREA (IN HECTARES)

STABLE	-----
*	-----
*	-----
UNSTABLE	-----

TSUNAMI INUNDATION AREAS

AREA (IN HECTARES

INSIDE	-----
OUTSIDE	-----

LIQUEFACTION POTENTIAL

AREA (IN HECTARES)

LOW	-----
*	-----
TO	-----
*	-----
*	-----
HIGH	-----

DAM FAILURE INUNDATION AREAS

DAM	AREA
XXXXXXXXXXXXXX	-----
XXXXXXXXXXXXXX	-----
XXXXXXXXXXXXXX	-----
XXXXXXXXXXXXXX	-----
XXXXXXXXXXXXXX	-----

MAXIMUM EARTHQUAKE INTENSITY

AREA (IN HECTARES)

A (4)-VERY VIOLENT	-----
B (3)-VIOLENT	-----
C (2)-VERY STRONG	-----
D (1)-STRONG	-----
E (0)-WEAK	-----
NEGLIGIBLE	-----

EARTHQUAKE INTENSITY -- DAMAGE AND RISK

FAULT	MAXIMUM MAGNITUDE	RECURRENCE (IN YEARS)	AVE. INTENSITY FOR AVE. ROCK
SAN ANDREAS	XXXXXX	XXXXXX	-----
CALAVERAS	XXXXXX	XXXXXX	-----
SAN GREGORIO	XXXXXX	XXXXXX	-----
HAYWARD	XXXXXX	XXXXXX	-----
CONCORD/GRN. VAL.	XXXXXX	XXXXXX	-----
HEALDSBURG/ROD. CR.	XXXXXX	XXXXXX	-----
MAACAMA	XXXXXX	XXXXXX	-----

INTENSITY INCREASES (OR DECREASES) FOR GEOLOGIC MATERIALS ON SITE

XXXXXXXXXXX	-----	XXXXXXXXXXX	-----	XXXXXXXXXXX	-----
XXXXXXXXXXX	-----	XXXXXXXXXXX	-----	XXXXXXXXXXX	-----
XXXXXXXXXXX	-----	XXXXXXXXXXX	-----	XXXXXXXXXXX	-----
XXXXXXXXXXX	-----	XXXXXXXXXXX	-----	XXXXXXXXXXX	-----

****EXPECTED DAMAGE (PER EVENT) AT VARIOUS INTENSITIES FOR ****
BUILDING TYPES PROPOSED FOR SITE

INTENSITY	BUILDING TYPES		
	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXXX
A (4)	-----%	-----%	-----%
B (3)	-----%	-----%	-----%
C (2)	-----%	-----%	-----%
D (1)	-----%	-----%	-----%
E (0)	-----%	-----%	-----%
<E	-----%	-----%	-----%

The AREA display provides data on the total number of hectare cells occurring in each of seven categories, ranging from stable to unstable.

Earthquake-Induced Landslide Susceptibility

As is the companion landslide susceptibility file, this computer file is a combination of the files of geology, landslides, and slope. The criteria used for combining these maps also are explained in Working Paper #5. It, too, is available only for San Mateo County but will become available for 15 additional quadrangles by early 1981 if problems with transtability can be solved.

The AREA display provides data on the total number of hectare cells occurring in each of four categories, ranging from stable to unstable.

Liquefaction Potential

Data on liquefaction potential was obtained by combining the files on faults and geology in the manner described in Working Paper #4. This information is available for all nine Bay Area counties.

The display provides data on the total number of hectare cells in each of six categories, ranging from low to high. It must be emphasized that the areas of "high" potential are only relatively high and are not as potentially damaging as those for other earthquake hazards.

Tsunami Inundation Areas

The data in this region-wide BASIS file was obtained from a U.S. Geological Survey Map (Reference 5). The display indicates the area (hectare cells) within and outside of the hazard area. Additional information on the file is contained in Working Paper #6.

Dam Failure Inundation Areas

The data in this region-wide computer file was obtained from maps drafted as part of the California Dam Safety Act. Additional information on the file is contained in Working Paper #7.

The AREA display will indicate which dams would flood the study area, should they fail, as well as the total number of hectare cells within the study area which would be inundated by each dam. The display has the capability of listing five separate dams. If no dams will inundate the area, the sheet will read "NONE".

Maximum Earthquake Intensities

Data on maximum earthquake intensity was obtained by combining the files on faults and geology in the manner described in Working Papers #1 - #2. The file is complete for all nine Bay Area counties, although the data is more detailed in areas of bedrock in San Mateo County because of the more complete geology file in that County.

The display indicates the number of hectare cells falling in each of six intensity categories ranging from very violent to negligible. The display uses the San Francisco intensity scale. A correspondence table between this scale and the modified Mercali intensity scale is provided in Working Paper #2.

Earthquake Intensity -- Damage and Risk

The bottom half of the AREA display sheet on impacts deals with information on damage and risk from earthquake groundshaking. Working Papers #1 - #3 focus on the method for displaying this type of information in map form. However, for specific sites much more detailed data on hypothetical earthquakes is more useful than the composite maps described. The basic assumptions are the same, however.

First, the display lists information on earthquakes that would effect the site by the fault on which they would originate. Seven faults are listed, together with the maximum magnitude event on each and the recurrence interval of the event (in years). See Working Paper #1 for additional background information. In addition, the intensity to be expected at the site for average rock is calculated by using the distance betweeen the centroid of the site and each fault in the attenuation formula for Franciscan Assemblage discussed in Working Paper #2. Again, this intensity is expressed in the San Francisco scale.

Because the intensity at a site also depends on the rock unit, the appropriate amount that the intensity should be modified for each geologic material at the site is then listed. The increases and decreases are provided for up to 16 materials as numbers, not letters. The necessary intensity modifications can be performed by converting San Francisco intensities A through E to 4 through 0, adding or subtracting these numbers, and then converting 4-0 back to A-E.

Working Paper #3 describes various data available or damage to be expected in various intensities for various magnitudes of earthquakes. This data is provided automatically for up to three building types proposed in a study area. The next step, that of converting this damage into present value of loss for all earthquakes, has not been provided for the study area because of the need to view this data in the context of the surrounding area, something best provided in map form.

MITIGATION SECTION

The contents of this section require working with a city or county to determine, for example:

- o conditions that would require further geotechnical investigation

TABLE 1-C

GEOLOGY AND SOILS - HAZARDS AND RESOURCES

MITIGATION

***THE SITE REQUIRES FURTHER GEOTECHNICAL INVESTIGATION AS PART OF THIS EIR.

(PRINT IF ANY OF THE FOLLOWING EXIST:)

1. LANDSLIDE RANKING IS GREATER THAN -----.
2. IF SLOPE IS GREATER THAN -----%.
3. IF SITE HAS AN EROSION CATEGORY OF ----- OR A SHRINK SWELL CATEGORY OF -----.
4. IF WITHIN AN ALQUIST-PRIOLO SPECIAL STUDY ZONE.
5. IF THE SITE MAY HAVE ----- LIQUEFACTION POTENTIAL.

***ADDITIONAL STRUCTURAL CONSIDERATIONS, GREATER THAN THOSE PROVIDED IN THE UNIFORM BUILDING CODE SECTION ON EARTHQUAKES, ARE REQUIRED.

(PRINT ONLY IF SITE HAS MAXIMUM EARTHQUAKE INTENSITY OF GREATER THAN -----.)

***THE LOCAL FIRE, POLICE, AND EMERGENCY SERVICE STAFF SHOULD REVIEW THE SITE AND BUILDING PLACES OF THE PROJECT TO ENSURE ADEQUATE ACCESS AND EGRESS IS PROVIDED.

(PRINT ONLY IF SITE IS WITHIN ANY OF THE FOLLOWING:)

1. A DAM INUNDATION AREA.
2. A TSUNAMI INUNDATION AREA.
3. A ---- OR LARGER SLOPE STABILITY CATEGORY.
4. A MAXIMUM INTENSITY CATEGORY OF GREATER THAN -----.

- o city policies that trigger certain ordinances based on site conditions

- o conditions that require fire, police, or emergency service staff review

Examples of mitigation measures that might be printed are provided in Table 1-C.

USERS MANUAL

ABAG plans to prepare a user's manual for the entire AREA display. The part on geology and soils would provide information on the sources of the information contained in the display. The manual therefore will contain information from Working Papers #1 - #7, as well as from this paper.

AN EXAMPLE

In order to illustrate the way a final display might appear, actual BASIS data was obtained in table form for the hectares in a site in San Mateo County and manually rearranged to fit in the proposed format. The display is included as Table 2, below.

TABLE 2-A

```
**************************************************
* AUTOMATED REGIONAL ENVIRONMENTAL ASSESSMENT *
**************************************************
   GEOLOGY AND SOILS - HAZARDS AND RESOURCES
                  -------
                  SETTING
                  -------
```

TOPOGRAPHY

ELEVATION (IN METERS)

MAXIMUM	1
MINIMUM	1
AVERAGE	1

PERCENT SLOPE

MAXIMUM	0
MINIMUM	0

AREA (IN HECTARES)

0-5%	61
5-15%	0
15-30%	0
30-50%	0
50-70%	0
70-100%	0
100%+	0

FAULTS

FAULT STUDY ZONE? NO

AVE. DISTANCE (IN KM) TO

MAJOR ACTIVE FAULTS

SAN ANDREAS	14
CALAVERAS	28
SAN GREGORIO	23
HAYWARD	19
CONCORD/GRN VAL.	32
HEALDSBURG/ROD. CR.	79
MAACAMA	128

LANDSLIDES

AREA (IN HECTARES)

ON AIR PHOTOS	0
FROM FIELD	0
FROM LOCAL FILES	0
TOTAL OF ABOVE	0

GEOLOGIC MATERIALS

AREA (IN HECTARES)

BAY MUD	24	ARTIFICIAL FILL	37

SOIL ASSOCIATIONS

AREA (HECTARES)	TYPE	SHRINK/ SWELL	PERMEA- BILITY	EROSION POTENTIAL	PRIME AG LAND
38	REYES-ALVISO	M	M	VL	NO
23	TIDAL FLATS	M	H	VL	NO

GEOLOGY AND SOILS - HAZARDS AND RESOURCES

IMPACTS

SLOPE STABILITY

RAINFALL-INDUCED LANDSLIDE SUSCEPTIBILITY

AREA (IN HECTARES)

STABLE	61
*	0
*	0
TO	0
*	0
*	0
UNSTABLE	0

EARTHQUAKE-INDUCED LANDSLIDE SUSCEPTIBILITY

AREA (IN HECTARES)

STABLE	61
*	0
*	0
UNSTABLE	0

TSUNAMI INUNDATION AREAS

AREA (IN HECTARES

INSIDE	0
OUTSIDE	61

LIQUEFACTION POTENTIAL

AREA (IN HECTARES)

LOW	0
*	0
TO	37
*	0
*	24
HIGH	0

DAM FAILURE INUNDATION AREAS

DAM	AREA
NONE	

MAXIMUM EARTHQUAKE INTENSITY

AREA (IN HECTARES)

A (4)-VERY VIOLENT	0
B (3)-VIOLENT	24
C (2)-VERY STRONG	37
D (1)-STRONG	0
E (0)-WEAK	0
NEGLIGIBLE	0

EARTHQUAKE INTENSITY -- DAMAGE AND RISK

FAULT	MAXIMUM MAGNITUDE	RECURRENCE (IN YEARS)	AVE. INTENSITY FOR AVE. ROCK
SAN ANDREAS	8.4(7.2)	1000(100)	E
CALAVERAS	7.3(6.7)	300(100)	E
SAN GREGORIO	7.1	200	E
HAYWARD	6.9	200	E
CONCORD/GRN. VAL.	7.0	200	E
HEALDSBURG/ROD. CR.	6.8	200	E
MAACAMA	7.1	300	E

INTENSITY INCREASES (OR DECREASES) FOR GEOLOGIC MATERIALS ON SITE

BAY MUD 2.9 ARTIFICIAL FILL 1.5

****EXPECTED DAMAGE (PER EVENT) AT VARIOUS INTENSITIES FOR ****
BUILDING TYPES PROPOSED FOR SITE

INTENSITY	BUILDING TYPES
	WOOD-FRAME
A (4)	16 %
B (3)	12 %
C (2)	5 %
D (1)	2 %
E (0)	0.2%
<E	0 %

TABLE 2-C

GEOLOGY AND SOILS - HAZARDS AND RESOURCES

MITIGATION

***THE SITE REQUIRES FURTHER GEOTECHNICAL INVESTIGATION AS PART OF THIS EIR.

1. THE THE SITE MAY HAVE MODERATELY HIGH LIQUEFACTION POTENTIAL.
2. THE SITE IS LOCATED ON BAY MUD.

***ADDITIONAL STRUCTURAL CONSIDERATIONS, GREATER THAN THOSE PROVIDED IN THE UNIFORM BUILDING CODE SECTION ON EARTHQUAKES, ARE REQUIRED.

1. THE SITE HAS A MAXIMUM EARTHQUAKE INTENSITY OF B (VIOLENT).

***THE LOCAL FIRE, POLICE, AND EMERGENCY SERVICE STAFF SHOULD REVIEW THE SITE AND BUILDING PLACES OF THE PROJECT TO ENSURE ADEQUATE ACRESS AND EGRESS IS PROVIDED.

1. THE SITE HAS A MAXIMUM EARTHQUAKE INTENSITY OF B (VIOLENT).

REFERENCES

1. Brabb, E. E., and Pampeyan, E. H., 1972, Preliminary Map of Landslide Deposits in San Mateo County, California, U.S. Geological Survey Miscellaneous Field Studies Map MF-344.

2. Brabb, E. E., personal communication in June 1979 (unpublished mapping).

3. Burke, D. B., Helley, E. J., Lajoie, K. R., Tinsley, J. C., and Weber, G. E., 1979, Geologic Map of the Flatlands Deposits of the San Francisco Bay Region: U.S. Geological Survey Professional Paper 944, 88p.

4. Perkins, J. B., 1978, Earthquake Intensity and Expected Cost in the San Francisco Bay Area, ABAG, 12 p.

5. Ritter, J. R., and Dupre, W. R., 1972, Map Showing Potential Inundation by Tsunamis in the San Francisco Bay Region, California, U.S. Geological Survey Miscellaneous Field Studies Map MF-480.

APPENDIX I

EARTHQUAKE MAPPING PROJECT - WORKING PAPER #9

EARTHQUAKE MAP APPLICATIONS FOR COMPOSITE EARTHQUAKE HAZARD MAPPING

INTRODUCTION

Separate maps can be produced illustrating the hazards associated with individual earthquake-related problems. Sometimes it is valuable, however, to produce a composite map showing the combined results of those individual hazards. This paper explores the feasibility of producing several types of composite maps. In addition, three sample composite maps produced for San Mateo County are described. This working paper is the ninth in a series of working papers prepared on the ABAG/USGS earthquake mapping project and the second working paper focusing on map applications.

DISCUSSION OF COMPOSITE MAPPING ISSUES

Different procedures exist for preparing composite maps. One major difference in those procedures is the method used to combine the maps. One method is to use the economic techniques of benefit-cost analysis to weight the relative importance of each map according to relative cost. Another method might be to overlay the maps using a set of criteria agreed upon by a group of experts in the field relying upon their background and expertise. More information on the use of dollars to combine maps is contained in USGS Professional Paper 945 (Reference 1).

If one uses cost, there are several issues that must be resolved. First, calculating the impact of hazard mitigation on risk can complicate any mapping procedure. For example, the expected cost of damages associated with earthquakes should be reduced since both a new California law (the Alquist-Priolo Special Studies Zones Act) is designed to prohibit most building of structures on or near active faults and counties now require developers to have geotechnical studies performed to reduce potential landslide damage. At the same time, however, these regulations are a cost to developers that increase the initial cost of housing (or other buildings) to consumers. (See Reference 2 for a discussion of these costs.) Therefore, the particular mix of damage costs and mitigation costs to be used in the analysis must be decided. This decision is related to the ultimate use of the information.

A second issue involves the type of damages to be included in the analysis. Damage to buildings is the simplest to estimate. Other damages could be examined, however, including losses to building contents, lifelines and other infrastructure. Losses to water systems may result in extensive fire damages. Secondary losses such as social disruption, loss of work, injury and even deaths can be included. Traffic engineers routinely assign a dollar value to human life. Such a value could be assigned to loss of life in earthquakes, yet this concept is disturbing to many people. Better still, a separate map could be produced showing expected numbers of lives to be lost. Virtually no data is available on the spatial distribution of these other losses in past earthquakes.

Finally, it again must be emphasized that the hazard or risk of damage maps produced show only those hazards inherent in a particular geographic location. No data on the existing or potential land use or building type for any location is included in the analysis. The ultimate use of the maps may be either to examine existing development or to analyze the hazards for various hypothetical new developments or development patterns. These uses also can affect the way in which the hazard maps are combined and damages are estimated.

SAMPLE COMPOSITE MAPS FOR SAN MATEO COUNTY

Two types of composite earthquake hazard maps have been produced for San Mateo County to illustrate the technique of combining maps. The first type of map uses damages expected from various hazards in an earthquake to weight the hazard maps and produce a composite maximum earthquake damage map. Those hazard maps included are:

- o fault surface rupture
- o maximum ground shaking intensity
- o liquefaction susceptibility
- o earthquake-induced landslide susceptibility
- o tsunami inundation
- o dam failure inundation

Because dams are very unlikely to fail in an earthquake and because the damages associated with failure are so large, two sample maps have been produced, one with and one without dam failure inundation areas included.

The second type of map uses the damages expected in an event, multiplies those values by the frequency with which they can be expected to occur, and discounts* the costs to their present value. The hazard maps combined include:

- o fault surface rupture
- o risk of ground shaking damage
- o liquefaction potential
- o an estimate of earthquake-induced landslide potential
- o tsunami inundation

Dam failure inundation is not included, again because of the low probability of failure.

*Discounting is explained in Working Paper #3.

For all three maps, economic losses are used as a basis for comparing and combining the individual hazard maps. Only information on damage to buildings is included. Damage to contents and infrastructure and those losses associated with fire, social disruption, injury, and death are not included. The maps do not deal with the costs of certain types of geotechnical studies and engineering mitigation. By only using damages, one can present the maps in terms of percent loss rather than assigning an average value to particular types of buildings and performing the calculations. Given the rapid changes in these values, such percentages appear to be most useful for these examples.

It must be stressed that the many assumptions that must be made to produce these maps make them hypothetical at best. They are useful, though, in demonstrating a valuable technique that can be used when more information becomes available, and in pointing out the many areas where more information is needed. The precise values used are described in the following sections.

COMPOSITE MAXIMUM EARTHQUAKE DAMAGE - TWO EXAMPLES

The maximum percent damage in any earthquake associated with individual categories on the hazard maps can be summed to produce a composite map. Because the damages vary within these categories from one type of building to another, a single type, wood frame dwellings, was chosen to illustrate this technique.

Ground Shaking

The categories on the maximum ground shaking intensity map can be related to percent damage to wood frame dwellings in an earthquake as follows:

Intensity A - 16%
Intensity B - 12%
Intensity C - 5%
Intensity D - 2%
Intensity E - 2%
Intensity <E - negligible

The source of these values is discussed in Working Paper #3.

Fault Surface Rupture

In order to estimate the percent damage to buildings from surface rupture, it is necessary to make some additional assumptions about the density and age of the dwellings. To assume damage, the dwellings must have been constructed prior to the enforcement of the Alquist-Priolo Special Studies Zones Act or to the enactment of a local ordinance preventing construction of such dwellings on active faults. A procedure for estimating damage is described in U.S.G.S. Professional 945 (Reference 1, pp. 105-109). As described, the fraction of buildings affected in an approximately square slice across the study zone is:

$$\sqrt{\frac{\text{fraction of area covered by buildings}}{\text{number of buildings per 40 acres (16 hectares)}}}$$

If the density is that of a typical suburban community, these numbers would be 5 dwellings per acre or 12.5 per hectare, with 18% of the area covered. Thus, the formula becomes:

$$\text{fraction of buildings affected} = \sqrt{\frac{0.18}{(16)(12.5)}} = 0.03$$

Again, using the method described in Reference 1, one can assume 100% damage to 40% of the buildings affected and 50% damage to 60% of those affected for an average of 70% damage to 3% of the buildings or an overall average of 2.1% damage for all dwellings within the zone. Although San Mateo County does not have any fault traces used in this mapping, damage data could be calculated in other areas. The trace is defined by the computer as a 100 meter wide band (1/4 the width of a study zone). The damage per event would be equivalent to that in the zone but confined to a narrower area, making the average damage 4 times as much, or 8.4% per event.

Liquefaction

As noted in Working Paper #4, there is virtually no data available on damage due to liquefaction. For illustration purposes, it is possible to assume that those buildings on areas that liquefy will suffer 22% damage (from Reference 1, pp. 50). The likelihood of liquefaction, according to Working Paper #4, ranges from almost 0 to 10% for those units on the liquefaction susceptibility map. Multiplying those two numbers together yield damages per event of 0 to 2.2%.

Earthquake-Induced Landslides

Estimating landslide damage accurately is again beyond the state-of-the-art. However, certain assumptions can be made for illustration. In general:

% damage = (fraction of buildings affected) x (fraction damage) x (100)

The damage will be similar to that for surface rupture, so one can assume that the damage will be about 70%. To obtain an estimate of the fraction affected, one can make the following assumptions for the categories of the earthquake-induced landslide susceptibility described in Working Paper #5:

- for Category 4 (unstable) that 10% of the buildings will be affected;
- for Category 3 (unstable in winter, of intermediate stability in summer) that 10% of the buildings will be affected for 50% of the year and that 1% of the buildings will be affected for 50% of the year for an average of 5.5%;

- o for Category 2 (of intermediate stability in winter and stable in summer) that 1% of the buildings will be affected for 50% of the year and none will be affected the remainder for an average of 0.5%;

- o for Category 1 (stable) that virtually no damage will occur.

Multiplying these fractions of buildings affected by the average damage of 70% yields:

Category 4 - 7%
Category 3 - 3.85%
Category 2 - 0.35%
Category 1 - 0%

Tsunami Inundation

An estimate of damage from tsunami inundation can be obtained from the National Flood Insurance Program insurance rates. Those rates for a typical dwelling in a general flood zone, Zone A, are .10%. The rate also calls for a 50% increase in Zone V, that appropriate for a 100-year tsunami associated with rather shallow flooding. The rate of 0.15% annually can be converted to a damage per event of 1.5% by multiplying by a discount rate of 10% and dividing by a frequency of 0.1.

Dam Failure Inundation

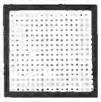
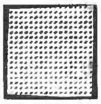
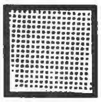
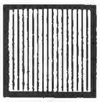
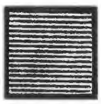
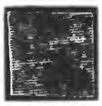
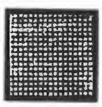
It is impossible to accurately estimate the damage per event due to dam failure inundation. The depth and velocity of flooding are two factors of major importance that are not available. Again, however, insurance rates can be used as a guide to estimate an annual rate of 3% for a damage failure of once every 100 years that again can be converted to a damage per event of 30% by dividing a frequency of .01 and multiplying by a discount rate of 10%. As stated in the previous section, this damage is not added into the main composite earthquake damage map, but is added into a map produced for comparison purposes.

Mapping Composite Maximum Earthquake Damage

Figure 1 is the maximum composite earthquake damage map without dam failure inundation, while Figure 2 includes dam failure inundation. They are produced by summing the damage amounts for each hectare from each of the hazards described above. These numbers are not completely additive since damage from one hazard is related to that from others and the totals may be more or less than the sum of the component damages. Calculating the extent of this inundation is beyond the state-of-the-art.

EXPLANATION FOR FIGURES 1 AND 2

COMPOSITE MAXIMUM EARTHQUAKE DAMAGE
WOOD FRAME DWELLINGS

SHADE PATTERN	AVERAGE DAMAGE PER EVENT*
	0 - 2 %
	3 - 5 %
	6 - 10%
	11 - 15%
	16 - 20%
	21 - 25%
	26 - 30%
	31 - 35%
	36 - 40%
	41 - 45%
	46 + %

*Estimate based on statistical procedures

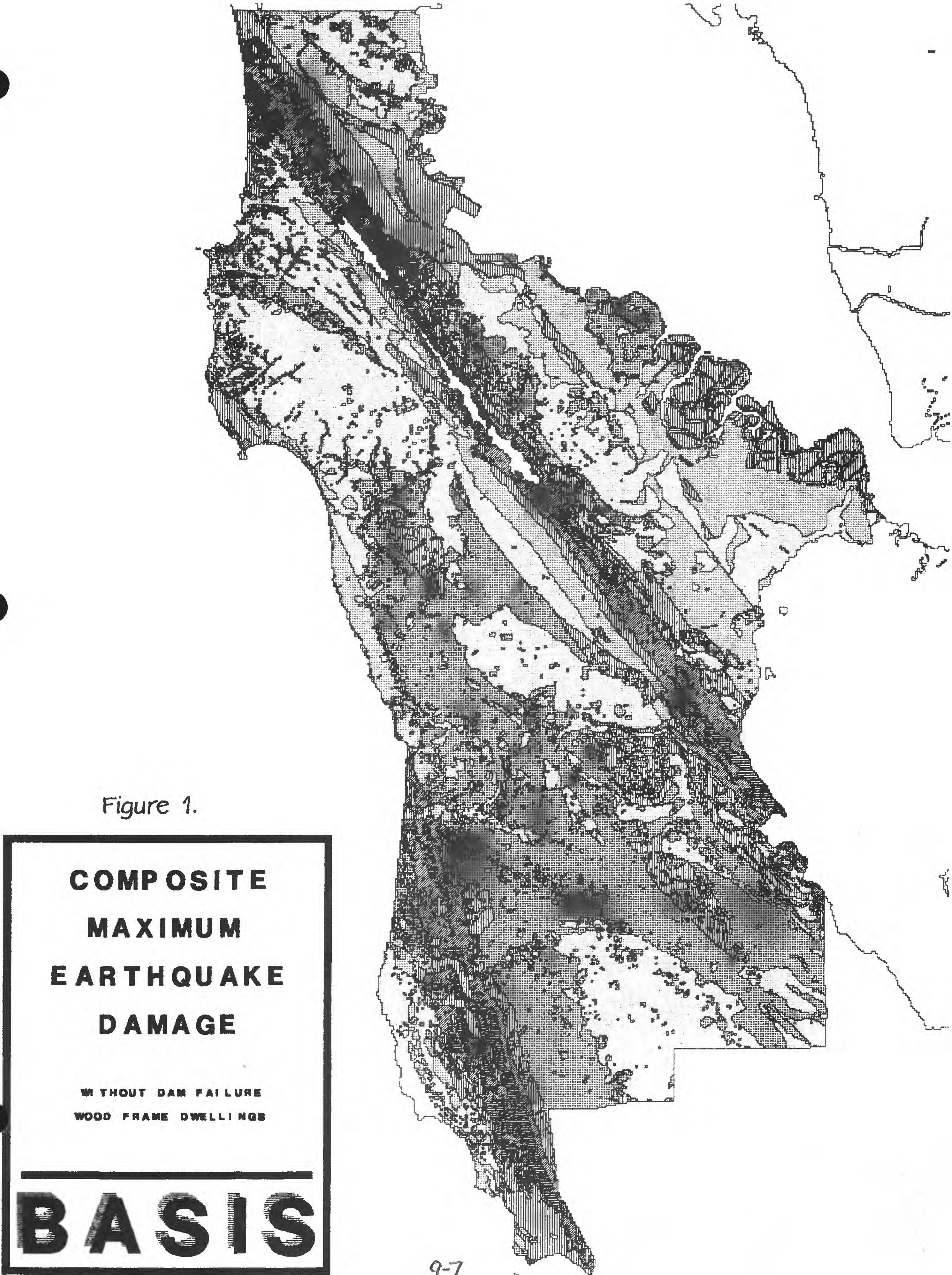

COMPOSITE
MAXIMUM
EARTHQUAKE
DAMAGE
WITHOUT DAM FAILURE
WOOD FRAME DWELLINGS
BASIS

Figure 1.

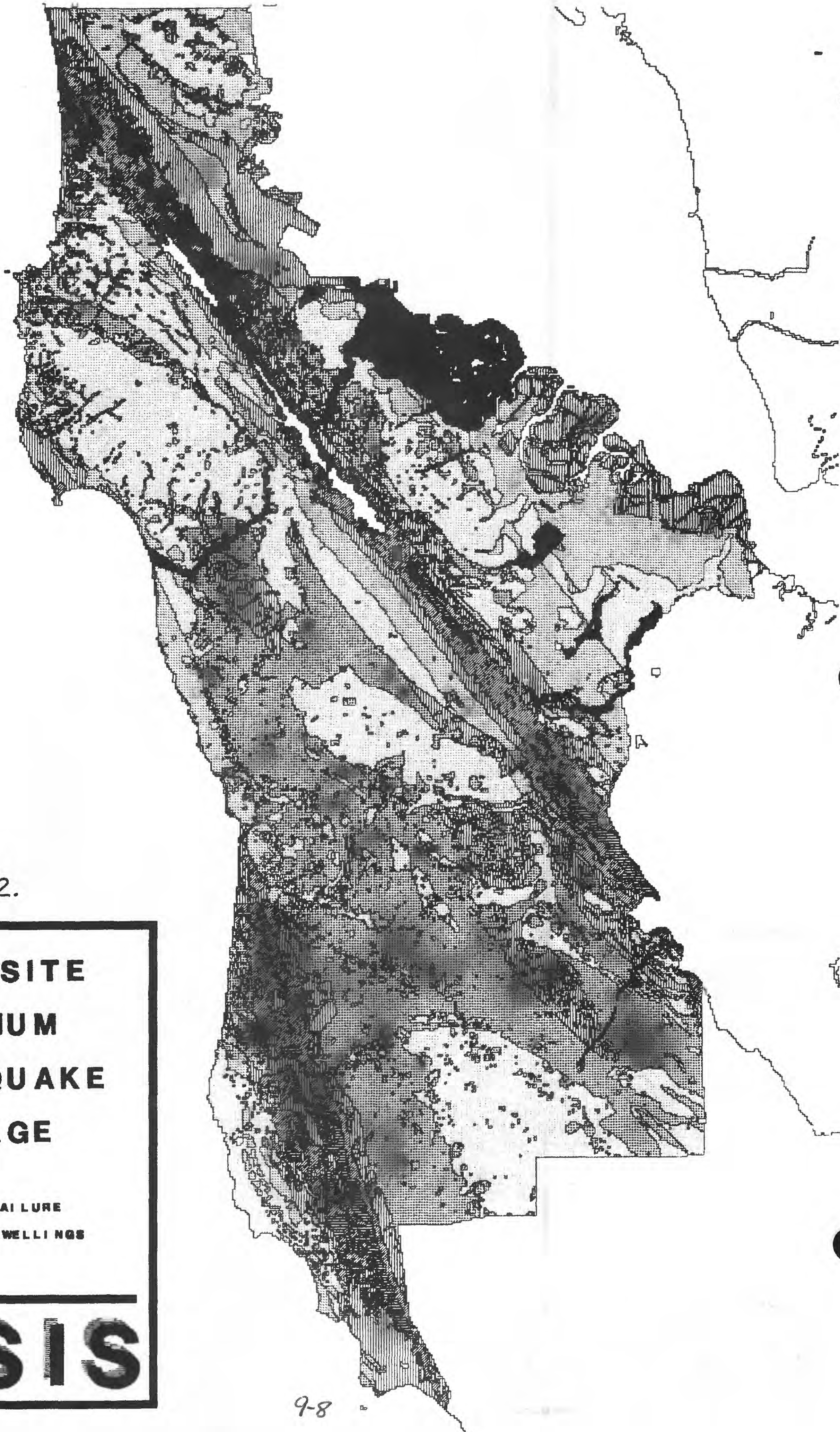


Figure 2.

COMPOSITE MAXIMUM EARTHQUAKE DAMAGE

WITH DAM FAILURE
WOOD FRAME DWELLINGS

BASIS

COMPOSITE RISK OF EARTHQUAKE DAMAGE

A composite risk of earthquake damage map can be produced by adding the present value of damages from several sources. Again, because these percentages vary with type of building, a single type, wood frame dwellings, was chosen to illustrate this technique.

Ground Shaking

The present value of damage percents displayed in the maps of risk of ground shaking damage, ranging from 0 to 3 percent for wood frame dwellings, are appropriate for use in this composite. These ground shaking maps are discussed in Working Paper #3.

Fault Surface Rupture

The damage per event (described in an earlier section) of 2.1% for zones and 8.4% for traces can be converted to a present value by multiplying by a frequency of earthquakes and dividing by a discount rate (10%). Thus, for the San Andreas and related faults, with a recurrence interval for a major earthquake assumed to be 100 years (see Working Paper #1), the present value of damage is .21%. Similarly, for the San Gregorio and related faults with a recurrence interval of 200 years, the present value of damage is .10%.

Liquefaction

Since the value in the liquefaction potential file is already the susceptibility multiplied by the opportunity (or frequency of failure), that value only has to be multiplied by the 22% damage value assumed in the previous section in liquefaction and divided by a discount rate (10%).

Earthquake-Induced Landslides

One can obtain a present value of damage from landslides by making some assumptions about opportunity for failure. Assuming that the San Gregorio, Calaveras or Hayward, and San Andreas faults are all close enough for major earthquakes on them to result in failure, one can multiply the damage per event (discussed earlier) by an opportunity of (.005) for the San Gregorio plus (.01) for the Calaveras or Hayward plus (.01) for the San Andreas for a total opportunity of (.025). This number is then divided by a discount rate of 10%. The values become:

Category 4 - 1.8%
Category 3 - .96%
Category 2 - .088%
Category 1 - 0%

Tsunami Inundation

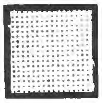
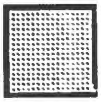
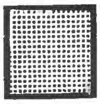
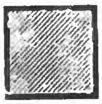
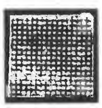
The present value of tsunami related damage is the 1.5% damage per event times the frequency of once every 500 years or .002 and divided by the discount rate of 10%, yielding .03%.

Mapping Composite Risk of Earthquake Damage

Figure 3 is the map produced by summing these present values of damage for each hectare from each of the risks described above. As with the maximum composite maps, it must be stated that these numbers are not completely additive. Damage from one hazard is related to that from others and the totals may be more or less than the sum of the individual values. Calculating the extent of this interaction is beyond the state-of-the-art.

EXPLANATION FOR FIGURE 3

COMPOSITE RISK OF EARTHQUAKE DAMAGE
WOOD FRAME DWELLINGS

SHADE PATTERN	EXPECTED DAMAGE DISCOUNTED TO PRESENT VALUE*
	0 - .2 %
	.3 - .5 %
	.6 -1.0 %
	1.1 -1.5 %
	1.6 -2.0 %
	2.1 -2.5 %
	2.6 -3.0 %
	3.1 -3.5 %
	3.6 -4.0 %
	4.1 -4.5 %
	4.6 + %

*Estimate based on statistical procedures using data on recurrence intervals and average building damage.

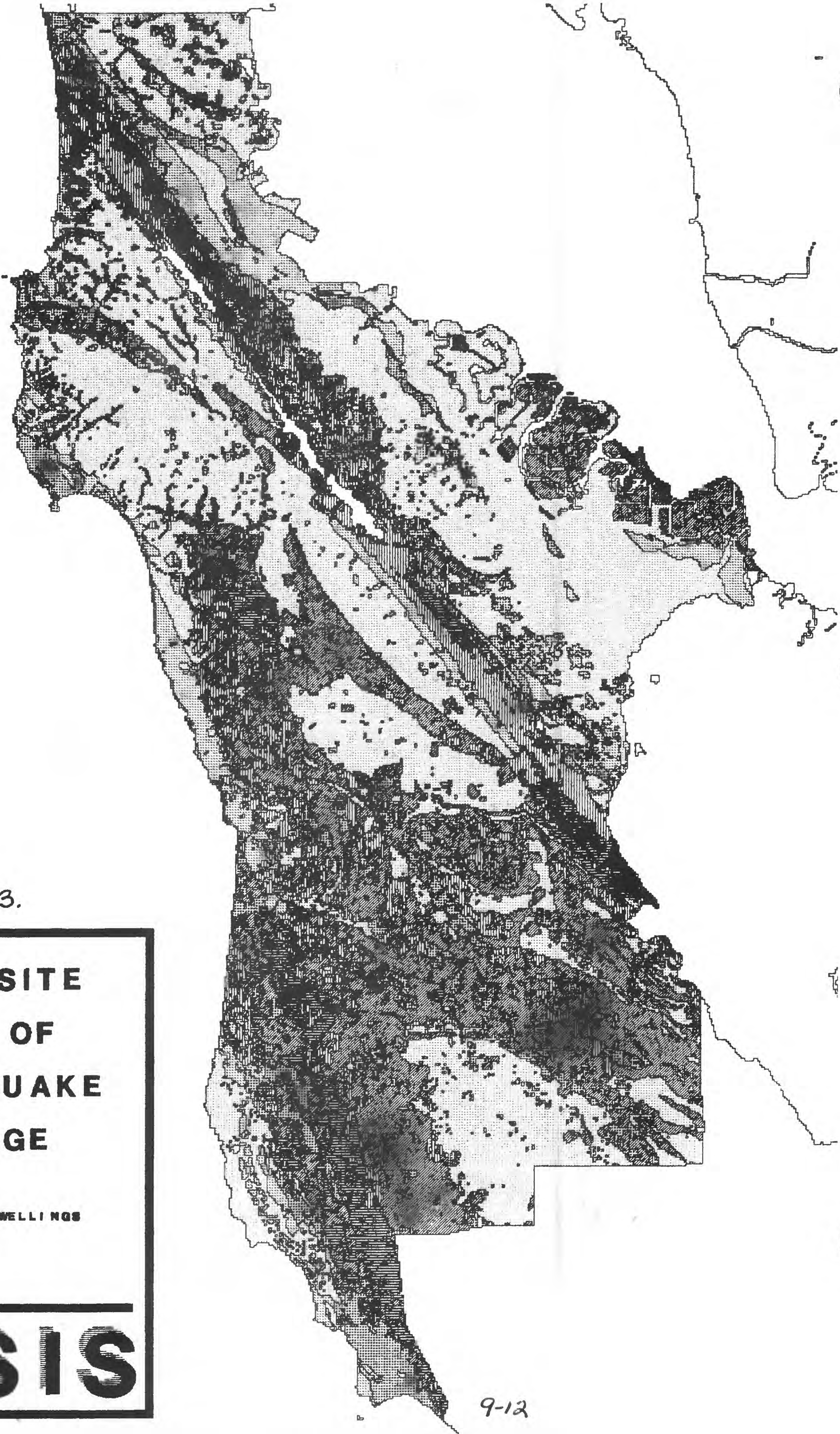


Figure 3.

COMPOSITE RISK OF EARTHQUAKE DAMAGE

WOOD FRAME DWELLINGS

BASIS

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2. Perkins, J.B., 1978, San Francisco Bay Region, A Review of Geotechnical Study Costs, Association of Bay Area Governments, 22 p.

APPENDIX J

EARTHQUAKE MAPPING PROJECT - WORKING PAPER #10

EARTHQUAKE MAP APPLICATIONS FOR AUTOMATED ASSESSMENT OF PROPERTY AND POPULATION AT RISK

INTRODUCTION

Maps are a valuable way of illustrating the location of earthquake related hazards. However, it is often useful to quantify the geographic area covered by different map categories to better express how different assumptions may affect the extent of a hazard and to compare two or more different hazards. In addition, by relating the hazard maps to political boundaries, such as counties or cities, or by relating them to mapped units for which socio-economic data are available (such as land use or census tracts), it is possible to develop general information on the property and the population exposed to the hazard.

This paper describes the method developed to obtain tabulations of hazards present within political boundaries and socio-economic categories, together with some sample findings. The paper also describes the feasibility of developing a method to use census and land use data to yield information on the population exposed to hazards. This working paper is the tenth in a series of working papers being prepared on the ABAG/USGS earthquake mapping project and the third working paper focusing on map applications.

THE POLITICAL AND SOCIAL BOUNDARY DATA

1970 Census tract boundries have been transferred onto U.S. Geological Survey 7-1/2 minute quandrangles, digitized, and thereby entered into BASIS. County boundaries have been obtained by aggregating census tracts.

The city boundaries are not the legal boundaries of the cities, for these change with each new annexation, but the spheres-of-influence assigned by each county's Local Agency Formation Commission (LAFCO)*. In addition, land use information was obtained by digitizing a series of maps, Land Use and Land Cover (Reference 1) showing four levels of land use categories. This information was the only political boundary and social data added to BASIS as part of this project.

*In Sonoma County, there are no spheres of influence. Comparable units are the general plan boundaries agreed upon by the cities and the County.

TABLES OF LAND AREA AND THE INFORMATION THEY PROVIDE

Theoretically, it is possible to tabulate the area in each of the categories on any of the six basic data file maps, nine hazard (derivative file) maps, or three composite map files by county, census tract, city or land use for a total of 18 times 4 or 72 tables. The tables including census tracts would be several pages long. Such large numbers of tables are of marginal use. Selected tables, however, can be useful in illustrating observations about the map files. Seven sets of tables have been prepared, both to compare several sets of maps and to illustrate this type of application.

Intensity Map Area Tabulations by City and County

Tables 1-5 compare the amount of land in each of the categories on the five sample intensity maps both by county (with a regional total) and by city (within San Mateo County only). Although the cities in San Mateo County have been used as an example, tables for all cities could be produced.

The table of maximum ground shaking intensity emphasizes that over 10% of the Bay Area can be exposed to a maximum ground shaking intensity of A or B, defined as very violent or violent, respectively, on the San Francisco intensity scale. Of the nine Bay Area counties, Contra Costa, Marin, Santa Clara and Sonoma fall at or near this regional average for violent ground shaking intensity, while Alameda, San Francisco and San Mateo are significantly higher and Napa and Solano are much lower. Within San Mateo County, Burlingame, Colma, Daly City, Menlo Park, Millbrae, Pacifica, Portola Valley, Redwood City, San Bruno, and Woodside could be exposed to the most violent ground shaking.

The areas exposed to greatest risk of ground shaking damage are not necessarily the same as those with the most violent maximum ground shaking intensities. Whereas Alameda, San Francisco and San Mateo might be exposed to the most violent shaking, Alameda and San Francisco counties have the largest areas of greatest risk, Marin and Solano Counties are exposed to less damage, and Contra Costa, Napa, San Mateo, Santa Clara, and Sonoma Counties have the least risk of damage. Within San Mateo County, Foster City, Menlo Park and Redwood City have the largest areas exposed to the greatest risk.

When comparing Tables 2 and 5, it becomes obvious that the assumption of strain release through many small earthquakes results in both an overall increase in risk of damage and a bunching of this risk close to faults.

Tables 2 through 4 illustrate the overall increase in damage as one changes from wood frame dwellings to reinforced concrete and tilt-up concrete buildings.

Liquefaction Map Area Tabulations by City and County

Tables 6-7 compare the amount of land in each of the categories on the liquefaction susceptibility map and the liquefaction potential map, again both by county (with a regional total) and by city (within San Mateo County only).

If one takes the regional average for areas with liquefaction susceptibility (prior to mitigation), the land in San Francisco is almost ten times more susceptible than that average, with Solano, Alameda and Marin Counties only slightly higher than the average, Contra Costa near the average, and Napa, San Mateo, Santa Clara and Sonoma lower.

When recurrence of failure is entered into the map file to produce liquefaction potential, San Francisco still has almost eight times more area exposed than the regional average, with Solano, Alameda and Marin higher, Contra Costa near the average, and Napa, San Mateo, Santa Clara and Sonoma lower. Overall, incorporating recurrence interval information does not significantly change the overall areas where liquefaction seems to be an issue.

In addition, the tables indicate that, within San Mateo County, liquefaction should be of greatest concern in Colma, Menlo Park, and Redwood City.

Landslide Susceptibility Map Area Tabulations by City and County

Tables 8-9 compare the amount of land in each of the categories on the rainfall-induced and earthquake-induced landslide susceptibility maps by the cities within San Mateo County and for that County as a whole. These tables illustrate that only 13-14% of the area in the highest category of landslide susceptibility are within city spheres of influence. Portola Valley and Woodside have the most area with potential slope stability problems. Most cities have more area in the highest category of earthquake-induced landslide susceptibility than in the highest category of rainfall-induced landslide susceptibility, especially Half Moon Bay, Hillsborough and Pacifica.

Inundation Map Area Tabulations by City and County

Tables 10-11 compare the amount of land that could be inundated should any dam fail or from a 500-year tsunami both by county (with a regional total) and by city (within San Mateo County only). A single tabulation has been used that groups all dams together since a table with a separate listing for each dam or dam groups (of which there are 213) would be unweildy. These tables confirm that dam failures potentially affect a much larger portion of the Bay Area than tsunamis (1,771 vs. 160 square kilometers). Only in Alameda, Marin and San Mateo Counties are more than 10 square kilometers potentially affected by tsunamis. In San Mateo County, over a quarter of that area is in Redwood City.

Table 11 indicates that about 10% of the Bay Area could be subject to inundation from a dam failure. The counties most subject to this hazard are Alameda, Santa Clara and Solano. Within San Mateo County, Foster City and San Mateo have the greatest area that could be flooded.

Maximum Composite Map Area Tabulations by City and County

Table 12 compares the amount of land in each of the categories on the composite maximum earthquake intensity map by city within San Mateo County and for that County as a whole. One can compare these numbers with those for the maps of individual earthquake hazards that make up the map. This table confirms that Portola Valley, with its combination of proximity to the San Andreas fault and susceptibility to landsliding, has the greatest area in the highest composite maximum damage category for wood frame dwellings. Again, it must be emphasized that these values relate to risks inherent in a particular geographic location and do not take into account either the actual land use or the State and local requirements that may have been enforced to minimize damage. Portola Valley, for example, has taken many such precautions.

Area Tabulations by Land Use Type

Tables 13-19 are examples of tabulations by types of land use for various earthquake hazard maps. Because land use data currently is available only for San Mateo County, this type of table can be prepared only for that County. The tables confirm some earlier conclusions, such as that most areas of high landslide susceptibility are in areas of rangeland and forest land. However, other conclusions can be reached. For example, there are large amounts of heavy industry located in areas of higher than average maximum intensities and susceptibility to liquefaction. In addition, over ten percent of the highest density residential dwellings are located in areas that can expect a statistical loss from ground shaking whose present value is 1 to 1.5% of the value of those structures.

Area Tabulations by Census Tract

Table 20 is an example of a tabulation of the amount of area in each of the several categories on an earthquake hazard map by census tract. The file of maximum ground shaking intensity was used. Even reducing the census tracts displayed to only those in San Mateo County (of which there are 138) does not make the table small enough to be particularly useful, except to those who are familiar with data in this form or that have the computer capability to make use of this type of data.

THE FEASIBILITY OF DETERMINING POPULATION AT RISK

One of the main values of census tract data is that it can provide information on the number of people exposed to various levels of earthquake hazards at night and during the day. To obtain this information, one could disaggregate the census tract data to individual hectares based on the land use file, and then reaggregate it to correspond to the hazard map categories of interest.

The population and dwelling data that is most accessible to be used to convert land use data to population at risk can be obtained from the latest ABAG Projections and Land Use Model (ABAG, 1980) for groups of census tracts called transportation planning zones. There are 440 of these zones in the region, 62 of them in San Mateo County. Population data should be used for the base year of 1975 since that period most closely corresponds to the data of the land use maps, although 1980 to 2000 projection data could be used to predict future population at risk if future land use data were available. This type of analysis appears to be quite beneficial, especially for those hazard maps that are useful in planning emergency response, such as dam failure inundation areas or maximum earthquake intensity. Therefore, the analysis will be performed for some maps and made available as part of a subsequent project.

TABLE 1:
AREA (IN HECTARES) FOR CATEGORIES OF
MAXIMUM GROUND SHAKING INTENSITY
BY JURISDICTION

JURISDICTION	SAN FRANCISCO INTENSITY SCALE					
	<E	E	D	C	B	A
Cities						
ATHERTON	0.	0.	573.	711.	10.	0.
BELMONT	0.	129.	785.	283.	21.	9.
BRISBANE	0.	130.	7.	427.	0.	0.
BURLINGAME	0.	0.	123.	342.	638.	114.
COLMA	0.	0.	6.	389.	86.	0.
DALY CITY	0.	161.	54.	677.	746.	572.
FOSTER CITY	0.	0.	0.	921.	72.	6.
HALF MOON BAY	871.	802.	1531.	2022.	548.	0.
HILLSBOROUGH	0.	0.	866.	675.	122.	19.
MENLO PARK	0.	4.	806.	1494.	698.	0.
MILLBRAE	0.	0.	0.	58.	579.	208.
PACIFICA	0.	686.	1078.	804.	525.	331.
PORTOLA VALLEY	0.	4.	244.	1120.	831.	1108.
REDWOOD CITY	0.	16.	1077.	3137.	1606.	43.
SAN BRUNO	0.	0.	8.	267.	543.	708.
SAN CARLOS	0.	95.	1061.	581.	20.	3.
SAN MATEO	0.	21.	1060.	2203.	263.	10.
SOUTH SAN FRANCISCO	0.	122.	157.	1155.	752.	307.
WOODSIDE	0.	0.	1060.	2107.	1058.	1249.
Counties						
ALAMEDA	39296.	50523.	42469.	25213.	33543.	0.
CONTRA COSTA	54370.	69843.	33027.	13644.	16528.	0.
MARIN	8125.	57824.	40531.	14608.	9295.	4383.
NAPA	141612.	33736.	10281.	9430.	388.	0.
SAN FRANCISCO	21.	1216.	1090.	7643.	2091.	0.
SAN MATEO	1308.	21422.	36739.	32231.	18267.	6356.
SANTA CLARA	100607.	44197.	87339.	60875.	37206.	4340.
SOLANO	72112.	93703.	16815.	21528.	11245.	0.
SONOMA	94519.	147883.	88234.	38634.	35104.	6005.
Regional Total						
BAY AREA	511970.	520347.	356525.	223806.	163667.	21084.

TABLE 2:
AREA (IN HECTARES) FOR CATEGORIES OF
RISK OF GROUND SHAKING DAMAGE
FOR WOOD FRAME DWELLINGS
BY JURISDICTION

JURISDICTION	PRESENT VALUE OF EXPECTED DAMAGE														
	0 - .2%	.3 - .5%	.6 - 1.0%	1.1 - 1.5%	1.6 - 2.0%	2.1 - 2.5%	2.6 - 3.0%	3.1 - 3.5%	3.6 - 4.0%	4.1 - 4.5%	4.6 - 5.0%	5.1 - 5.5%	5.6 - 6.0%	6.1 - 6.5%	6.6+%
Cities															
ATHERTON	1284.	10.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
BELMONT	1197.	10.	11.	0.	0.	0.	9.	0.	0.	0.	0.	0.	0.	0.	0.
BRISBANE	556.	8.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
BURLINGAME	465.	543.	95.	110.	0.	4.	0.	0.	0.	0.	0.	0.	0.	0.	0.
COLMA	395.	86.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DALY CITY	892.	631.	115.	572.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
FOSTER CITY	921.	0.	0.	0.	72.	0.	6.	0.	0.	0.	0.	0.	0.	0.	0.
HALF MOON BAY	3204.	2022.	548.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
HILLSBOROUGH	1541.	122.	0.	19.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
MENLO PARK	2078.	273.	0.	0.	651.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
MILLBRAE	58.	563.	16.	197.	0.	11.	0.	0.	0.	0.	0.	0.	0.	0.	0.
PACIFICA	2114.	538.	442.	320.	0.	11.	0.	0.	0.	0.	0.	0.	0.	0.	0.
PORTOLA VALLEY	1371.	828.	0.	1108.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
REDWOOD CITY	4197.	58.	31.	0.	1550.	0.	43.	0.	0.	0.	0.	0.	0.	0.	0.
SAN BRUNO	275.	507.	36.	680.	0.	28.	0.	0.	0.	0.	0.	0.	0.	0.	0.
SAN CARLOS	1736.	21.	0.	0.	0.	0.	3.	0.	0.	0.	0.	0.	0.	0.	0.
SAN MATEO	3094.	230.	209.	1.	14.	0.	9.	0.	0.	0.	0.	0.	0.	0.	0.
SOUTH SAN FRANCISCO	1434.	649.	103.	307.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
WOODSIDE	3167.	1058.	0.	1249.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
Counties															
ALAMEDA	135753.	21348.	13041.	5799.	10603.	4522.	0.	0.	0.	0.	0.	0.	0.	0.	0.
CONTRA COSTA	157641.	10644.	7784.	7782.	4078.	426.	0.	0.	0.	0.	0.	0.	0.	0.	0.
MARIN	118257.	3674.	606.	5146.	2409.	4459.	352.	0.	21.	0.	0.	0.	0.	0.	0.
NAPA	190263.	62.	0.	1561.	3787.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
SAN FRANCISCO	7485.	2531.	322.	132.	1599.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
SAN MATEO	82787.	16278.	8575.	6231.	2328.	55.	70.	0.	0.	0.	0.	0.	0.	0.	0.
SANTA CLARA	258603.	38948.	14298.	16676.	6101.	100.	0.	0.	0.	0.	0.	0.	0.	0.	0.
SOLANO	182435.	3298.	3720.	14348.	11118.	289.	0.	0.	0.	0.	0.	0.	0.	0.	0.
SONOMA	348183.	31634.	13481.	6298.	10945.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
Regional Total BAY AREA	1481507.	128417.	61827.	63973.	52968.	9851.	422.	0.	21.	0.	0.	0.	0.	0.	0.

TABLE 3:
AREA (IN HECTARES) FOR CATEGORIES OF
RISK OF GROUND SHAKING DAMAGE
FOR CONCRETE BLOCK AND STEEL FRAME BUILDINGS
BY JURISDICTION

JURISDICTION	PRESENT VALUE OF EXPECTED DAMAGE														
	0 - .2%	.3 - .5%	.6 - 1.0%	1.1-1.5%	1.6-2.0%	2.1-2.5%	2.6-3.0%	3.1-3.5%	3.6-4.0%	4.1-4.5%	4.6-5.0%	5.1-5.5%	5.6-6.0%	6.1-6.5%	6.6+%
Cities															
ATHERTON	504.	69.	376.	326.	19.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
BELMONT	914.	0.	148.	139.	6.	11.	0.	0.	0.	0.	0.	0.	0.	9.	0.
BRISBANE	130.	7.	0.	419.	8.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
BURLINGAME	123.	0.	298.	301.	286.	186.	2.	17.	0.	0.	0.	0.	0.	4.	0.
COLMA	6.	0.	389.	86.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DALY CITY	161.	54.	612.	696.	32.	552.	45.	58.	0.	0.	0.	0.	0.	0.	0.
FOSTER CITY	0.	0.	0.	921.	0.	0.	0.	0.	0.	0.	0.	72.	0.	6.	0.
HALF MOON BAY	1712.	312.	2095.	1150.	379.	126.	0.	0.	0.	0.	0.	0.	0.	0.	0.
HILLSBOROUGH	866.	0.	675.	122.	0.	15.	2.	2.	0.	0.	0.	0.	0.	0.	0.
MENLO PARK	648.	130.	587.	740.	246.	0.	0.	0.	0.	0.	650.	1.	0.	0.	0.
MILLBRAE	0.	0.	58.	502.	61.	209.	0.	4.	0.	0.	0.	0.	0.	11.	0.
PACIFICA	1740.	25.	349.	447.	356.	316.	151.	30.	0.	0.	0.	0.	3.	8.	0.
PORTOLA VALLEY	248.	0.	1123.	828.	0.	1100.	0.	8.	0.	0.	0.	0.	0.	0.	0.
REDWOOD CITY	1093.	0.	548.	2020.	586.	39.	0.	0.	0.	0.	77.	1473.	0.	43.	0.
SAN BRUNO	8.	0.	267.	490.	17.	583.	84.	49.	0.	0.	0.	0.	0.	28.	0.
SAN CARLOS	1156.	0.	367.	192.	42.	0.	0.	0.	0.	0.	0.	0.	0.	3.	0.
SAN MATEO	1071.	10.	865.	1176.	209.	202.	1.	0.	0.	0.	0.	14.	0.	9.	0.
SOUTH SAN FRANCISCO	279.	0.	643.	968.	193.	357.	0.	53.	0.	0.	0.	0.	0.	0.	0.
WOODSIDE	1060.	0.	2107.	6058.	0.	1219.	0.	30.	0.	0.	0.	0.	0.	0.	0.
Counties															
ALAMEDA	91569.	22161.	28695.	14717.	7899.	8867.	123.	1477.	0.	0.	1315.	4841.	6038.	3364.	0.
CONTRA COSTA	104795.	37855.	17457.	10352.	3146.	5397.	559.	1446.	1145.	737.	2143.	3310.	13.	0.	0.
MARIN	97065.	4736.	14076.	4561.	1544.	2960.	801.	440.	191.	1572.	1915.	2834.	1801.	407.	21.
NAPA	179617.	4875.	3806.	1051.	976.	0.	0.	0.	0.	1661.	3299.	388.	0.	0.	0.
SAN FRANCISCO	1263.	233.	2294.	4806.	643.	1099.	0.	0.	0.	0.	1677.	54.	0.	0.	0.
SAN MATEO	41496.	9607.	29707.	21711.	3968.	6679.	375.	328.	0.	0.	768.	1560.	3.	122.	0.
SANTA CLARA	176024.	29261.	51363.	22111.	16747.	26007.	5988.	1269.	292.	153.	2967.	2544.	0.	0.	0.
SOLANO	115326.	57276.	13012.	3536.	278.	165.	0.	25.	497.	13727.	10816.	750.	0.	0.	0.
SONOMA	276626.	45962.	40066.	28242.	1937.	6436.	0.	0.	0.	327.	8031.	2914.	0.	0.	0.
Regional Total															
BAY AREA	1083781.	211966.	200476.	111087.	37138.	57610.	7846.	4985.	2125.	18177.	32931.	19195.	7855.	3893.	21.

TABLE 4:
AREA (IN HECTARES) FOR CATEGORIES OF RISK OF GROUND SHAKING DAMAGE FOR TILT-UP CONCRETE BUILDINGS BY JURISDICTION

JURISDICTION	PRESENT VALUE OF EXPECTED DAMAGE														
	0 - .2%	.3 - .5%	.6 - 1.0%	1.1 - 1.5%	1.6 - 2.0%	2.1 - 2.5%	2.6 - 3.0%	3.1 - 3.5%	3.6 - 4.0%	4.1 - 4.5%	4.6 - 5.0%	5.1 - 5.5%	5.6 - 6.0%	6.1 - 6.5%	6.6+%
Cities															
ATHERTON	0.	504.	69.	312.	73.	0.	326.	10.	0.	0.	0.	0.	0.	0.	0.
BELMONT	129.	785.	0.	128.	115.	18.	32.	0.	4.	7.	0.	0.	0.	0.	9.
BRISBANE	130.	0.	7.	0.	0.	42.	377.	8.	0.	0.	0.	0.	0.	0.	0.
BURLINGAME	0.	123.	0.	298.	0.	257.	44.	309.	163.	0.	2.	17.	0.	0.	4.
COLMA	0.	6.	0.	389.	0.	86.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DALY CITY	161.	0.	54.	610.	2.	686.	10.	35.	549.	0.	45.	58.	0.	0.	0.
FOSTER CITY	0.	0.	0.	0.	2.	919.	0.	0.	0.	0.	0.	0.	0.	0.	78.
HALF MOON BAY	1673.	39.	1492.	915.	502.	648.	53.	325.	107.	20.	0.	0.	0.	0.	0.
HILLSBOROUGH	0.	866.	0.	675.	0.	122.	0.	0.	15.	0.	2.	2.	0.	0.	0.
MENLO PARK	4.	644.	130.	553.	281.	170.	334.	235.	0.	0.	0.	0.	0.	0.	651.
MILLBRAE	0.	0.	0.	58.	0.	502.	0.	100.	170.	0.	0.	4.	0.	0.	11.
PACIFICA	687.	1053.	25.	349.	345.	102.	126.	281.	162.	93.	161.	30.	0.	0.	11.
PORTOLA VALLEY	4.	244.	0.	1123.	0.	828.	0.	649.	451.	0.	0.	8.	0.	0.	0.
REDWOOD CITY	16.	1077.	0.	535.	821.	952.	796.	50.	8.	31.	0.	0.	0.	0.	1593.
SAN BRUNO	0.	8.	0.	267.	0.	490.	0.	189.	411.	4.	80.	49.	0.	0.	28.
SAN CARLOS	95.	1061.	0.	279.	260.	20.	41.	1.	0.	0.	0.	0.	0.	0.	3.
SAN MATEO	21.	1050.	10.	858.	156.	959.	270.	7.	189.	13.	1.	0.	0.	0.	23.
SOUTH SAN FRANCISCO	122.	157.	0.	611.	82.	622.	296.	231.	281.	38.	0.	53.	0.	0.	0.
WOODSIDE	0.	1060.	0.	2107.	0.	1058.	0.	877.	342.	0.	0.	7.	23.	0.	0.
Counties															
ALAMEDA	72233.	19336.	30373.	18449.	5596.	10389.	3051.	4852.	7500.	2173.	79.	1457.	20.	0.	15558.
CONTRA COSTA	93763.	11032.	41178.	11645.	5511.	5440.	2340.	2883.	3700.	1919.	150.	1348.	880.	363.	6203.
MARIN	65996.	31069.	4736.	11266.	4210.	2680.	976.	2237.	558.	1808.	193.	203.	260.	74.	8658.
NAPA	164880.	16554.	4574.	1803.	487.	1051.	976.	0.	0.	0.	0.	0.	0.	0.	5348.
SAN FRANCISCO	1245.	18.	233.	1125.	1438.	4236.	301.	643.	1099.	0.	0.	0.	0.	0.	1731.
SAN MATEO	22731.	18765.	17942.	21033.	5673.	14488.	3572.	5250.	3502.	251.	336.	273.	55.	0.	2453.
SANTA CLARA	130310.	50491.	25502.	35619.	17927.	15560.	12215.	13491.	15643.	8690.	1512.	646.	764.	190.	5766.
SOLANO	110402.	4970.	57579.	11345.	3687.	338.	832.	1.	439.	0.	0.	0.	25.	412.	25378.
SONOMA	235160.	41608.	50588.	31363.	14896.	11632.	6933.	5080.	2008.	1.	0.	0.	0.	0.	11272.
Regional Total															
BAY AREA	896720.	194243.	232705.	143648.	59425.	65814.	31196.	34437.	34449.	14842.	2270.	3927.	2004.	1039.	82367.

TABLE 5:
AREA (IN HECTARES) FOR CATEGORIES OF
RISK OF CROUND SHAKING DAMAGE
FOR WOOD FRAME DWELLINGS
(sample for all small earthquakes)

JURISDICTION	PRESENT VALUE OF EXPECTED DAMAGE														
	0 - .2%	.3 - .5%	.6 -1.0%	1.1-1.5%	1.6-2.0%	2.1-2.5%	2.6-3.0%	3.1-3.5%	3.6-4.0%	4.1-4.5%	4.6-5.0%	5.1-5.5%	5.6-6.0%	6.1-6.5%	6.6+%
Cities															
ATHERTON	1284.	10.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
BELMONT	1197.	21.	0.	0.	0.	0.	0.	0.	0.	9.	0.	0.	0.	0.	0.
BRISBANE	564.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
BURLINGAME	465.	638.	0.	0.	0.	0.	0.	0.	110.	4.	0.	0.	0.	0.	0.
COLMA	395.	86.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DALY CITY	892.	746.	0.	0.	0.	0.	0.	0.	572.	0.	0.	0.	0.	0.	0.
FOSTER CITY	921.	0.	72.	0.	0.	0.	0.	0.	0.	6.	0.	0.	0.	0.	0.
HALF MOON BAY	5226.	16.	0.	0.	532.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
HILLSBOROUGH	1541.	122.	0.	0.	0.	0.	0.	0.	19.	0.	0.	0.	0.	0.	0.
MENLO PARK	2304.	47.	651.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
MILLBRAE	58.	579.	0.	0.	0.	0.	0.	0.	197.	11.	0.	0.	0.	0.	0.
PACIFICA	2569.	513.	12.	0.	0.	0.	0.	0.	320.	3.	0.	0.	8.	0.	0.
PORTOLA VALLEY	1371.	828.	0.	0.	0.	0.	0.	0.	1108.	0.	0.	0.	0.	0.	0.
REDWOOD CITY	4230.	56.	1550.	0.	0.	0.	0.	0.	0.	43.	0.	0.	0.	0.	0.
SAN BRUNO	275.	543.	0.	0.	0.	0.	0.	0.	680.	28.	0.	0.	0.	0.	0.
SAN CARLOS	1737.	20.	0.	0.	0.	0.	0.	0.	0.	3.	0.	0.	0.	0.	0.
SAN MATEO	3284.	249.	14.	0.	0.	0.	0.	0.	1.	9.	0.	0.	0.	0.	0.
SOUTH SAN FRANCISCO	1434.	752.	0.	0.	0.	0.	0.	0.	307.	0.	0.	0.	0.	0.	0.
WOODSIDE	3167.	1058.	0.	0.	0.	0.	0.	0.	1249.	0.	0.	0.	0.	0.	0.
Counties															
ALAMEDA	158947.	0.	8086.	0.	16569.	2788.	4676.	0.	0.	0.	0.	0.	0.	0.	0.
CONTRA COSTA	170703.	930.	202.	1.	12947.	3548.	11.	13.	0.	0.	0.	0.	0.	0.	0.
MARIN	119961.	1374.	2783.	4247.	1974.	199.	0.	3.	1.	18.	105.	0.	7.	0.	4252.
NAPA	190325.	1561.	3399.	0.	0.	388.	0.	0.	0.	0.	0.	0.	0.	0.	0.
SAN FRANCISCO	9478.	360.	1677.	54.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
SAN MATEO	91704.	8600.	2340.	0.	7324.	0.	0.	0.	6231.	117.	0.	0.	8.	0.	0.
SANTA CLARA	291011.	10263.	8759.	216.	11576.	1664.	6581.	206.	4041.	206.	203.	0.	0.	0.	0.
SOLANO	200097.	151.	3915.	0.	10413.	832.	0.	0.	0.	0.	0.	0.	0.	0.	0.
SONOMA	368536.	705.	5453.	0.	21456.	8386.	0.	0.	0.	0.	0.	0.	0.	0.	6005.
Regional Total															
BAY AREA	1601262.	23944.	36614.	4518.	82259.	17805.	11268.	222.	10273.	341.	308.	0.	15.	0.	10257.

TABLE 6:
AREA (IN HECTARES) FOR CATEGORIES OF
LIQUEFACTION SUSCEPTIBILITY
BY JURISDICTION

JURISDICTION	VERY LOW 0%	LOW <.1%	...MODERATE... .1%	.2%	HIGH... 1.4%	... 1.8%	... 2.1%	...HIGH 2.4%	VERY HIGH 10.0%
					RELATIVE LIKELIHOOD OF LIQUEFACTION				
Cities									
ATHERTON	251.	505.	18.	520.	0.	0.	0.	0.	0.
BELMONT	899.	140.	111.	68.	9.	0.	0.	0.	0.
BRISBANE	172.	0.	385.	7.	0.	0.	0.	0.	0.
BURLINGAME	549.	120.	349.	195.	0.	0.	0.	4.	0.
COLMA	10.	0.	0.	439.	0.	0.	0.	0.	32.
DALY CITY	1181.	0.	151.	799.	0.	0.	71.	0.	8.
FOSTER CITY	0.	0.	921.	0.	78.	0.	0.	0.	0.
HALF MOON BAY	2944.	1682.	29.	895.	0.	0.	224.	0.	0.
HILLSBOROUGH	1590.	75.	4.	13.	0.	0.	0.	0.	0.
MENLO PARK	466.	769.	644.	472.	651.	0.	0.	0.	0.
MILLBRAE	456.	0.	81.	297.	0.	0.	0.	11.	0.
PACIFICA	2696.	28.	192.	404.	0.	0.	93.	11.	0.
PORTOLA VALLEY	3035.	125.	0.	147.	0.	0.	0.	0.	0.
REDWOOD CITY	918.	763.	2267.	338.	1593.	0.	0.	0.	0.
SAN BRUNO	715.	0.	102.	681.	0.	0.	0.	28.	0.
SAN CARLOS	1134.	238.	173.	212.	3.	0.	0.	0.	0.
SAN MATEO	1263.	676.	1181.	414.	23.	0.	0.	0.	0.
SOUTH SAN FRANCISCO	890.	0.	609.	890.	0.	0.	0.	0.	104.
WOODSIDE	5102.	14.	30.	328.	0.	0.	0.	0.	0.
Counties									
ALAMEDA	118944.	22086.	5461.	28003.	0.	15558.	992.	0.	0.
CONTRA COSTA	118808.	21507.	14457.	21952.	0.	6203.	4485.	0.	0.
MARIN	115304.	5577.	5.	3632.	0.	8394.	1854.	0.	0.
NAPA	163731.	12618.	15.	13653.	0.	5348.	82.	0.	0.
SAN FRANCISCO	2923.	0.	1723.	1742.	0.	1731.	3942.	0.	0.
SAN MATEO	86807.	8661.	8474.	8993.	2398.	0.	791.	55.	144.
SANTA CLARA	240957.	38352.	10047.	39532.	0.	5506.	170.	0.	0.
SOLANO	75383.	31254.	33800.	48896.	0.	25815.	255.	0.	0.
SONOMA	335211.	31322.	2801.	26260.	0.	11272.	3513.	0.	0.
Regional Total									
BAY AREA	1258068.	171377.	76783.	192663.	2398.	79827.	16084.	55.	144.

TABLE 7:
AREA (IN HECTARES) FOR CATEGORIES OF
LIQUEFACTION POTENTIAL
BY JURISDICTION

JURISDICTION	LIQUEFACTION SUSCEPTIBILITY X LIQUEFACTION OPPORTUNITY (in percent)														
	0 -.009	.010-.025	.026-.045	.046-.070	.071-.094	.095-.114	.115-.140	.141-.160	.161-.185	.186-.205	.206-.230	.231-.250	.251-.275	.276-.299	.300+
Cities															
ATHERTON	764.	10.	520.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
BELMONT	1150.	0.	68.	0.	0.	0.	0.	0.	0.	0.	9.	0.	0.	0.	0.
BRISBANE	557.	0.	7.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
BURLINGAME	1018.	0.	195.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	4.
COLMA	10.	0.	439.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	32.
DALY CITY	1332.	0.	799.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	79.
FOSTER CITY	921.	0.	0.	0.	0.	0.	0.	0.	0.	0.	78.	0.	0.	0.	0.
HALF MOON BAY	4655.	0.	895.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	224.	0.
HILLSBOROUGH	1669.	0.	13.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
MENLO PARK	1121.	758.	472.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	651.	0.
MILLBRAE	537.	0.	297.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	11.
PACIFICA	2917.	0.	404.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	16.	88.
PORTOLA VALLEY	5160.	0.	147.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
REDWOOD CITY	3729.	219.	338.	0.	0.	0.	0.	0.	0.	0.	1173.	0.	0.	420.	0.
SAN BRUNO	817.	0.	681.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	28.
SAN CARLOS	1545.	0.	212.	0.	0.	0.	0.	0.	0.	0.	3.	0.	0.	0.	0.
SAN MATEO	3120.	0.	414.	0.	0.	0.	0.	0.	0.	0.	23.	0.	0.	0.	0.
SOUTH SAN FRANCISCO	1499.	0.	890.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	104.
WOODSIDE	5146.	0.	328.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
Counties															
ALAMEDA	120560.	25961.	24127.	3868.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	16550.
CONTRA COSTA	135990.	27194.	13653.	830.	0.	0.	0.	581.	0.	0.	0.	2480.	0.	0.	7627.
MARIN	121044.	0.	3632.	0.	0.	0.	0.	0.	0.	0.	0.	118.	775.	2.	9353.
NAPA	176590.	598.	13055.	0.	0.	0.	82.	0.	0.	0.	0.	0.	0.	0.	5348.
SAN FRANCISCO	4654.	0.	1742.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1513.	4160.
SAN MATEO	102770.	2103.	9063.	0.	0.	0.	0.	0.	0.	0.	1286.	305.	0.	1450.	347.
SANTA CLARA	242079.	44165.	15888.	22859.	0.	0.	0.	0.	0.	28.	78.	0.	0.	0.	5570.
SOLANO	140092.	35762.	13405.	79.	0.	0.	0.	125.	130.	486.	0.	6307.	0.	369.	18653.
SONOMA	369496.	4465.	21795.	0.	0.	0.	108.	0.	0.	0.	1278.	0.	0.	0.	13399.
Regional Total															
BAY AREA	1413275.	144248.	115360.	27636.	0.	0.	190.	706.	130.	514.	2642.	9210.	775.	3334.	81007.

TABLE 8:
AREA (IN HECTARES) FOR CATEGORIES OF
RAINFALL-INDUCED LANDSLIDE SUSCEPTIBILITY
BY JURISDICTION

JURISDICTION	LOW... I	II	III	IV	V	VI	...HIGH VII
Cities							
ATHERTON	1293.	0.	0.	0.	0.	0.	1.
BELMONT	954.	238.	8.	0.	0.	0.	27.
BRISBANE	530.	20.	0.	0.	0.	0.	14.
BURLINGAME	1064.	110.	19.	0.	0.	0.	24.
COLMA	473.	7.	0.	0.	0.	0.	1.
DALY CITY	1629.	434.	3.	0.	0.	0.	144.
FOSTER CITY	999.	0.	0.	0.	0.	0.	0.
HALF MOON BAY	4622.	252.	307.	384.	0.	0.	209.
HILLSBOROUGH	942.	522.	203.	0.	0.	0.	15.
MENLO PARK	2992.	0.	4.	0.	0.	0.	2.
MILLBRAE	584.	212.	21.	0.	0.	0.	28.
PACIFICA	1824.	1503.	3.	0.	0.	0.	95.
PORTOLA VALLEY	1243.	164.	376.	125.	0.	0.	1387.
REDWOOD CITY	5752.	73.	40.	0.	0.	0.	14.
SAN BRUNO	1187.	309.	8.	0.	0.	0.	22.
SAN CARLOS	1356.	330.	56.	0.	0.	0.	18.
SAN MATEO	2988.	415.	93.	0.	0.	0.	61.
SOUTH SAN FRANCISCO	2271.	181.	1.	0.	0.	0.	40.
WOODSIDE	2213.	908.	1675.	66.	0.	0.	612.
County Total							
SAN MATEO	53272.	13864.	19268.	5858.	4406.	245.	19411.

TABLE 9:
AREA (IN HECTARES) FOR CATEGORIES OF
EARTHQUAKE-INDUCED LANDSLIDE SUSCEPTIBILITY
BY JURISDICTION

JURISDICTION	LOW... 1	2	3	...HIGH 4
Cities				
ATHERTON	1217.	75.	2.	0.
BELMONT	907.	107.	181.	32.
BRISBANE	433.	73.	26.	32.
BURLINGAME	824.	238.	120.	35.
COLMA	351.	84.	40.	6.
DALY CITY	903.	649.	517.	141.
FOSTER CITY	997.	2.	0.	0.
HALF MOON BAY	3514.	819.	783.	658.
HILLSBOROUGH	460.	392.	574.	256.
MENLO PARK	2903.	86.	9.	0.
MILLBRAE	427.	163.	211.	44.
PACIFICA	1741.	626.	624.	434.
PORTOLA VALLEY	903.	635.	755.	1002.
REDWOOD CITY	5420.	231.	170.	58.
SAN BRUNO	942.	200.	311.	73.
SAN CARLOS	1481.	109.	93.	77.
SAN MATEO	2623.	370.	436.	128.
SOUTH SAN FRANCISCO	1782.	479.	187.	45.
WOODSIDE	3098.	1156.	688.	532.
County Total				
SAN MATEO	53753.	15687.	19809.	27075.

TABLE 10:
AREA (IN HECTARES) FOR CATEGORIES OF TSUNAMI INUNDATION BY JURISDICTION

JURISDICTION	WITHIN	OUTSIDE
Cities		
ATHERTON	0.	1294.
BELMONT	3.	1224.
BRISBANE	10.	554.
BURLINGAME	115.	1102.
COLMA	0.	481.
DALY CITY	0.	2210.
FOSTER CITY	987.	12.
HALF MOON BAY	168.	5606.
HILLSBOROUGH	0.	1682.
MENLO PARK	283.	2719.
MILLBRAE	13.	832.
PACIFICA	116.	3309.
PORTOLA VALLEY	0.	3307.
REDWOOD CITY	1042.	4837.
SAN BRUNO	0.	1526.
SAN CARLOS	0.	1760.
SAN MATEO	218.	3339.
SOUTH SAN FRANCISCO	173.	2320.
WOODSIDE	0.	5474.
Counties		
ALAMEDA	5478.	185588.
CONTRA COSTA	875.	187480.
MARIN	3592.	131332.
NAPA	1.	195672.
SAN FRANCISCO	915.	11154.
SAN MATEO	3554.	112770.
SANTA CLARA	267.	334459.
SOLANO	463.	214945.
SONOMA	890.	409651.
Regional Total		
BAY AREA	16035.	1783051.

TABLE 11:
AREA (IN HECTARES) FOR CATEGORIES OF DAM FAILURE INUNDATION BY JURISDICTION

JURISDICTION	WITHIN	OUTSIDE
Cities		
ATHERTON	111.	1183.
BELMONT	106.	1121.
BRISBANE	0.	564.
BURLINGAME	122.	1095.
COLMA	0.	481.
DALY CITY	0.	2210.
FOSTER CITY	999.	0.
HALF MOON BAY	159.	5615.
HILLSBOROUGH	196.	1486.
MENLO PARK	199.	2803.
MILLBRAE	0.	845.
PACIFICA	0.	3425.
PORTOLA VALLEY	70.	3237.
REDWOOD CITY	276.	5603.
SAN BRUNO	0.	1526.
SAN CARLOS	0.	1760.
SAN MATEO	1874.	1683.
SOUTH SAN FRANCISCO	0.	2493.
WOODSIDE	23.	5451.
Counties		
ALAMEDA	35088.	155978.
CONTRA COSTA	12709.	175646.
MARIN	2578.	132346.
NAPA	10821.	184852.
SAN FRANCISCO	460.	11609.
SAN MATEO	4529.	111795.
SANTA CLARA	38430.	296296.
SOLANO	56536.	158872.
SONOMA	15961.	394580.
Regional Total		
BAY AREA	177112.	1621974.

TABLE 12:
AREA (IN HECTARES) FOR CATEGORIES OF COMPOSITE MAXIMUM EARTHQUAKE DAMAGE WITHOUT DAM FAILURE FOR WOOD FRAME DWELLINGS

JURISDICTION	PERCENT DAMAGE						
Cities	0 - 2%	3 - 5%	6 -10%	.11-15%	16-20%	21-25%	26+%
ATHERTON	573.	709.	2.	10.	0.	0.	0.
BELMONT	742.	249.	202.	19.	15.	0.	0.
BRISBANE	131.	367.	38.	28.	0.	0.	0.
BURLINGAME	122.	243.	66.	613.	137.	36.	0.
COLMA	3.	316.	70.	90.	2.	0.	0.
DALY CITY	214.	572.	92.	518.	693.	121.	0.
FOSTER CITY	0.	7.	914.	72.	6.	0.	0.
HALF MOON BAY	2500.	1177.	1143.	875.	77.	2.	0.
HILLSBOROUGH	519.	251.	637.	204.	71.	0.	0.
MENLO PARK	772.	1442.	86.	695.	3.	0.	0.
MILLBRAE	0.	27.	16.	461.	227.	114.	0.
PACIFICA	1464.	588.	404.	311.	583.	75.	0.
PORTOLA VALLEY	210.	641.	226.	547.	1180.	491.	0.
REDWOOD CITY	917.	2733.	573.	1613.	43.	0.	0.
SAN BRUNO	8.	256.	5.	526.	519.	212.	0.
SAN CARLOS	1083.	491.	115.	62.	9.	0.	0.
SAN MATEO	786.	1758.	679.	302.	32.	0.	0.
SOUTH SAN FRANCISCO	258.	851.	298.	736.	334.	16.	0.
WOODSIDE	780.	1518.	517.	1271.	1216.	172.	0.
County Total							
SAN MATEO	33075.	20516.	31802.	17713.	10485.	2733.	0.

TABLE 13:
AREA (IN HECTARES) FOR CATEGORIES OF
MAXIMUM GROUND SHAKING INTENSITY
BY LAND USE TYPE

LAND USE TYPE	SAN FRANCISCO INTENSITY SCALE					
	<E	E	D	C	B	A
1 AND FEWER RESIDENTIAL DU/HECTARE	0.	30.	74.	23.	4.	5.
2 TO 8 RESIDENTIAL DU/HECTARE	17.	147.	2236.	2361.	871.	962.
9 AND MORE RESIDENTIAL DU/HECTARE	0.	406.	3538.	5072.	1873.	1282.
RETAIL AND WHOLESALE COMMERCIAL	0.	42.	302.	1199.	554.	63.
COMMERCIAL OUTDOOR RECREATION	0.	5.	21.	76.	23.	0.
ELEMENTARY AND SECONDARY SCHOOLS	0.	22.	248.	440.	199.	162.
COLLEGES AND UNIVERSITIES	0.	0.	124.	18.	1.	23.
OTHER EDUCATION	0.	0.	46.	13.	3.	1.
HOSPITALS, REHAB. CENTERS, ETC	0.	0.	13.	75.	15.	4.
MILITARY INSTALLATIONS	0.	7.	5.	9.	44.	4.
OTHER PUBLIC INSTITUTIONS	0.	0.	35.	59.	8.	9.
RESEARCH CENTERS	0.	0.	43.	56.	6.	0.
LIGHT INDUSTRY	0.	31.	44.	544.	118.	3.
HEAVY INDUSTRY	0.	10.	29.	966.	1350.	10.
TRANSPORTATION AND UTILITIES	0.	0.	1.	2.	6.	7.
HIGHWAY	5.	33.	112.	565.	394.	123.
RAILWAY	0.	3.	12.	170.	27.	1.
AIRPORTS	0.	0.	4.	147.	784.	1.
PORT FACILITIES	0.	0.	0.	8.	0.	0.
POWER TRANSMISSION	0.	4.	1.	80.	68.	6.
SEWAGE TREATMENT	0.	0.	0.	22.	7.	3.
COMMERCIAL/INDUSTRIAL COMPLEXES	0.	0.	0.	93.	0.	0.
MIXED URBAN AND BUILT-UP	0.	5.	28.	116.	85.	8.
EXTENSIVE RECREATION	0.	0.	2.	14.	20.	12.
GOLF COURSES	0.	0.	133.	371.	260.	30.
RACETRACKS	0.	0.	3.	59.	15.	0.
CEMETERIES	0.	0.	30.	282.	149.	9.
PARKS	0.	0.	56.	96.	40.	33.
OPEN SPACE - URBAN	9.	9.	28.	114.	45.	22.
CROPLAND AND PASTURE	0.	0.	4.	0.	0.	0.
IRRIGATED CROPLAND	40.	217.	1004.	1633.	1108.	59.
NON-IRRIGATED CROPLAND	0.	205.	407.	329.	597.	0.
PASTURE	0.	155.	916.	391.	118.	5.
ORCHARDS OR GROVES	0.	0.	6.	11.	11.	54.
FLORICULTURE - GREENHOUSES	0.	0.	45.	86.	29.	0.
FARMSTEADS AND OTHER AGRICULTURE	3.	15.	74.	69.	41.	2.
HERBACEOUS RANGELAND	437.	3223.	6133.	5067.	3253.	854.
SHRUB AND BRUSH RANGELAND	0.	10.	3.	0.	0.	0.
CHAPARRAL	0.	1982.	3729.	1063.	364.	204.
COASTAL SHRUB	609.	4023.	2976.	1861.	949.	118.
MIXED RANGELAND	23.	606.	466.	374.	1082.	180.
REDWOOD FOREST	0.	8148.	8151.	2563.	876.	126.
PINE FOREST	0.	143.	45.	104.	19.	5.
EVERGREEN MIXED FOREST	156.	1828.	5569.	3705.	1737.	1830.
STREAMS AND CANALS	0.	0.	0.	112.	31.	1.
LAKES	0.	4.	2.	13.	9.	9.
RESERVOIRS	0.	9.	30.	45.	73.	37.
BAYS AND ESTUARIES	0.	0.	5.	69.	44.	0.
FORESTED WETLANDS	0.	0.	0.	0.	1.	26.
NON-FORESTED WETLANDS	0.	2.	32.	549.	631.	57.
BEACHES	0.	12.	3.	67.	23.	15.
SAND OTHER THAN BEACHES	0.	0.	6.	38.	28.	12.
BARE EXPOSED ROCK	0.	9.	2.	2.	0.	0.
STRIP MINES/QUARRIES/GRAVEL PITS	1.	47.	30.	34.	16.	4.
TRANSITIONAL AREAS	0.	1.	34.	1.	1.	15.
SANITARY LAND FILL	0.	6.	6.	138.	25.	0.
OTHER TRANSITIONAL	0.	19.	82.	1044.	305.	123.
MIXED BARREN LAND	8.	0.	0.	1.	0.	0.

TABLE 14:
AREA (IN HECTARES) FOR CATEGORIES OF
RISK OF GROUND SHAKING DAMAGE
FOR WOOD FRAME DWELLINGS
BY LAND USE TYPE

LAND USE TYPE	PRESENT VALUE OF EXPECTED DAMAGE								
	0 - .2%	.3 - .5%	.6-1.0%	1.1-1.5%	1.6-2.0%	2.1-2.5%	2.6-3.0%	3.1-3.5%	3.6-4.0%
1 AND FEWER RESIDENTIAL DU/HECTARE.	52.	12.	3.	5.	0.	0.	0.	0.	0.
2 TO 8 RESIDENTIAL DU/HECTARE......	2339.	938.	74.	956.	0.	0.	0.	0.	0.
9 AND MORE RESIDENTIAL DU/HECTARE..	4394.	2126.	499.	1277.	3.	4.	1.	0.	0.
RETAIL AND WHOLESALE COMMERCIAL....	1101.	549.	113.	55.	5.	0.	8.	0.	0.
COMMERCIAL OUTDOOR RECREATION......	79.	16.	7.	0.	1.	0.	0.	0.	0.
ELEMENTARY AND SECONDARY SCHOOLS...	365.	227.	66.	162.	0.	0.	0.	0.	0.
COLLEGES AND UNIVERSITIES..........	18.	0.	1.	23.	0.	0.	0.	0.	0.
OTHER EDUCATION....................	11.	4.	1.	1.	0.	0.	0.	0.	0.
HOSPITALS, REHAB. CENTERS, ETC.....	75.	15.	0.	4.	0.	0.	0.	0.	0.
MILITARY INSTALLATIONS.............	12.	43.	2.	4.	0.	0.	0.	0.	0.
OTHER PUBLIC INSTITUTIONS..........	58.	7.	1.	9.	0.	0.	0.	0.	0.
RESEARCH CENTERS...................	56.	6.	0.	0.	0.	0.	0.	0.	0.
LIGHT INDUSTRY.....................	523.	112.	25.	1.	4.	2.	0.	0.	0.
HEAVY INDUSTRY.....................	968.	30.	4.	0.	1321.	0.	10.	0.	0.
TRANSPORTATION AND UTILITIES.......	2.	0.	0.	7.	6.	0.	0.	0.	0.
HIGHWAY............................	506.	412.	76.	121.	1.	2.	0.	0.	0.
RAILWAY............................	166.	19.	8.	1.	0.	0.	0.	0.	0.
AIRPORTS...........................	134.	680.	120.	0.	0.	1.	0.	0.	0.
PORT FACILITIES....................	8.	0.	0.	0.	0.	0.	0.	0.	0.
POWER TRANSMISSION.................	75.	11.	1.	2.	61.	4.	0.	0.	0.
SEWAGE TREATMENT...................	20.	6.	3.	3.	0.	0.	0.	0.	0.
COMMERCIAL/INDUSTRIAL COMPLEXES....	80.	13.	0.	0.	0.	0.	0.	0.	0.
MIXED URBAN AND BUILT-UP...........	93.	79.	40.	2.	0.	2.	4.	0.	0.
EXTENSIVE RECREATION...............	12.	10.	10.	12.	0.	0.	0.	0.	0.
GOLF COURSES.......................	289.	254.	77.	22.	0.	8.	0.	0.	0.
RACETRACKS.........................	45.	17.	15.	0.	0.	0.	0.	0.	0.
CEMETERIES.........................	282.	148.	3.	9.	0.	0.	0.	0.	0.
PARKS..............................	91.	47.	6.	33.	1.	0.	0.	0.	0.
OPEN SPACE - URBAN.................	89.	56.	15.	22.	0.	0.	0.	0.	0.
CROPLAND AND PASTURE...............	4.	0.	0.	0.	0.	0.	0.	0.	0.
IRRIGATED CROPLAND.................	1118.	1534.	1039.	58.	0.	0.	0.	0.	0.
NON-IRRIGATED CROPLAND.............	368.	326.	597.	0.	0.	0.	0.	0.	0.
PASTURE............................	916.	388.	118.	5.	0.	0.	0.	0.	0.
ORCHARDS OR GROVES.................	11.	11.	0.	54.	0.	0.	0.	0.	0.
FLORICULTURE - GREENHOUSES.........	58.	84.	8.	0.	0.	0.	0.	0.	0.
FARMSTEADS AND OTHER AGRICULTURE...	72.	49.	41.	2.	0.	0.	0.	0.	0.
HERBACEOUS RANGELAND...............	5798.	2955.	2600.	829.	57.	4.	8.	0.	0.
SHRUB AND BRUSH RANGELAND..........	1.	0.	0.	0.	0.	0.	0.	0.	0.
CHAPARRAL..........................	2152.	545.	107.	204.	0.	0.	0.	0.	0.
COASTAL SHRUB......................	1602.	1169.	833.	118.	0.	0.	0.	0.	0.
MIXED RANGELAND....................	421.	354.	981.	180.	0.	0.	0.	0.	0.
REDWOOD FOREST.....................	3690.	809.	555.	126.	0.	0.	0.	0.	0.
PINE FOREST........................	111.	19.	0.	5.	0.	0.	0.	0.	0.
EVERGREEN MIXED FOREST.............	4513.	1735.	378.	1687.	0.	0.	0.	0.	0.
STREAMS AND CANALS.................	112.	0.	0.	0.	31.	0.	1.	0.	0.
LAKES..............................	8.	8.	8.	9.	0.	0.	0.	0.	0.
RESERVOIRS.........................	36.	50.	15.	37.	23.	0.	0.	0.	0.
BAYS AND ESTUARIES.................	71.	10.	0.	0.	34.	0.	0.	0.	0.
FORESTED WETLANDS..................	0.	1.	0.	26.	0.	0.	0.	0.	0.
NON-FORESTED WETLANDS..............	468.	90.	7.	19.	616.	0.	38.	0.	0.
BEACHES............................	1.	66.	23.	15.	0.	0.	0.	0.	0.
SAND OTHER THAN BEACHES............	6.	38.	28.	12.	0.	0.	0.	0.	0.
BARE EXPOSED ROCK..................	2.	2.	0.	0.	0.	0.	0.	0.	0.
STRIP MINES/QUARRIES/GRAVEL PITS...	29.	9.	13.	4.	0.	0.	0.	0.	0.
TRANSITIONAL AREAS.................	0.	2.	0.	15.	0.	0.	0.	0.	0.
SANITARY LAND FILL.................	142.	2.	0.	0.	25.	0.	0.	0.	0.
OTHER TRANSITIONAL.................	987.	174.	50.	95.	139.	28.	0.	0.	0.
MIXED BARREN LAND..................	0.	1.	0.	0.	0.	0.	0.	0.	0.

TABLE 15:
AREA (IN HECTARES) FOR CATEGORIES OF
LIQUEFACTION SUSCEPTIBILITY
BY LAND USE TYPE

LAND USE TYPE	VERY LOW 0%	LOW <.1%	...MODERATE... .1%	.2%	HIGH.......... 1.4%	1.8%	2.1%	..........HIGH 2.4%	VERY HIGH 10.0%
1 AND FEWER RESIDENTIAL DU/HECTARE.	81.	36.	1.	16.	0.	0.	2.	0.	0.
2 TO 8 RESIDENTIAL DU/HECTARE......	4782.	721.	39.	1034.	0.	0.	18.	0.	0.
9 AND MORE RESIDENTIAL DU/HECTARE..	4933.	2178.	1965.	2994.	4.	11.	45.	4.	37.
RETAIL AND WHOLESALE COMMERCIAL....	284.	320.	706.	794.	13.	0.	7.	0.	36.
COMMERCIAL OUTDOOR RECREATION......	18.	11.	65.	30.	1.	0.	0.	0.	0.
ELEMENTARY AND SECONDARY SCHOOLS...	426.	192.	91.	357.	0.	0.	4.	0.	1.
COLLEGES AND UNIVERSITIES..........	124.	32.	1.	9.	0.	0.	0.	0.	0.
OTHER EDUCATION....................	9.	40.	0.	14.	0.	0.	0.	0.	0.
HOSPITALS, REHAB. CENTERS, ETC.....	43.	12.	6.	46.	0.	0.	0.	0.	0.
MILITARY INSTALLATIONS.............	20.	4.	8.	37.	0.	0.	0.	0.	0.
OTHER PUBLIC INSTITUTIONS..........	23.	40.	20.	23.	0.	0.	0.	0.	5.
RESEARCH CENTERS...................	70.	31.	1.	3.	0.	0.	0.	0.	0.
LIGHT INDUSTRY.....................	60.	47.	428.	196.	4.	0.	0.	2.	3.
HEAVY INDUSTRY.....................	44.	0.	900.	90.	1331.	0.	0.	0.	0.
TRANSPORTATION AND UTILITIES.......	1.	0.	2.	7.	6.	0.	0.	0.	0.
HIGHWAY............................	489.	99.	387.	244.	1.	2.	8.	2.	0.
RAILWAY............................	24.	5.	115.	69.	0.	0.	0.	0.	0.
AIRPORTS...........................	5.	127.	796.	7.	0.	0.	0.	1.	0.
PORT FACILITIES....................	0.	0.	8.	0.	0.	0.	0.	0.	0.
POWER TRANSMISSION.................	10.	2.	78.	4.	61.	0.	0.	4.	0.
SEWAGE TREATMENT...................	5.	0.	26.	0.	0.	0.	1.	0.	0.
COMMERCIAL/INDUSTRIAL COMPLEXES....	0.	21.	72.	0.	0.	0.	0.	0.	0.
MIXED URBAN AND BUILT-UP...........	52.	16.	131.	33.	4.	0.	2.	2.	2.
EXTENSIVE RECREATION...............	15.	10.	11.	12.	0.	0.	0.	0.	0.
GOLF COURSES.......................	313.	127.	77.	229.	0.	0.	40.	8.	0.
RACETRACKS.........................	0.	0.	43.	34.	0.	0.	0.	0.	0.
CEMETERIES.........................	59.	5.	0.	384.	0.	0.	1.	0.	21.
PARKS..............................	74.	53.	42.	44.	1.	0.	0.	0.	11.
OPEN SPACE - URBAN.................	88.	12.	70.	40.	0.	0.	7.	0.	10.
CROPLAND AND PASTURE...............	4.	0.	0.	0.	0.	0.	0.	0.	0.
IRRIGATED CROPLAND.................	950.	2076.	54.	840.	0.	0.	136.	0.	5.
NON-IRRIGATED CROPLAND.............	772.	664.	2.	87.	0.	0.	13.	0.	0.
PASTURE............................	1387.	156.	0.	35.	0.	0.	7.	0.	0.
ORCHARDS OR GROVES.................	45.	1.	0.	36.	0.	0.	0.	0.	0.
FLORICULTURE - GREENHOUSES.........	3.	32.	13.	103.	0.	0.	6.	0.	3.
FARMSTEADS AND OTHER AGRICULTURE...	116.	50.	2.	33.	0.	0.	3.	0.	0.
HERBACEOUS RANGELAND...............	16938.	1022.	282.	582.	65.	0.	74.	4.	0.
SHRUB AND BRUSH RANGELAND..........	13.	0.	0.	0.	0.	0.	0.	0.	0.
CHAPARRAL..........................	7245.	33.	26.	31.	0.	0.	7.	0.	0.
COASTAL SHRUB......................	9903.	207.	27.	176.	0.	0.	223.	0.	0.
MIXED RANGELAND....................	2504.	78.	14.	122.	0.	0.	13.	0.	0.
REDWOOD FOREST.....................	19723.	133.	1.	7.	0.	0.	0.	0.	0.
PINE FOREST........................	316.	0.	0.	0.	0.	0.	0.	0.	0.
EVERGREEN MIXED FOREST.............	14469.	106.	13.	220.	0.	0.	12.	0.	5.
STREAMS AND CANALS.................	0.	0.	112.	0.	32.	0.	0.	0.	0.
LAKES..............................	16.	1.	14.	2.	0.	0.	4.	0.	0.
RESERVOIRS.........................	113.	9.	39.	8.	23.	0.	2.	0.	0.
BAYS AND ESTUARIES.................	0.	2.	82.	0.	34.	0.	0.	0.	0.
FORESTED WETLANDS..................	6.	0.	14.	7.	0.	0.	0.	0.	0.
NON-FORESTED WETLANDS..............	7.	11.	574.	15.	654.	7.	3.	0.	0.
BEACHES............................	26.	12.	3.	0.	0.	0.	79.	0.	0.
SAND OTHER THAN BEACHES............	19.	0.	0.	0.	0.	0.	65.	0.	0.
BARE EXPOSED ROCK..................	9.	4.	0.	0.	0.	0.	0.	0.	0.
STRIP MINES/QUARRIES/GRAVEL PITS...	95.	0.	19.	17.	0.	0.	1.	0.	0.
TRANSITIONAL AREAS.................	52.	0.	0.	0.	0.	0.	0.	0.	0.
SANITARY LAND FILL.................	8.	6.	136.	0.	25.	0.	0.	0.	0.
OTHER TRANSITIONAL.................	291.	38.	972.	90.	139.	0.	10.	28.	5.
MIXED BARREN LAND..................	8.	0.	0.	0.	0.	0.	1.	0.	0.

TABLE 16:
AREA (IN HECTARES) FOR CATEGORIES OF
RAINFALL-INDUCED LANDSLIDE SUSCEPTIBILITY
BY LAND USE TYPE

LAND USE TYPE	LOW I	II	III	IV	V	VI	HIGH VII
1 AND FEWER RESIDENTIAL DU/HECTARE.	97.	23.	6.	3.	0.	0.	7.
2 TO 8 RESIDENTIAL DU/HECTARE......	4724.	653.	480.	35.	35.	0.	641.
9 AND MORE RESIDENTIAL DU/HECTARE..	10514.	1201.	71.	0.	0.	0.	148.
RETAIL AND WHOLESALE COMMERCIAL....	2046.	80.	4.	0.	0.	0.	6.
COMMERCIAL OUTDOOR RECREATION......	122.	2.	1.	0.	0.	0.	0.
ELEMENTARY AND SECONDARY SCHOOLS...	950.	92.	1.	0.	0.	0.	27.
COLLEGES AND UNIVERSITIES..........	129.	35.	2.	0.	0.	0.	0.
OTHER EDUCATION....................	62.	1.	0.	0.	0.	0.	0.
HOSPITALS, REHAB. CENTERS, ETC.....	91.	13.	3.	0.	0.	0.	0.
MILITARY INSTALLATIONS.............	68.	1.	0.	0.	0.	0.	0.
OTHER PUBLIC INSTITUTIONS..........	104.	6.	0.	0.	0.	0.	0.
RESEARCH CENTERS...................	102.	0.	3.	0.	0.	0.	0.
LIGHT INDUSTRY.....................	730.	5.	0.	0.	0.	0.	1.
HEAVY INDUSTRY.....................	2345.	0.	7.	0.	0.	0.	12.
TRANSPORTATION AND UTILITIES.......	16.	0.	0.	0.	0.	0.	0.
HIGHWAY............................	1067.	105.	30.	0.	3.	0.	18.
RAILWAY............................	209.	0.	0.	0.	0.	0.	0.
AIRPORTS...........................	936.	0.	0.	0.	0.	0.	0.
PORT FACILITIES....................	8.	0.	0.	0.	0.	0.	0.
POWER TRANSMISSION.................	159.	0.	0.	0.	0.	0.	0.
SEWAGE TREATMENT...................	29.	1.	0.	0.	0.	0.	2.
COMMERCIAL/INDUSTRIAL COMPLEXES....	93.	0.	0.	0.	0.	0.	0.
MIXED URBAN AND BUILT-UP...........	201.	17.	6.	2.	0.	0.	15.
EXTENSIVE RECREATION...............	40.	6.	0.	0.	0.	0.	0.
GOLF COURSES.......................	730.	28.	2.	0.	0.	0.	2.
RACETRACKS.........................	77.	0.	0.	0.	0.	0.	0.
CEMETERIES.........................	453.	13.	2.	0.	0.	0.	2.
PARKS..............................	202.	11.	6.	0.	0.	0.	6.
OPEN SPACE - URBAN.................	186.	33.	4.	0.	0.	0.	4.
CROPLAND AND PASTURE...............	0.	0.	4.	0.	0.	0.	0.
IRRIGATED CROPLAND.................	3528.	216.	121.	41.	29.	12.	101.
NON-IRRIGATED CROPLAND.............	1008.	95.	153.	88.	14.	0.	180.
PASTURE............................	355.	110.	373.	177.	62.	33.	475.
ORCHARDS OR GROVES.................	53.	1.	13.	0.	0.	0.	15.
FLORICULTURE - GREENHOUSES.........	159.	0.	0.	0.	0.	0.	1.
FARMSTEADS AND OTHER AGRICULTURE...	106.	16.	11.	12.	3.	1.	55.
HERBACEOUS RANGELAND...............	5953.	2366.	3363.	1244.	1334.	89.	4565.
SHRUB AND BRUSH RANGELAND..........	1.	0.	4.	0.	0.	0.	8.
CHAPARRAL..........................	872.	974.	2161.	577.	826.	62.	1870.
COASTAL SHRUB......................	5930.	2564.	623.	429.	173.	5.	812.
MIXED RANGELAND....................	839.	466.	528.	353.	6.	4.	535.
REDWOOD FOREST.....................	1498.	1765.	7430.	2179.	1245.	5.	5740.
PINE FOREST........................	142.	71.	75.	6.	0.	0.	22.
EVERGREEN MIXED FOREST.............	2663.	2705.	3740.	712.	674.	33.	4079.
STREAMS AND CANALS.................	144.	0.	0.	0.	0.	0.	0.
LAKES..............................	24.	4.	1.	0.	0.	0.	8.
RESERVOIRS.........................	145.	24.	11.	0.	0.	0.	14.
BAYS AND ESTUARIES.................	118.	0.	0.	0.	0.	0.	0.
FORESTED WETLANDS..................	23.	0.	4.	0.	0.	0.	0.
NON-FORESTED WETLANDS..............	1259.	4.	0.	0.	0.	0.	1.
BEACHES............................	106.	3.	3.	0.	2.	1.	4.
SAND OTHER THAN BEACHES............	72.	0.	0.	0.	0.	0.	12.
BARE EXPOSED ROCK..................	5.	0.	0.	0.	0.	0.	8.
STRIP MINES/QUARRIES/GRAVEL PITS...	98.	32.	0.	0.	0.	0.	2.
TRANSITIONAL AREAS.................	43.	3.	1.	0.	0.	0.	5.
SANITARY LAND FILL.................	175.	0.	0.	0.	0.	0.	0.
OTHER TRANSITIONAL.................	1435.	114.	17.	0.	0.	0.	5.
MIXED BARREN LAND..................	7.	2.	0.	0.	0.	0.	0.

TABLE 17:
AREA (IN HECTARES) FOR CATEGORIES OF
EARTHQUAKE-INDUCED LANDSLIDE SUSCEPTIBILITY
BY LAND USE TYPE

LAND USE TYPE	LOW..... 1	2	3	.....HIGH 4
1 AND FEWER RESIDENTIAL DU/HECTARE.	92.	7.	27.	10.
2 TO 8 RESIDENTIAL DU/HECTARE......	3481.	1487.	1031.	569.
9 AND MORE RESIDENTIAL DU/HECTARE..	8498.	1716.	1364.	356.
RETAIL AND WHOLESALE COMMERCIAL....	1831.	186.	107.	12.
COMMERCIAL OUTDOOR RECREATION......	106.	12.	7.	0.
ELEMENTARY AND SECONDARY SCHOOLS...	739.	199.	95.	37.
COLLEGES AND UNIVERSITIES..........	74.	36.	47.	9.
OTHER EDUCATION....................	57.	0.	5.	1.
HOSPITALS, REHAB. CENTERS, ETC.....	66.	19.	17.	5.
MILITARY INSTALLATIONS.............	61.	8.	0.	0.
OTHER PUBLIC INSTITUTIONS..........	85.	10.	12.	3.
RESEARCH CENTERS...................	76.	25.	4.	0.
LIGHT INDUSTRY.....................	674.	29.	28.	5.
HEAVY INDUSTRY.....................	2338.	4.	16.	6.
TRANSPORTATION AND UTILITIES.......	14.	2.	0.	0.
HIGHWAY............................	785.	230.	173.	35.
RAILWAY............................	198.	11.	0.	0.
AIRPORTS...........................	931.	5.	0.	0.
PORT FACILITIES....................	8.	0.	0.	0.
POWER TRANSMISSION.................	155.	4.	0.	0.
SEWAGE TREATMENT...................	26.	3.	3.	0.
COMMERCIAL/INDUSTRIAL COMPLEXES....	93.	0.	0.	0.
MIXED URBAN AND BUILT-UP...........	177.	20.	21.	23.
EXTENSIVE RECREATION...............	29.	9.	5.	3.
GOLF COURSES.......................	505.	193.	52.	12.
RACETRACKS.........................	72.	5.	0.	0.
CEMETERIES.........................	378.	74.	13.	5.
PARKS..............................	172.	36.	13.	4.
OPEN SPACE - URBAN.................	158.	29.	36.	4.
CROPLAND AND PASTURE...............	0.	0.	4.	0.
IRRIGATED CROPLAND.................	2471.	766.	514.	297.
NON-IRRIGATED CROPLAND.............	811.	239.	306.	182.
PASTURE............................	242.	280.	680.	383.
ORCHARDS OR GROVES.................	41.	22.	17.	2.
FLORICULTURE - GREENHOUSES.........	110.	24.	21.	5.
FARMSTEADS AND OTHER AGRICULTURE...	50.	36.	69.	49.
HERBACEOUS RANGELAND...............	4886.	2524.	5670.	5834.
SHRUB AND BRUSH RANGELAND..........	2.	2.	2.	7.
CHAPARRAL..........................	2203.	741.	1120.	3278.
COASTAL SHRUB......................	5628.	1735.	1609.	1564.
MIXED RANGELAND....................	718.	356.	629.	1028.
REDWOOD FOREST.....................	6605.	2676.	2745.	7836.
PINE FOREST........................	232.	52.	22.	10.
EVERGREEN MIXED FOREST.............	4492.	1617.	3080.	5417.
STREAMS AND CANALS.................	140.	4.	0.	0.
LAKES..............................	16.	9.	8.	4.
RESERVOIRS.........................	118.	30.	35.	11.
BAYS AND ESTUARIES.................	114.	4.	0.	0.
FORESTED WETLANDS..................	8.	11.	8.	0.
NON-FORESTED WETLANDS..............	1223.	32.	9.	0.
BEACHES............................	73.	16.	23.	7.
SAND OTHER THAN BEACHES............	72.	0.	3.	9.
BARE EXPOSED ROCK..................	5.	1.	2.	5.
STRIP MINES/QUARRIES/GRAVEL PITS...	63.	22.	35.	12.
TRANSITIONAL AREAS.................	14.	23.	14.	1.
SANITARY LAND FILL.................	157.	17.	1.	0.
OTHER TRANSITIONAL.................	1360.	78.	99.	34.
MIXED BARREN LAND..................	4.	3.	2.	0.

TABLE 18:
AREA (IN HECTARES) FOR CATEGORIES OF
DAM FAILURE INUNDATION
BY LAND USE TYPE

LAND USE TYPE	WITHIN	OUTSIDE
1 AND FEWER RESIDENTIAL DU/HECTARE.	0.	136.
2 TO 8 RESIDENTIAL DU/HECTARE......	298.	6296.
9 AND MORE RESIDENTIAL DU/HECTARE..	2005.	10134.
RETAIL AND WHOLESALE COMMERCIAL....	258.	1894.
COMMERCIAL OUTDOOR RECREATION......	36.	89.
ELEMENTARY AND SECONDARY SCHOOLS...	92.	978.
COLLEGES AND UNIVERSITIES..........	1.	165.
OTHER EDUCATION....................	0.	63.
HOSPITALS, REHAB. CENTERS, ETC.....	2.	105.
MILITARY INSTALLATIONS.............	0.	69.
OTHER PUBLIC INSTITUTIONS..........	12.	98.
RESEARCH CENTERS...................	5.	100.
LIGHT INDUSTRY.....................	12.	726.
HEAVY INDUSTRY.....................	0.	2364.
TRANSPORTATION AND UTILITIES.......	2.	14.
HIGHWAY............................	102.	1124.
RAILWAY............................	15.	194.
AIRPORTS...........................	0.	936.
PORT FACILITIES....................	0.	8.
POWER TRANSMISSION.................	50.	109.
SEWAGE TREATMENT...................	3.	29.
COMMERCIAL/INDUSTRIAL COMPLEXES....	44.	49.
MIXED URBAN AND BUILT-UP...........	36.	205.
EXTENSIVE RECREATION...............	6.	42.
GOLF COURSES.......................	74.	709.
RACETRACKS.........................	63.	14.
CEMETERIES.........................	0.	470.
PARKS..............................	52.	173.
OPEN SPACE - URBAN.................	47.	180.
CROPLAND AND PASTURE...............	0.	4.
IRRIGATED CROPLAND.................	182.	3879.
NON-IRRIGATED CROPLAND.............	0.	1538.
PASTURE............................	0.	1585.
ORCHARDS OR GROVES.................	0.	82.
FLORICULTURE - GREENHOUSES.........	19.	141.
FARMSTEADS AND OTHER AGRICULTURE...	12.	192.
HERBACEOUS RANGELAND...............	228.	18736.
SHRUB AND BRUSH RANGELAND..........	0.	13.
CHAPARRAL..........................	8.	7334.
COASTAL SHRUB......................	14.	10522.
MIXED RANGELAND....................	11.	2720.
REDWOOD FOREST.....................	142.	19722.
PINE FOREST........................	0.	316.
EVERGREEN MIXED FOREST.............	182.	14643.
STREAMS AND CANALS.................	45.	99.
LAKES..............................	0.	37.
RESERVOIRS.........................	4.	190.
BAYS AND ESTUARIES.................	13.	105.
FORESTED WETLANDS..................	0.	27.
NON-FORESTED WETLANDS..............	157.	1114.
BEACHES............................	3.	116.
SAND OTHER THAN BEACHES............	0.	84.
BARE EXPOSED ROCK..................	0.	13.
STRIP MINES/QUARRIES/GRAVEL PITS...	0.	132.
TRANSITIONAL AREAS.................	0.	52.
SANITARY LAND FILL.................	14.	161.
OTHER TRANSITIONAL.................	448.	1123.
MIXED BARREN LAND..................	0.	9.

TABLE 19:
AREA (IN HECTARES) FOR CATEGORIES OF
COMPOSITE MAXIMUM EARTHQUAKE DAMAGE
WITHOUT DAM FAILURE
FOR WOOD FRAME DWELLINGS

LAND USE TYPE	PERCENT DAMAGE						
	0 - 2%	3 - 5%	6 -10%	11-15%	16-20%	21-25%	26+%
1 AND FEWER RESIDENTIAL DU/HECTARE.	84.	9.	29.	8.	5.	1.	0.
2 TO 8 RESIDENTIAL DU/HECTARE......	1784.	1725.	1049.	889.	966.	155.	0.
9 AND MORE RESIDENTIAL DU/HECTARE..	3390.	4137.	1150.	1586.	1351.	320.	0.
RETAIL AND WHOLESALE COMMERCIAL....	309.	1042.	164.	501.	114.	6.	0.
COMMERCIAL OUTDOOR RECREATION......	24.	64.	14.	20.	3.	0.	0.
ELEMENTARY AND SECONDARY SCHOOLS...	263.	386.	43.	194.	159.	25.	0.
COLLEGES AND UNIVERSITIES..........	86.	13.	43.	0.	20.	4.	0.
OTHER EDUCATION....................	41.	13.	5.	2.	1.	1.	0.
HOSPITALS, REHAB. CENTERS, ETC.....	9.	64.	15.	10.	8.	1.	0.
MILITARY INSTALLATIONS.............	10.	8.	3.	44.	4.	0.	0.
OTHER PUBLIC INSTITUTIONS..........	35.	47.	11.	4.	10.	3.	0.
RESEARCH CENTERS...................	40.	56.	3.	5.	1.	0.	0.
LIGHT INDUSTRY.....................	71.	485.	54.	123.	3.	0.	0.
HEAVY INDUSTRY.....................	13.	838.	152.	1351.	10.	0.	0.
TRANSPORTATION AND UTILITIES.......	1.	0.	2.	6.	7.	0.	0.
HIGHWAY............................	115.	527.	52.	288.	227.	14.	0.
RAILWAY............................	15.	166.	0.	27.	1.	0.	0.
AIRPORTS...........................	3.	85.	63.	784.	1.	0.	0.
PORT FACILITIES....................	0.	2.	6.	0.	0.	0.	0.
POWER TRANSMISSION.................	4.	44.	37.	68.	6.	0.	0.
SEWAGE TREATMENT...................	0.	14.	8.	7.	0.	3.	0.
COMMERCIAL/INDUSTRIAL COMPLEXES....	0.	57.	36.	0.	0.	0.	0.
MIXED URBAN AND BUILT-UP...........	17.	97.	25.	82.	16.	4.	0.
EXTENSIVE RECREATION...............	2.	12.	0.	16.	15.	1.	0.
GOLF COURSES.......................	100.	336.	38.	236.	47.	5.	0.
RACETRACKS.........................	3.	59.	0.	15.	0.	0.	0.
CEMETERIES.........................	30.	258.	24.	136.	22.	0.	0.
PARKS..............................	56.	64.	32.	32.	38.	3.	0.
OPEN SPACE - URBAN.................	39.	49.	71.	36.	25.	7.	0.
CROPLAND AND PASTURE...............	0.	0.	4.	0.	0.	0.	0.
IRRIGATED CROPLAND.................	1012.	1293.	466.	930.	317.	30.	0.
NON-IRRIGATED CROPLAND.............	441.	275.	219.	325.	177.	101.	0.
PASTURE............................	249.	231.	931.	117.	55.	2.	0.
ORCHARDS OR GROVES.................	6.	10.	1.	4.	56.	5.	0.
FLORICULTURE - GREENHOUSES.........	42.	62.	23.	29.	3.	1.	0.
FARMSTEADS AND OTHER AGRICULTURE...	37.	43.	65.	24.	34.	1.	0.
HERBACEOUS RANGELAND...............	4281.	1914.	6818.	2875.	2436.	590.	0.
SHRUB AND BRUSH RANGELAND..........	4.	1.	8.	0.	0.	0.	0.
CHAPARRAL..........................	2063.	686.	3641.	596.	336.	20.	0.
COASTAL SHRUB......................	6084.	1107.	1754.	804.	678.	109.	0.
MIXED RANGELAND....................	502.	224.	617.	434.	549.	405.	0.
REDWOOD FOREST.....................	8370.	1063.	7973.	1724.	572.	160.	0.
PINE FOREST........................	177.	97.	13.	16.	12.	1.	0.
EVERGREEN MIXED FOREST.............	3009.	1701.	5092.	2215.	1970.	719.	0.
STREAMS AND CANALS.................	0.	67.	45.	31.	1.	0.	0.
LAKES..............................	2.	8.	7.	10.	9.	1.	0.
RESERVOIRS.........................	25.	37.	21.	58.	45.	8.	0.
BAYS AND ESTUARIES.................	0.	29.	45.	44.	0.	0.	0.
FORESTED WETLANDS..................	0.	0.	0.	0.	27.	0.	0.
NON-FORESTED WETLANDS..............	4.	317.	262.	619.	60.	2.	0.
BEACHES............................	14.	29.	37.	17.	16.	6.	0.
SAND OTHER THAN BEACHES............	4.	28.	12.	25.	3.	12.	0.
BARE EXPOSED ROCK..................	4.	4.	5.	0.	0.	0.	0.
STRIP MINES/QUARRIES/GRAVEL PITS...	69.	14.	20.	14.	15.	0.	0.
TRANSITIONAL AREAS.................	22.	0.	14.	1.	15.	0.	0.
SANITARY LAND FILL.................	12.	86.	52.	25.	0.	0.	0.
OTHER TRANSITIONAL.................	79.	527.	523.	300.	135.	7.	0.
MIXED BARREN LAND..................	6.	2.	1.	0.	0.	0.	0.

TABLE 20:
AREA (IN HECTARES) FOR CATEGORIES OF
MAXIMUM GROUND SHAKING INTENSITY
BY CENSUS TRACT

SAN FRANCISCO INTENSITY SCALE

	<E	E	D	C	B	A
6001.00	0.	973.	108.	705.	1.	0.
6002.00	0.	9.	55.	50.	0.	0.
6003.00	0.	147.	0.	69.	0.	0.
6004.00	0.	32.	0.	60.	0.	0.
6005.00	0.	60.	0.	73.	0.	0.
6006.00	0.	0.	0.	71.	4.	0.
6007.00	0.	7.	0.	76.	0.	0.
6008.00	0.	0.	0.	28.	31.	0.
6009.00	0.	0.	0.	63.	140.	6.
6010.00	0.	0.	0.	0.	46.	234.
6011.00	0.	0.	0.	0.	70.	23.
6012.00	0.	0.	0.	106.	108.	1.
6013.00	0.	0.	0.	108.	5.	0.
6014.00	0.	0.	0.	0.	126.	16.
6015.00	0.	0.	0.	0.	32.	67.
6016.00	0.	1.	5.	417.	273.	231.
6017.00	0.	0.	0.	4.	91.	23.
6018.00	0.	0.	0.	18.	151.	17.
6019.00	0.	0.	8.	201.	12.	0.
6020.00	0.	0.	103.	78.	5.	0.
6021.00	0.	0.	10.	42.	0.	0.
6022.00	0.	0.	3.	92.	0.	0.
6023.00	0.	59.	30.	638.	252.	0.
6024.00	0.	0.	0.	30.	228.	9.
6025.00	0.	0.	0.	0.	11.	118.
6026.00	0.	0.	0.	0.	2.	143.
6027.00	0.	0.	7.	46.	29.	91.
6028.00	0.	0.	0.	8.	18.	105.
6029.00	0.	0.	4.	3.	39.	65.
6030.00	0.	0.	122.	29.	213.	46.
6031.00	0.	256.	311.	138.	147.	1.
6032.00	10.	324.	10.	156.	5.	0.
6033.00	0.	299.	305.	207.	4.	0.
6034.00	0.	192.	450.	249.	71.	2.
6035.00	0.	0.	44.	8.	0.	51.
6036.00	0.	0.	10.	23.	22.	159.
6037.00	0.	0.	0.	0.	1.	160.
6038.00	0.	0.	0.	10.	27.	270.
6039.00	0.	0.	0.	1.	141.	32.
6040.00	0.	0.	0.	0.	79.	5.
6041.00	0.	0.	0.	133.	217.	8.
6042.00	0.	0.	0.	83.	16.	0.
6043.00	0.	0.	0.	103.	725.	32.
6044.00	0.	0.	0.	23.	169.	8.
6045.00	0.	0.	0.	4.	149.	8.
6046.00	0.	0.	0.	6.	30.	102.

SAN FRANCISCO INTENSITY SCALE

	<E	E	D	C	B	A
6047.00	0.	0.	0.	24.	53.	33.
6048.00	0.	0.	0.	0.	95.	5.
6049.00	0.	0.	0.	3.	80.	72.
6050.00	0.	0.	11.	119.	164.	81.
6051.00	0.	0.	17.	14.	218.	7.
6052.00	0.	0.	0.	37.	53.	1.
6053.00	0.	0.	67.	36.	3.	0.
6054.00	0.	0.	3.	80.	184.	0.
6055.00	0.	0.	30.	74.	3.	0.
6056.00	0.	0.	382.	370.	86.	15.
6057.00	0.	0.	468.	268.	13.	0.
6058.00	0.	0.	122.	0.	0.	0.
6059.00	0.	0.	45.	32.	2.	0.
6060.00	0.	0.	36.	25.	16.	0.
6061.00	0.	9.	9.	229.	1.	9.
6062.00	0.	0.	14.	95.	12.	0.
6063.00	0.	0.	31.	61.	10.	0.
6064.00	0.	0.	21.	62.	8.	0.
6065.00	0.	0.	85.	53.	0.	0.
6066.00	0.	0.	2.	58.	53.	0.
6067.00	0.	0.	135.	56.	6.	0.
6068.00	0.	0.	156.	145.	5.	1.
6069.00	0.	0.	8.	214.	191.	62.
6070.00	0.	1.	199.	14.	6.	0.
6071.00	0.	11.	96.	17.	0.	0.
6072.00	0.	0.	46.	49.	11.	0.
6073.00	0.	0.	39.	85.	2.	0.
6074.00	0.	0.	19.	91.	7.	0.
6075.00	0.	0.	3.	133.	58.	0.
6076.00	0.	0.	0.	132.	5.	0.
6077.00	0.	0.	0.	170.	3.	0.
6078.00	0.	0.	0.	114.	2.	0.
6079.00	0.	0.	0.	120.	9.	0.
6080.00	0.	0.	0.	658.	66.	6.
6081.00	0.	0.	0.	73.	0.	0.
6082.00	0.	0.	0.	102.	0.	0.
6083.00	0.	0.	0.	69.	4.	0.
6084.00	0.	0.	0.	123.	0.	0.
6085.00	0.	0.	4.	159.	19.	0.
6086.00	0.	0.	23.	121.	7.	9.
6087.00	0.	62.	154.	39.	0.	0.
6088.00	0.	8.	251.	24.	8.	0.
6089.00	0.	26.	295.	43.	3.	0.
6090.00	0.	39.	68.	28.	0.	0.
6091.00	0.	9.	20.	306.	3.	1.
6092.00	0.	52.	63.	94.	0.	0.

SAN FRANCISCO INTENSITY SCALE

	<E	E	D	C	B	A
6093.00	0.	1.	76.	17.	0.	0.
6094.00	0.	6.	64.	36.	0.	0.
6095.00	0.	9.	149.	30.	0.	0.
6096.00	0.	15.	817.	436.	322.	70.
6097.00	0.	0.	337.	203.	25.	6.
6098.00	0.	2.	138.	80.	0.	0.
6099.00	0.	11.	66.	51.	0.	0.
6100.00	0.	2.	120.	15.	2.	0.
6101.00	0.	0.	8.	44.	0.	0.
6102.00	0.	0.	2.	351.	2.	12.
6103.00	0.	0.	0.	1608.	1552.	33.
6104.00	0.	0.	0.	103.	0.	0.
6105.00	0.	0.	0.	125.	0.	0.
6106.00	0.	0.	3.	194.	0.	0.
6107.00	0.	0.	1.	110.	0.	0.
6108.00	0.	0.	19.	34.	1.	0.
6109.00	0.	0.	39.	35.	34.	0.
6110.00	0.	1.	82.	57.	0.	0.
6111.00	0.	0.	252.	79.	0.	0.
6112.00	0.	0.	0.	111.	0.	0.
6113.00	0.	0.	67.	97.	15.	0.
6114.00	0.	0.	421.	446.	12.	0.
6115.00	0.	0.	150.	267.	0.	0.
6116.00	0.	0.	0.	89.	0.	0.
6117.00	0.	0.	21.	487.	505.	0.
6118.00	0.	0.	44.	287.	187.	0.
6119.00	0.	0.	6.	224.	0.	0.
6120.00	0.	0.	68.	58.	0.	0.
6121.00	0.	0.	85.	18.	0.	0.
6122.00	0.	0.	107.	88.	0.	0.
6123.00	0.	0.	0.	41.	0.	0.
6124.00	0.	0.	82.	72.	0.	0.
6125.00	0.	0.	77.	6.	0.	0.
6126.00	0.	0.	129.	0.	0.	0.
6127.00	0.	0.	126.	4.	0.	0.
6128.00	0.	0.	128.	36.	0.	0.
6129.00	0.	0.	74.	61.	0.	0.
6130.00	0.	5.	80.	694.	119.	4.
6131.00	0.	3.	5.	110.	0.	0.
6132.00	0.	1.	344.	1111.	887.	1180.
6133.00	0.	0.	319.	453.	163.	0.
6134.00	0.	0.	864.	1580.	808.	1182.
6135.00	677.	4504.	7827.	4182.	1095.	1496.
6136.00	548.	594.	148.	347.	409.	0.
6137.00	72.	131.	636.	687.	18.	0.
6138.00	1.	13561.	18261.	8089.	6952.	0.

APPENDIX K

A GUIDE TO

ABAG'S

EARTHQUAKE HAZARD MAPPING

CAPABILITY

MARCH 1980

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ACKNOWLEDGEMENTS:

We would like to thank those many people at USGS and working for cities and counties in the Bay Area who took the time to review the many papers that form the basis for this guide.

TABLE OF CONTENTS

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INTRODUCTION

PURPOSES

Since February 1979, ABAG has been developing a series of computer-based map files showing various basic data maps related to earthquakes and several maps derived from those illustrating various earthquake hazards. The project was started for two reasons:

- o to provide information that could be used by local governments in their seismic safety and safety programs
- o to provide an input to various other planning programs at ABAG.

FORMAT

This project, unlike many that result in the publication of a final report, will be continuing and various map files will be expanded or upgraded. Therefore, this guide has been designed as a loose-leaf folder so that pages or sections can be replaced or added as ABAG's earthquake hazard mapping capability changes and expands.

The guide contains this introduction and three main sections:

- o a set of sheets describing each of the basic data map files and a cover sheet for that section
- o a set of sheets describing each of the hazard map files and a cover sheet for them
- o a set of sheets describing several applications for the map files (also with a cover sheet).

The guide has also been designed to include a set of the working papers that have been developed to further describe the assumptions that were made and the data used to develop the hazard maps. A sheet summarizing the Working Papers is at the end of the report.

EARTHQUAKE MAPPING AND ABAG'S EARTHQUAKE PREPAREDNESS PROGRAM

ABAG's concerns about earthquake safety grew out of three separate, but related, programs. ABAG served as a liaison with other regional planning agencies and with county and local governments in the San Francisco Bay Region Environment and Resources Planning Study. The study, begun in January 1970, was jointly sponsored by the U.S. Geological Survey and the Department of Housing and Urban Development. ABAG completed a report for this study in February 1976, Quantitative Land Capability Analysis - A Method of Applying Earth Science Informion to Planning and Decision Making. The report describes the use of benefit-cost analysis in weighing the relatve importance of selected earth science hazards, constraints and resources. The report was published as U.S.G.S. Professional Paper 945 in 1979.

During the same period, ABAG prepared a booklet entitled Hazards Evaluation for Disaster Preparedness Planning summarizing the results of a study on evaluating hazards sponsored by the Defense Civil Preparedness Agency of the Department of Defense, completed in August 1975. The project focused on developing a standard method for evaluating earthquakes and several other natural and man-made sources of disasters.

The findings of these reports, as well as other related information, were given to ABAG's member governments in February, 1976 at a General Assembly entitled "On Shaky Ground". ABAG's General Assembly indicated that a program to help prepare the region for coping with major earthquakes is extremely important. Such a program also has been supported by ABAG's Executive Board, Work Program and Coordination Committee and various other committees.

These desires led to the revision of ABAG's General Plan to include several objectives dealing with improving seismic safety and a series of actions to accomplish these objectives focusing on:

- o incorporating seismic safety concerns into ABAG's plan and project review function
- o supporting or advocating legislation at the State and federal level
- o providing assistance to ABAG's member governments in improving their safety and seismic safety programs

The service activities have led to several recent projects, including:

- o a survey of local regulations related to geologic and hydrologic hazards, constraints and resources
- o a survey of geotechnical study costs
- o a review of earthquake insurance issues
- o an extensive review of earthquake hazards and local government liability

The study of liability also resulted in ABAG's advocacy of State legislation that was passed by the legislature and signed by the Governor in 1979.

This earthquake mapping project is providing strong technical support for the Earthquake Preparedness Program. It is enabling ABAG staff to conduct land capability type analyses not only for all nine Bay Area counties, but also at the fine resolution of one hectare (2-1/2 acres).

These overlaying and modeling capabilities are extremely important not only for creating the hazard maps in the first place, but also for combining earthquake hazard concerns with other physical and social constraints for site evaluation and impacts analyses.

EARTHQUAKE MAPPING AND THE BAY AREA SPATIAL INFORMATION SYSTEM (BASIS)

This project is closely tied to ABAG's BASIS program. A major objective of BASIS is to develop a regional geographic data base that can be directly used in local, as well as regional, planning applications. It was developed to tie together the data development and map analysis capabilities that had previously been done by outside agencies using different computers and different resolutions. (The land capability study that used a system at the University of California at Davis was one such application.)

BASIS is structured around an array of grid cells, each representing a land area of one hectare (100 meters square) in the UTM coordinate system. It requires over two million of these cells to cover the nine-county Bay Region. Each cell on the ground corresponds to one unit of computer storage; the unit contains data codes representing the characteristics of that cell. Data can be acquired either by reading a tape or by digitizing a map. BASIS is capable of using data based on other coordinated systems (such as longitude/latitude or LANDSAT reference points) by mathematically transforming these reference systems to a common UTM base. This project greatly increases the data available for each cell. The basic data map files listed in the main body of this guide are a product of direct data acquisition.

Much of the power of BASIS lies in its ability to manipulate the basic data map files. A composite of many data sets can be produced through an overlay or modeling process, and can include distance searches or other calculations. Most of the hazard map files are the product of these processes.

BASIS runs on ABAG's V76 computer system, which can handle data transfer to or from most other computer systems. The computer configuration includes a digitizer for encoding mapped data, an electrostatic plotter for producing computer maps, and terminals for on-line access to the data base. The V76 computer contains 128K words of fast semiconductor memory and special operations for handling mathematical operations of high speeds. Six terminals on-line to the computer are used for data entry and user interaction. Data storage is on one 88M byte disk drive and one nine-track tape drive.

BASIS DATA MAP FILES

As of March 1980, the earthquake hazard maps are based on six basic data map files described on the following pages:

- o geology
- o faults
- o topography
- o landslides
- o tsunami inundation areas
- o dam failure inundation areas

In addition, a land use file has been created to illustrate some applications.

Each of the following sheets consists of five major sections describing various aspects of the map file on the front. The five sections include:

- o Coverage - the area of the region covered (including a map) and the resolution of the data
- o Source - the scale and name of the source used (if many sources are used a working paper containing the complete list may be referenced)
- o Major categories on map the categories in the file - are listed to the extent practicable
- o Used with other files to produce hazard files on - a cross-reference to the hazard map files using this basic data file
- o Limitations and future plans - limitations in coverage or accuracy are described, together with future plans to upgrade each file

A 1:1 million scale reproduction of the file appears on the back for illustration only. At this scale, a complete map explanation would be meaningless. Potential users should contact ABAG staff to obtain maps of their area of interest and an explanation for those maps.

There are other basic files in BASIS that have not been improved in conjunction with this earthquake mapping project. These files can be divided into two categories, files depicting the physical environment and those depicting the social environment:

PHYSICAL ENVIRONMENT

- o average annual precipitation - region-wide
- o vegetation - San Mateo County only
- o National Flood Insurance Program maps - unincorporated areas and some cities
- o flood-prone areas defined by U.S.G.S. in 1972 - region-wide
- o coastline features from U.S.G.S. 7-1/2 minute quadrangles - region-wide
- o soil associations (generalized from soils types) - region-wide
- o average yield from wells - region-wide
- o digital terrain tape elevations - region-wide.
- o slope stability (generalized to 25 hectare resolution) - region-wide
- o air quality problem areas - region-wide
- o water quality problem areas - region-wide

SOCIAL ENVIRONMENT

- o 1970 census tracts - region-wide
- o county boundaries - region-wide
- o city sphere-of-influence boundaries - region-wide
- o airports, seaports, vacant industrial lands - region-wide
- o some transportation data
- o landfill sites and service areas

GEOLOGY

BASIC DATA MAP FILE

COVERAGE: All Bay Area counties with San Mateo County in more detail

March 1980
Hectare resolution

SOURCE:
SCALE: 1:62,500 (for basic geology) and 1:125,000 (for flatlands deposits)
NAME: U.S.G.S. Professional Paper 944--Flatlands deposits of the S.F. Bay Area; Geology Map of San Mateo County by Earl Brabb and Earl Pampeyan of U.S.G.S. (in press); various U.S.G.S. and C.D.M.G. maps of other counties generalized (see Working Paper #2 for more information).

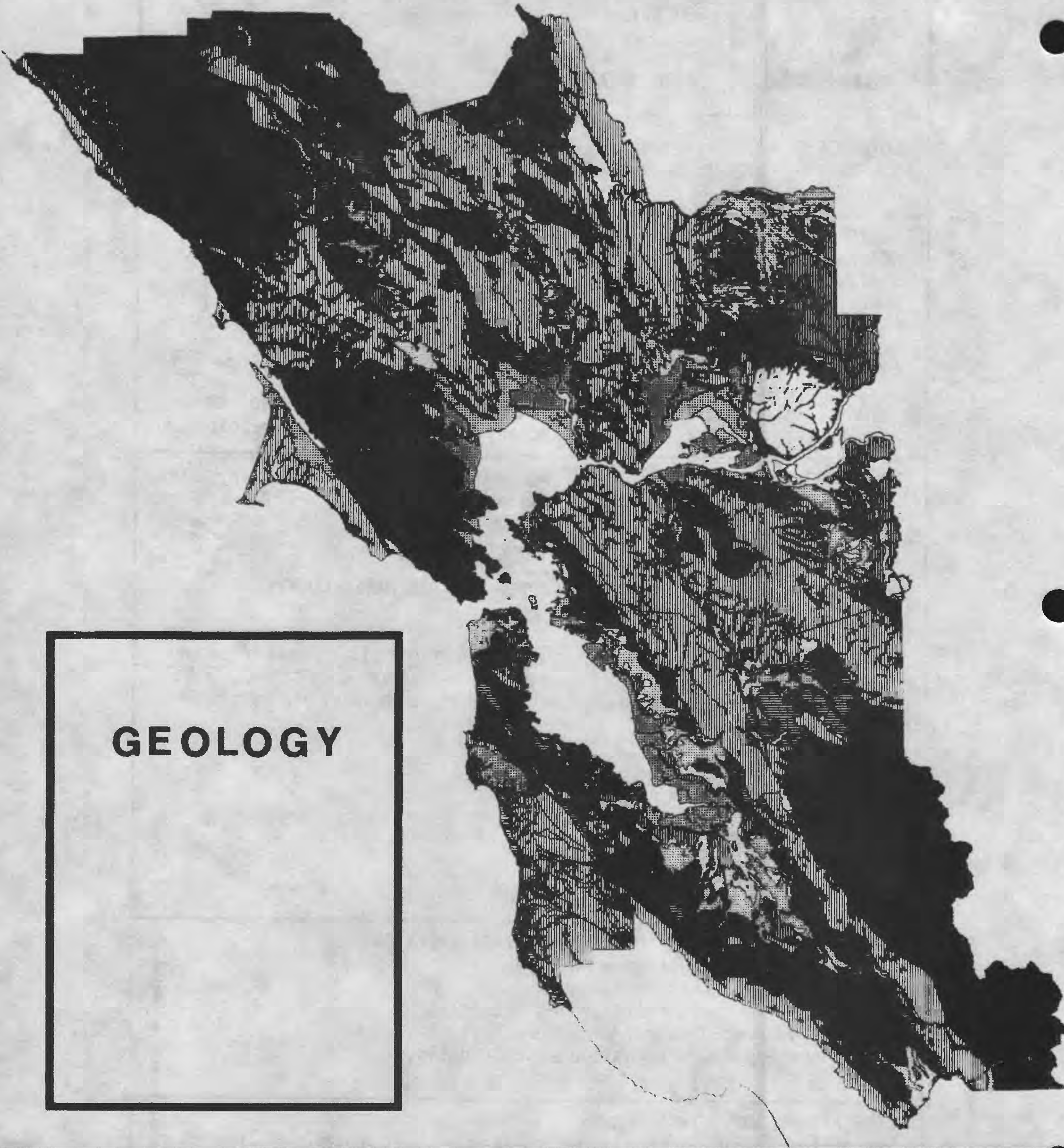
MAJOR CATEGORIES ON MAP:
Holocene stream channels
Holo. alluvium - coarse
Holo. alluvium - fine
Holo. basin deposits
Quaternary colluvium
Holo. beach and sand deps.
Holo. Bay mud
Artificial fill
Pleistocene sand
Pleis. marine terrace
Pleis. alluvium - coarse
Pleis. alluvium - fine
Late Pleis. alluvium
Early Pleis. alluvium
Colma Formation
Montezuma Hills Formation
Quaternary undivided (urban)
Franciscan Assemblage (General)
Granitic rocks (General)
Materials of Quat./Tertiary age (General)
Other Tertiary or older materials (General)

ADDED FOR SAN MATEO COUNTY:

The last four categories are broken into 47 geologic formations and members. For example, the Franciscan is subdivided into seven rock types.

USED WITH OTHER FILES TO PRODUCE HAZARD FILES ON:
- o maximum ground shaking intensity
- o risk of ground shaking damage
- o liquefaction susceptibility and potential
- o rainfall-induced landslide susceptibility
- o earthquake-induced landslide susceptibility

LIMITATIONS AND FUTURE PLANS:
The geology file currently is available only in detail for San Mateo County. The level of detail will be increased for fifteen 7-1/2 minute quadrangles of high development potential in 1980 and early 1981. Additional detailed geology will be added for other areas as time and money become available.



GEOLOGY

BASIS

BAY AREA SPATIAL INFORMATION SYSTEM

FAULTS

BASIC DATA MAP FILE

COVERAGE: All Bay Area counties and parts of adjacent counties

March 1980
Hectare resolution

SOURCE:
SCALE: Largely 1:24,000 with some at 1:60,000, 1:125,000, and 1:250,000
NAME: Special Studies Zones Maps prepared by the State Geologist and additional mapping of fault traces by U.S.G.S. personnel of faults they consider active or probably active. (See Working Paper #1 for a list of sources for the mapping used.)

MAJOR CATEGORIES ON MAP AS STUDY ZONES:

San Andreas*
Hayward*
Crosley*
Calaveras*
San Gregorio*
Maacama
Healdsburg*
Rodgers Creek*
Tolay*
Concord*
Green Valley*
Antioch*
Evergreen*
Pleasanton*
Serra
Silver Creek*
Piercy
Coyote Creek
Sargent*
Butano
Monte Vista*
Shannon

AS FAULT TRACES

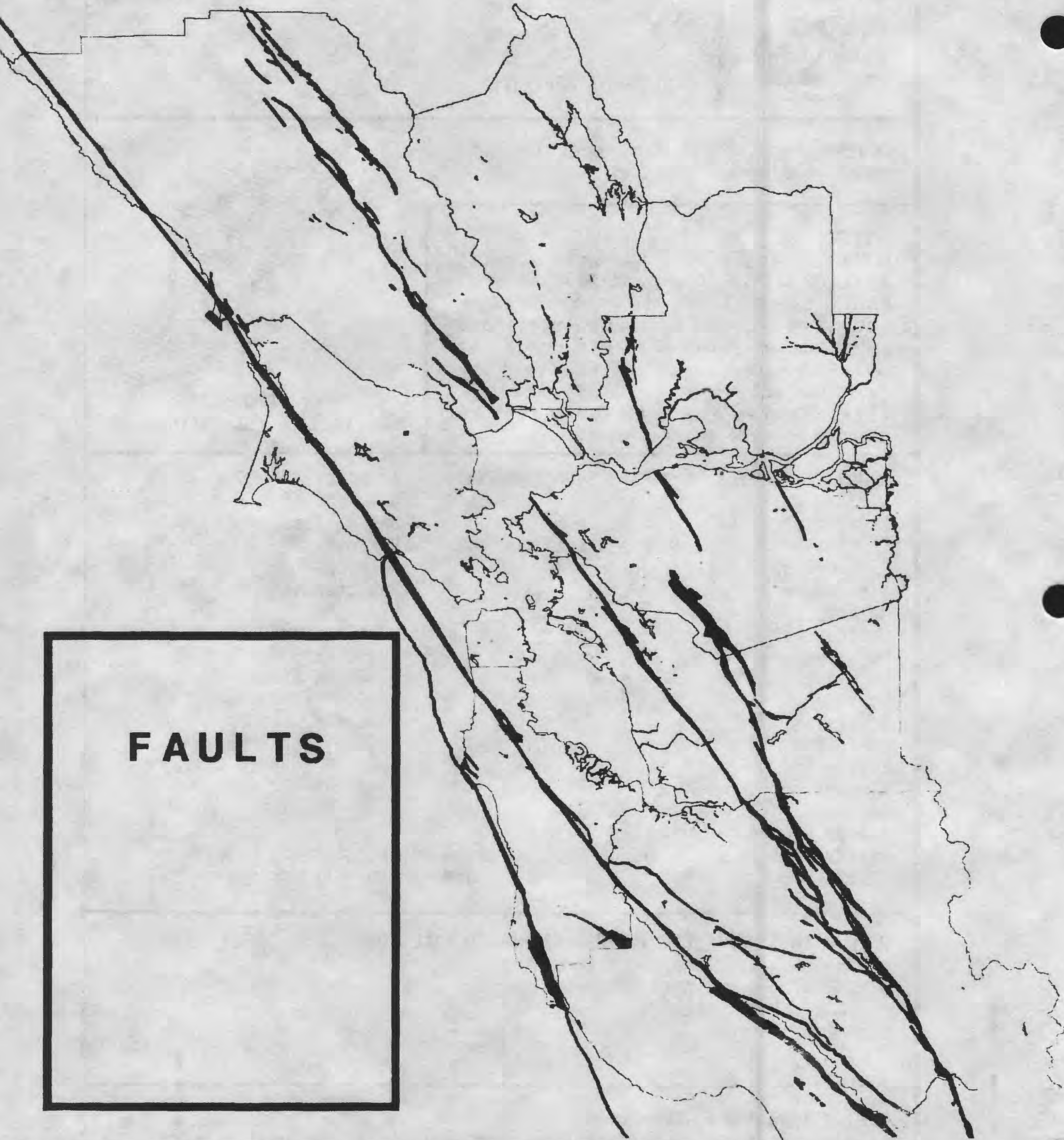
Greenville*
Las Positas*
Verona*
Berrocal*
San Joaquin*
Midway*
West Napa*
Cordelia*
Dunnigan Hills*
Faults near Trenton*
Maacama*
East of Santa Rosa*
East of Bennett Valley*
Zayante*

*included in intensity mapping (main faults only; no branches)

USED WITH OTHER FILES TO PRODUCE HAZARD FILES ON:

o maximum ground shaking intensity
o risk of ground shaking damage
o liquefaction potential
o surface rupture

LIMITATIONS AND FUTURE PLANS:
Changes in Special Studies Zones and in fault traces will be made as new information becomes available. Traces of faults mapped as Study Zones generally are not included. These traces could be added at a future time if a pressing need develops.



FAULTS

BASIS BAY AREA SPATIAL INFORMATION SYSTEM

TOPOGRAPHY

BASIC DATA MAP FILE

COVERAGE: San Mateo County only

SOURCE:
SCALE: Hectare resolution tapes

NAME: Digital terrain model tapes from U.S.G.S. with elevation accuracy of + or - 5 meters

March 1980
Hectare resolultion

MAJOR CATEGORIES ON MAP:
Average elevation, in meters, for each hectare

In addition, where the digital elevation model data is available, a program has been run to produce the maximum slope by using the maximum change in elevation between any given cell and the eight surrounding cells (allowing for the longer distance between the cell and those at the four diagonal corners). Other ways of producing slope files could be produced at the request of potential users. The slope file is currently stored as six categories:

0 - 5% slope	30 - 50% slope
5 - 15% slope	50 - 70% slope
15 - 30% slope	100+% slope

USED WITH OTHER FILES TO PRODUCE HAZARD FILES ON:
- o rainfall-induced landslide susceptibility
- o earthquake-induced landslide susceptibility

LIMITATIONS AND FUTURE PLANS:
The topography file is available only for San Mateo County. The file will be expanded to include fifteen 7-1/2 minute quandrangles of high development potential in 1980 and early 1981. The file will be expanded further as money becomes available. When using this file, one should remain aware of the limitations in elevation accuracy (within 5 meters) and spatial accuracy (one hectare).

PERCENT SLOPE

BASIS

LANDSLIDES

BASIC DATA MAP FILE

COVERAGE: San Mateo County only

SOURCE:
SCALE: 1:62,500
NAME: Preliminary Map of Landslide Deposits in San Mateo County, CA (1972) by Earl Brabb and Earl Pampeyan of U.S.G.S. (Misc. Field Studies Map MF-344) based on aerial photos with some field checking and some use of local government records and consultants reports.

March 1980
Hectare resolution

MAJOR CATEGORIES ON MAP:
Large landslide - definitely present
Large landslide - probably present
Large landslide - of questionable presence
Large landslide - definitely present, of questionable activity
Large landslide - probably present, of questionable activity
Large landslide - field checked and definitely active
Small landslide - mapped from aerial photographs
Small landslide - mapped in the field
Small landslide - subsidence of road or ground from public sources
Small landslide - active landslide mapped from public sources
Small landslide - active landslide mapped by private firm

In addition, an area of historic liquefaction (from the 1906 earthquake) in San Mateo County is included on this file based on data supplied by Les Youd of U.S.G.S.

USED WITH OTHER FILES TO PRODUCE HAZARD FILES ON:
- o rainfall-induced landslide susceptibility
- o earthquake-induced landslide susceptibility
- o liquefaction susceptibility and potential (the area of historic liquefaction)

LIMITATIONS AND FUTURE PLANS:
The file is available only for San Mateo County. The file will be expanded to include fifteen 7-1/2 minute quadrangles of high development potential in 1980 and early 1981. The file will be expanded further as time and money become available. The file has been set up to allow for the inclusion of data from local government files and consultants reports. This data, even for San Mateo Co., is out of date.

LANDSLIDES

BASIS

TSUNAMI INUNDATION AREAS

BASIC DATA MAP FILE

COVERAGE: All nine Bay Area counties

SOURCE:
SCALE: 1:125,500

NAME: Map Showing Areas of Potential Inundation by Tsunamis in the San Francisco Bay Region, CA (1972) by J.R. Ritter and W.R. Dupre of U.S.G.S. (Misc. Field Studies Map MF-480) based on a 500-year event. See Working Paper #6.

March 1980
Hectare resolution

MAJOR CATEGORIES ON MAP:

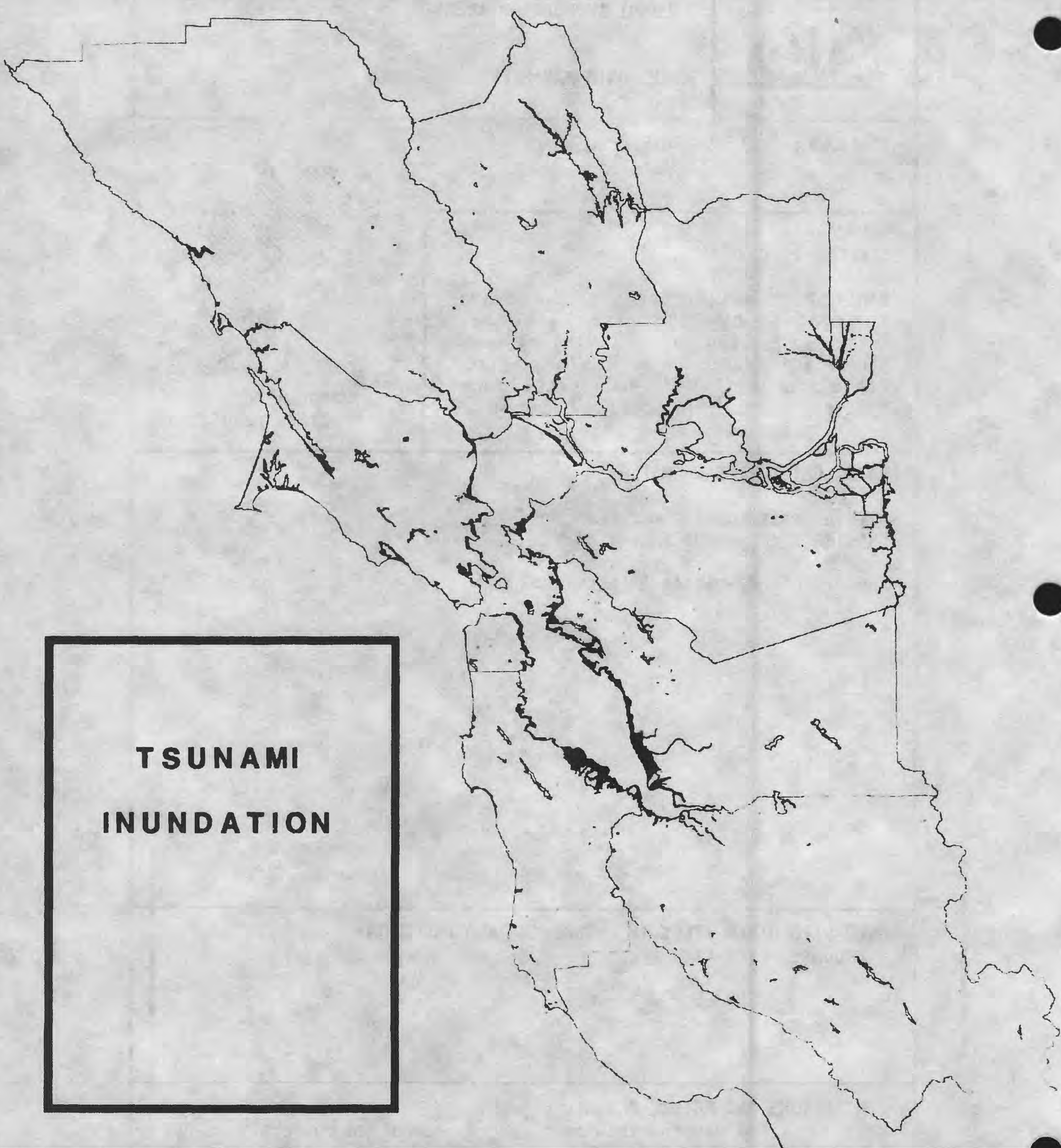
Within areas to be inundated
Outside areas to be inundated

(no depth information is provided)

USED WITH OTHER FILES TO PRODUCE HAZARD FILES ON:
o tsunami inundation areas

LIMITATIONS AND FUTURE PLANS:
More detailed mapping showing depth of inundation currently is not available in usable form. However, special studies being done in conjunction with the Federal Flood Insurance Program should be available by early 1981. The possibility of replacing this file with more detailed information will be examined at that time.

TSUNAMI INUNDATION



BASIS

BAY AREA SPATIAL INFORMATION SYSTEM

DAM FAILURE INUNDATION AREAS

BASIC DATA MAP FILE

COVERAGE: All nine Bay Area counties

March 1980
Hectare resolution

SOURCE:
SCALE: Originals from 1:2,400 to 1:24,000 all redrafted at 1:24,000
NAME: Maps submitted by dam owners to the California Office of Emergency Services to comply with the California Dam Safety Act (Section 8589.5 of the Government Code) for those dams or reservoirs whose total failure would cause injury or loss of life.

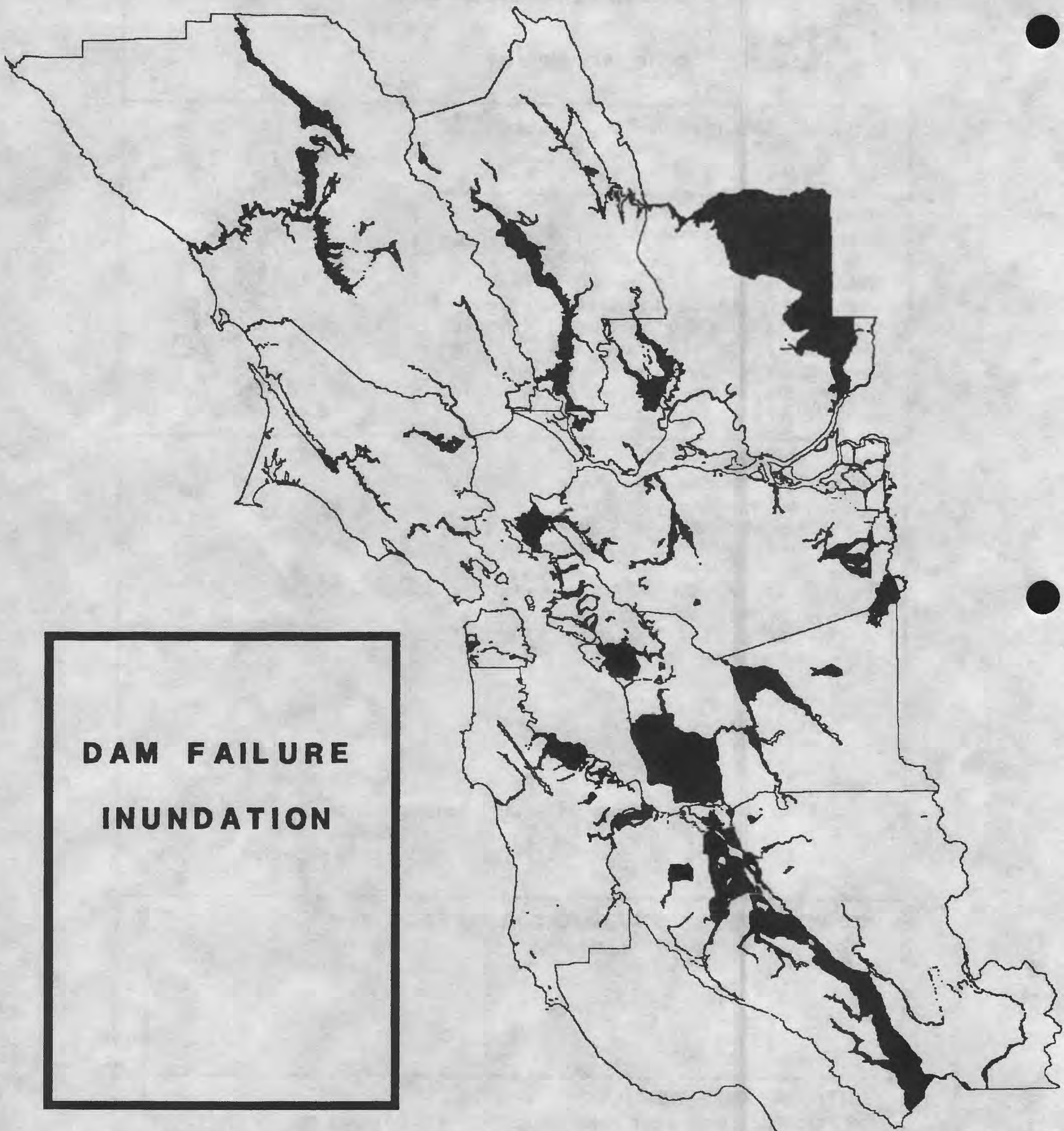
MAJOR CATEGORIES ON MAP:
For each of the 134 dams where inundation maps were required:
- within the inundation area
- outside of the inundation area
- (no depth information is provided)

The dams for which maps are provided include:
- 28 in Alameda County
- 24 in Contra Costa County
- 4 in Marin County
- 16 in Napa County
- 6 in San Francisco
- 11 in San Mateo County
- 28 in Santa Clara County
- 9 in Solano County
- 7 in Sonoma County
- 1 from Mendocino County affecting Sonoma County

A complete list of the dams is included in Working Paper #7.

USED WITH OTHER FILES TO PRODUCE HAZARD FILES ON:
o dam failure inundation areas

LIMITATIONS AND FUTURE PLANS:
The State Department of Water Resources established the criteria to be used by the dam owners to produce the maps and reviewed the completed maps for compliance with the criteria. The file does not contain information on depth of inundation although this information is available from some of the dam owners.



BASIS BAY AREA SPATIAL INFORMATION SYSTEM

LAND USE--1975-1976

BASIC DATA MAP FILE

COVERAGE: San Mateo County only

March 1980
Hectare resolution

SOURCE:
SCALE: 1:24,000

NAME: Land Use and Land Cover Maps prepared by U.S.G.S. showing four levels of land use categories; the maps are published as U.S.G.S. Open File Maps 78-738 to 78-755 and use the classification of Anderson and others of U.S.G.S. described in Prof. Paper 964.

MAJOR CATEGORIES ON MAP:

Urban or Built-up Land
- Residential
  - 3 sub-categories
- Commercial and services
  - 7 sub-categories with 1 further subdivided
- Industrial
  - 2 sub-categories
- Transportation, communication and utilities
  - 6 sub-categories
- Commercial and industrial complexes
- Mixed urban or built-up land
- Other urban or built-up land
  - 4 sub-categories with 1 further subdivided

Agricultural Land
- Cropland and pasture
  - 2 subcategories with 1 further subdivided
- Orchards, groves, vineyards, nurseries and ornamental horticulture
  - 3 sub-categories
- Confined feeding operations
- Other agricultural land

Rangeland
- Herbaceous rangeland
- Shrub and brush rangeland
  - 2 sub-categories
- Mixed rangeland

Forest Land
- Deciduous forest land
- Evergreen forest land
  - 3 sub-categories
- Mixed forest land

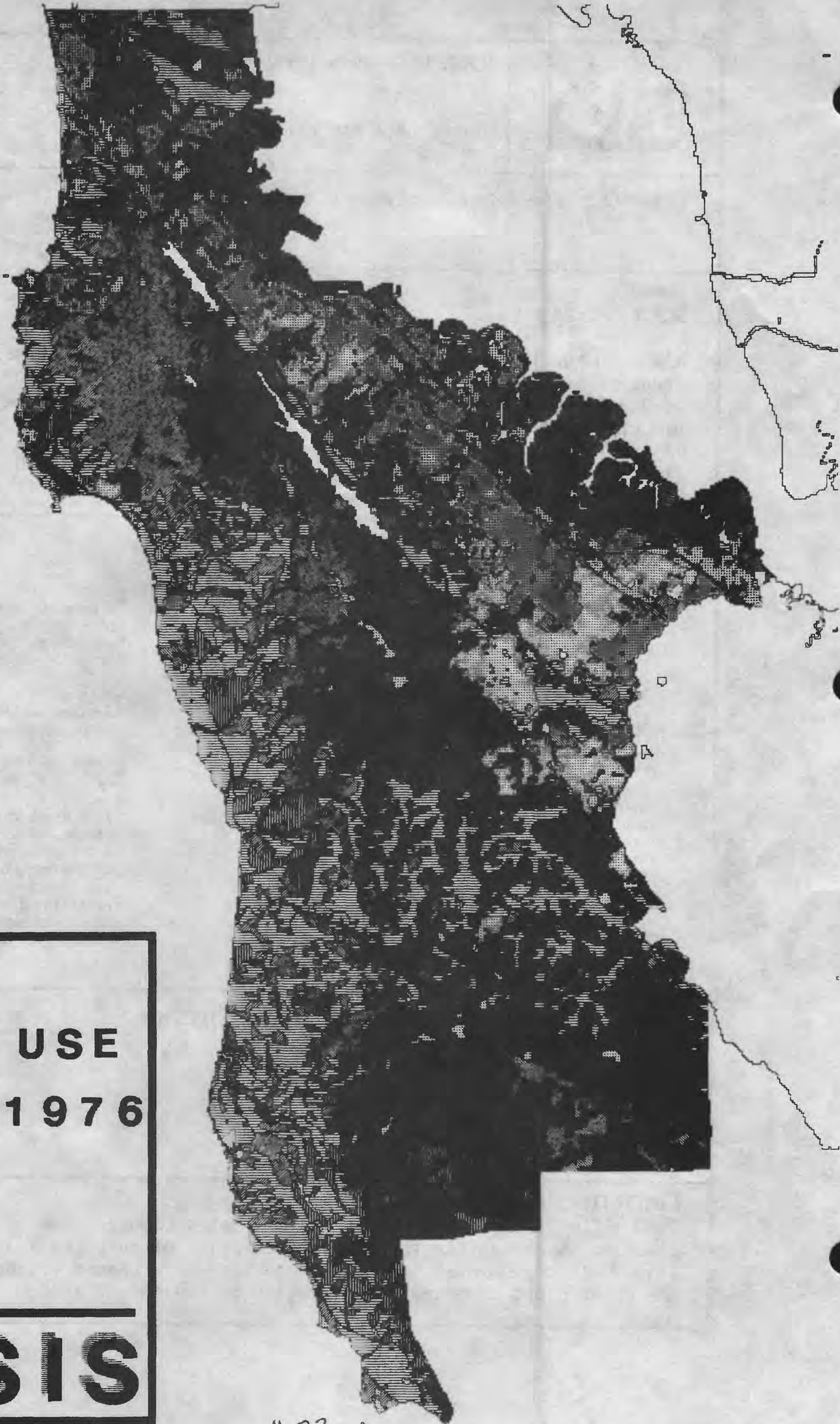
Water
- Streams and canals
- Lakes
- Reservoirs
- Bays and estuaries

Wetland
- Forested wetland
- Non-forested wetland

Barren Land
- Dry salt falts
- Beaches
- Sandy areas other than beaches
- Bare exposed rock
- Strip mines, quarries and gravel pits
- Transitional areas
  - 2 sub-categories
- Mixed barren land

USED WITH OTHER FILES TO PRODUCE HAZARD FILES ON:
o used only on applications

LIMITATIONS AND FUTURE PLANS:
This file is only available for San Mateo County. However, ABAG plans to obtain a file for the entire region of only the first two levels of categories (no sub-categories or further divisions) for the other eight counties in the region by the end of 1980.



LAND USE 1975 1976

BASIS

HAZARD MAP FILES

As of March 1980, the first six basic data maps have been combined to create six hazard map files and three of the basic maps have been converted to three additional hazard files:

- o maximum ground shaking intensity
- o risk of ground shaking damage
- o liquefaction susceptibility
- o liquefaction potential
- o rainfall-induced landslide susceptibility
- o earthquake-induced landslide susceptibility
- o fault surface rupture
- o tsunami hazard areas
- o dam failure hazard areas

Each of the following sheets consists of five major sections describing various aspects of the map files on the front. The five sections include:

- o Coverage - the area of the region covered (including a map) and the resolution of the data
- o Source - the basic data map files and the key assumptions used
- o Diagram of components - a figure depicting the interrelationship of the basic data map files used to create the hazard map files
- o Further information on this file is contained in - a list of the working papers further describing the map development and, if applicable, other relevant documents (complete citations are not provided but can be obtained from the working papers)
- o Limitations and future plans - limitations in coverage or accuracy are described, together with future plans to upgrade each file

A 1:1 million scale reproduction of the file appears on the back of each sheet. At this scale, an explanation of individual map categories is meaningless. Potential users should contact ABAG staff to obtain maps of their area of interest and an explanation for those maps.

MAXIMUM GROUND SHAKING INTENSITY

HAZARD MAP FILE

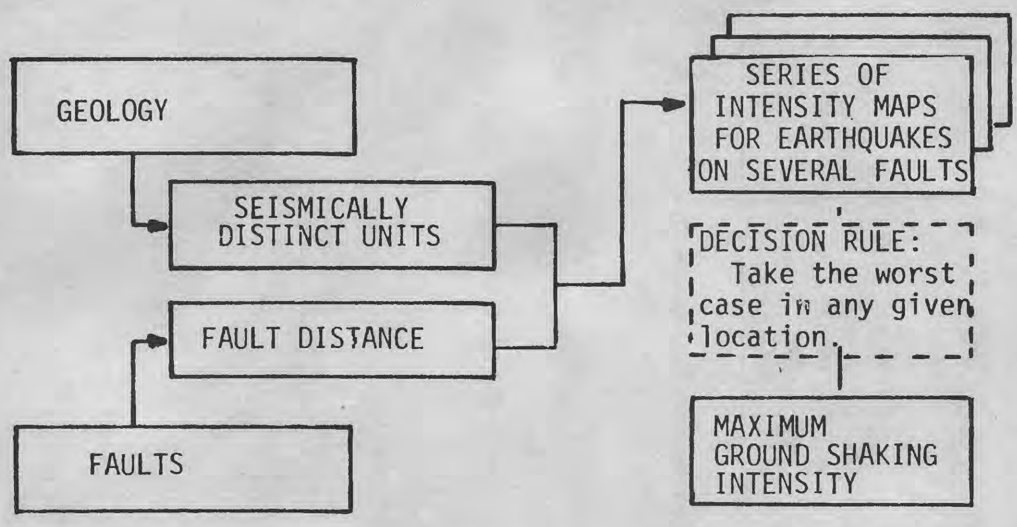
COVERAGE: All Bay Area counties with San Mateo County in more detail

SOURCE: The basic data map files on faults and geology are combined to produce this map using data on:

- o maximum magnitude for each fault
- o maximum intensity associated with each maximum magnitude
- o the attenuation of intensity with distance from the fault rupture
- o the effect of local geology on intensity

March 1980
Hectare resolution

DIAGRAM OF COMPONENTS:



FURTHER INFORMATION ON THIS FILE IS CONTAINED IN:

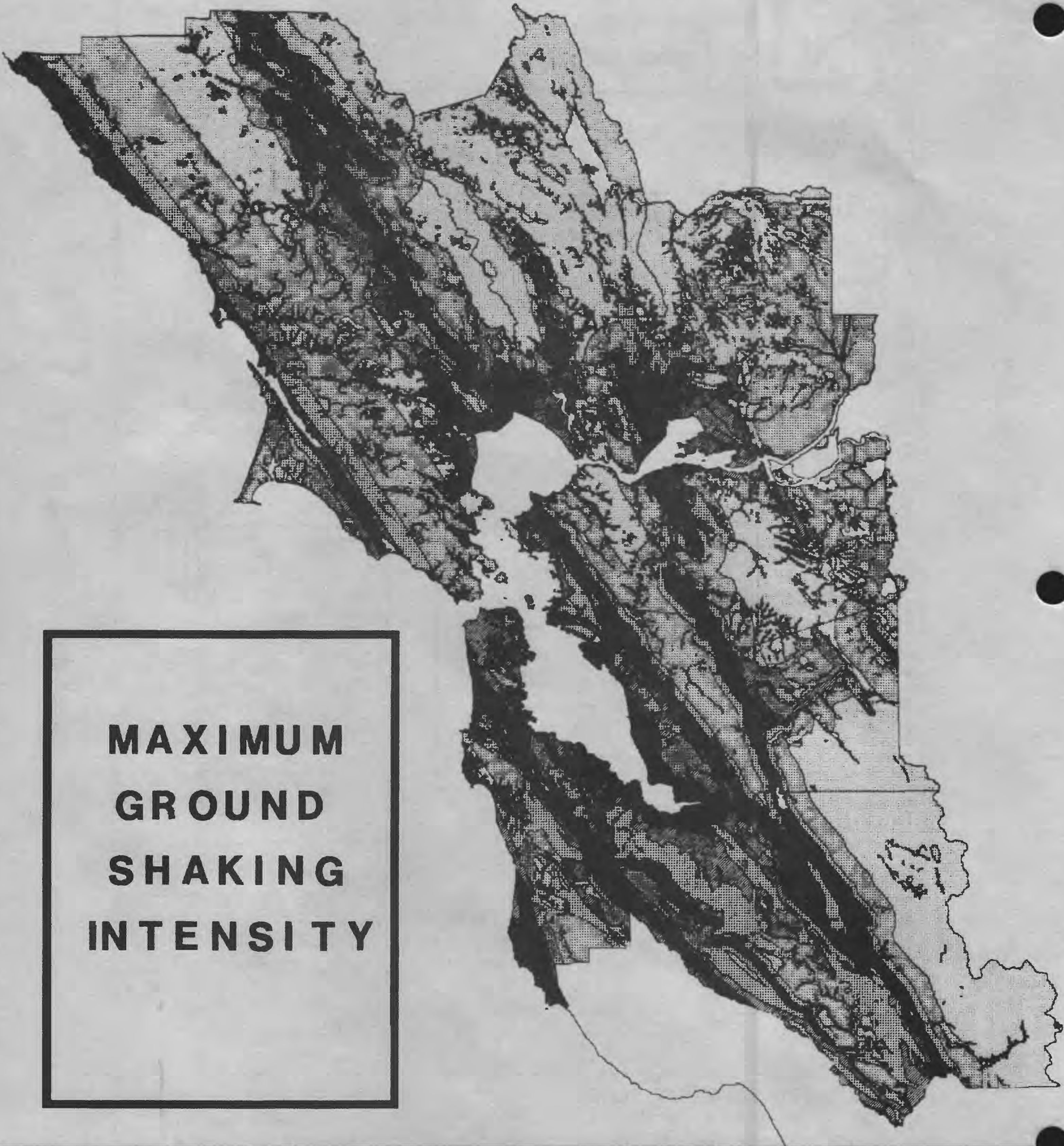
- o Working Paper #1: Faults and Ground Shaking Intensity
- o Working Paper #2: Attenuation, Geologic Materials and Ground Shaking
- o Working Paper #3: Damage and Ground Shaking Intensity

The method is from U.S.G.S. Profession Paper 941-A (Borcherdt & others)

LIMITATIONS AND FUTURE PLANS:

The difference in the detail of geology information between San Mateo County and the rest of the region is fairly insignificant. This file will be recreated as new geology data is entered in the geology file, however. The intensity data is included as San Francisco intensities rather than as modified Mercali intensities. New data on attenuation for modified Mercali intensities would enable the improvement of this file. Data on acceleration may be available by 1982 from U.S.G.S.

MAXIMUM GROUND SHAKING INTENSITY



BASIS

BAY AREA SPATIAL INFORMATION SYSTEM

RISK OF GROUND SHAKING INTENSITY

HAZARD MAP FILE

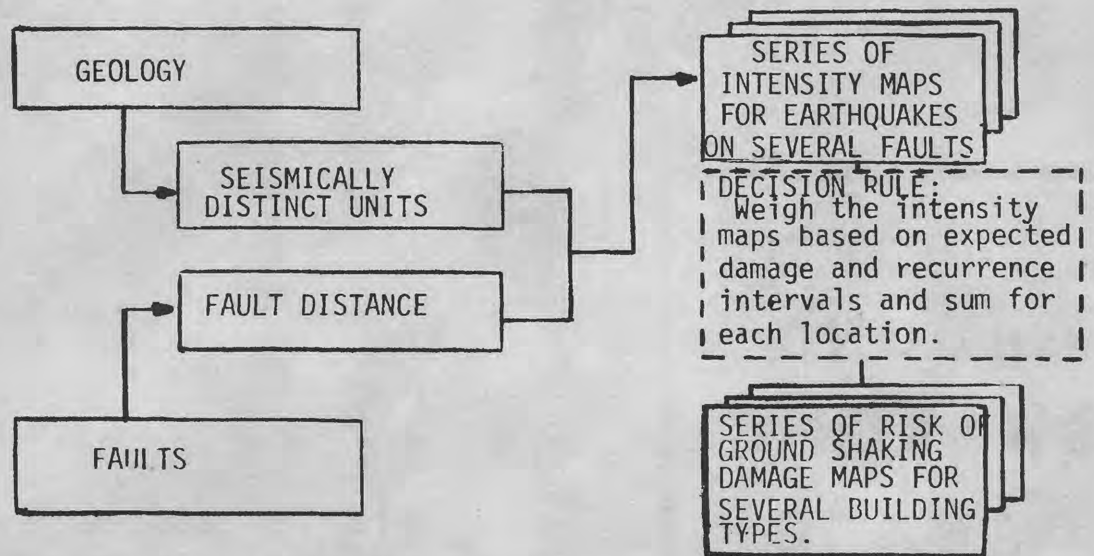
COVERAGE: All Bay Area counties with San Mateo County in more detail

SOURCE: The basic data map files on faults and geology are combined to produce this map using data on:

- o frequency of different magnitudes of earthquakes on each fault
- o damage associated with intensity
- o the source data used in the maximum ground shaking intensity file

March 1980
Hectare resolution

DIAGRAM OF COMPONENTS:



FURTHER INFORMATION ON THIS FILE IS CONTAINED IN:

- o Working Paper #1: Faults and Ground Shaking Intensity
- o Working Paper #2: Attenuation, Geologic Materials and Ground Shaking
- o Working Paper #3: Damage and Ground Shaking Intensity

The method is a refinement of a method described in an earlier ABAG publication, Earthquake Intensity and Expected Cost (1978).

LIMITATIONS AND FUTURE PLANS:
The difference in the detail of geology information between San Mateo County and the rest of the region is fairly insignificant. This file will be recreated as more geology data becomes available. Better data on recurrence intervals of various magnitudes of earthquakes and on the long term slip rate of faults would greatly improve the reliability of the file. The damage data and resulting risk data are statistical and cannot be applied to any given buildings.

RISK OF

GROUND SHAKING DAMAGE

TILT UP CONCRETE BUILDINGS

BASIS BAY AREA SPATIAL INFORMATION SYSTEM

LIQUEFACTION SUSCEPTIBILITY

HAZARD MAP FILE

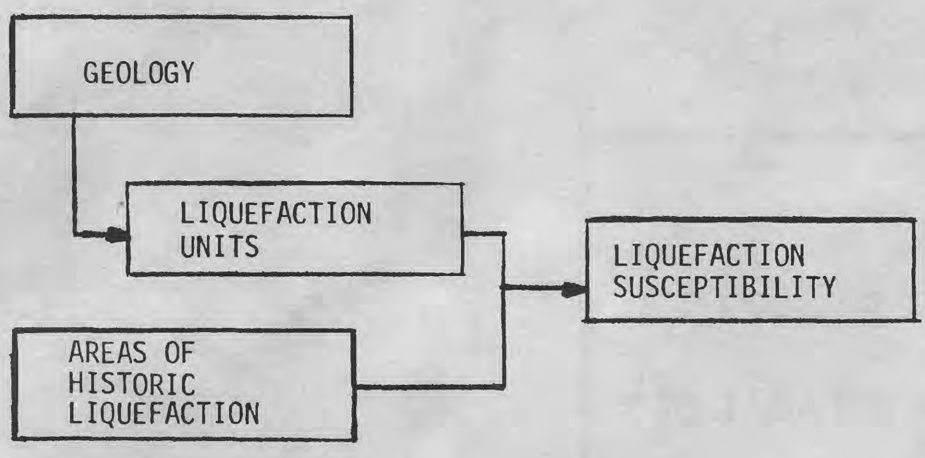
COVERAGE: All nine Bay Area counties

SOURCE: The basic data map file on geology was converted to a hazard file based on:
- o type and age of deposit
- o extent of cohesionless materials
- o possibility of cohesionless materials liquefying
- o likelihood of saturation

(historic liquefaction areas also included)

March 1980
Hectare resolution

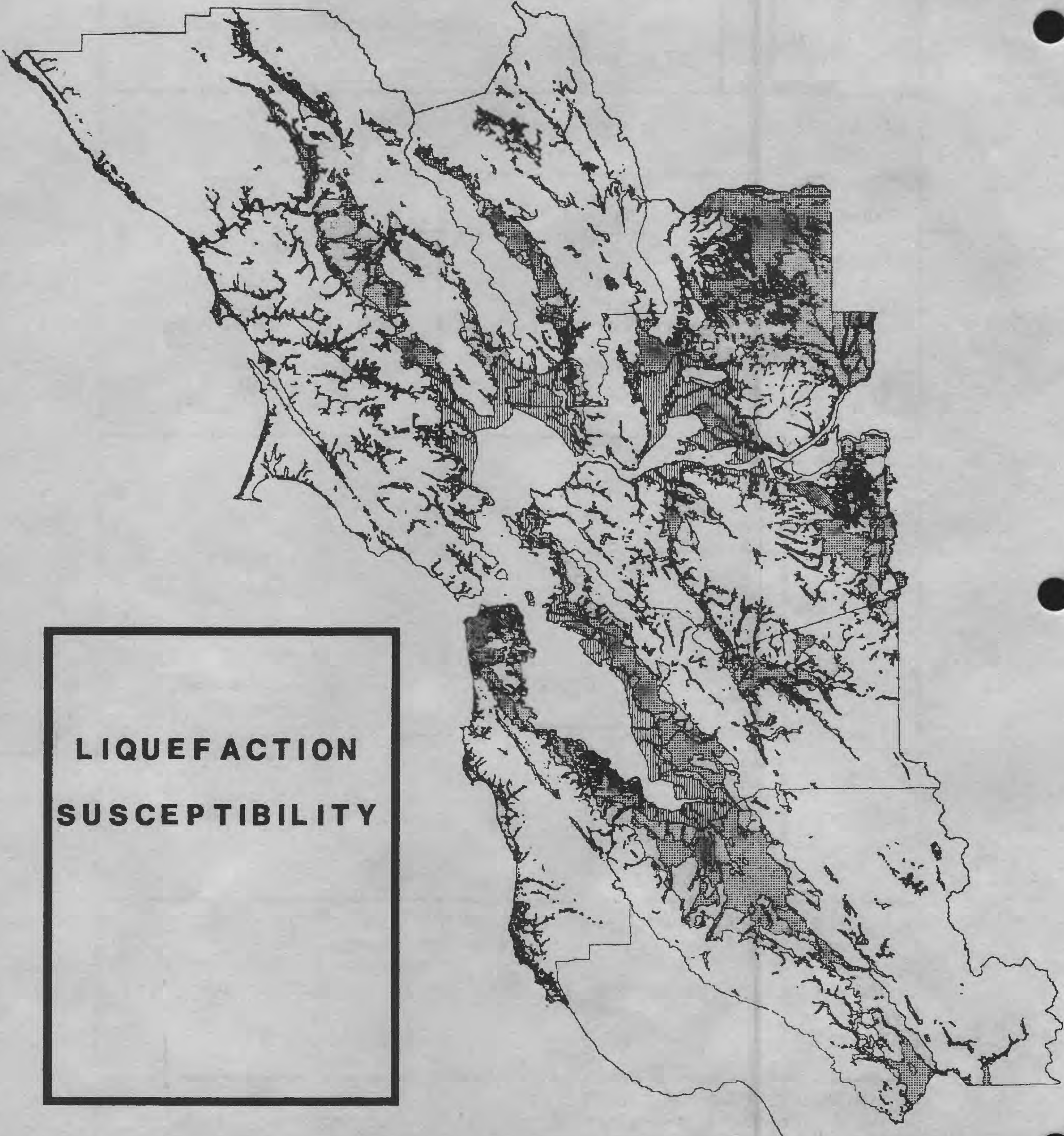
DIAGRAM OF COMPONENTS:



FURTHER INFORMATION ON THIS FILE IS CONTAINED IN:
o Working Paper #4: Liquefaction Potential Mapping

The method is based on several publications of Les Youd and others of U.S.G.S.

LIMITATIONS AND FUTURE PLANS:
The difference in the detail of geology information between San Mateo County and the rest of the region does not affect this file. If a map of ground water table were available for the region, the data on saturation could be improved significantly.



LIQUEFACTION SUSCEPTIBILITY

BASIS BAY AREA SPATIAL INFORMATION SYSTEM

LIQUEFACTION POTENTIAL

HAZARD MAP FILE

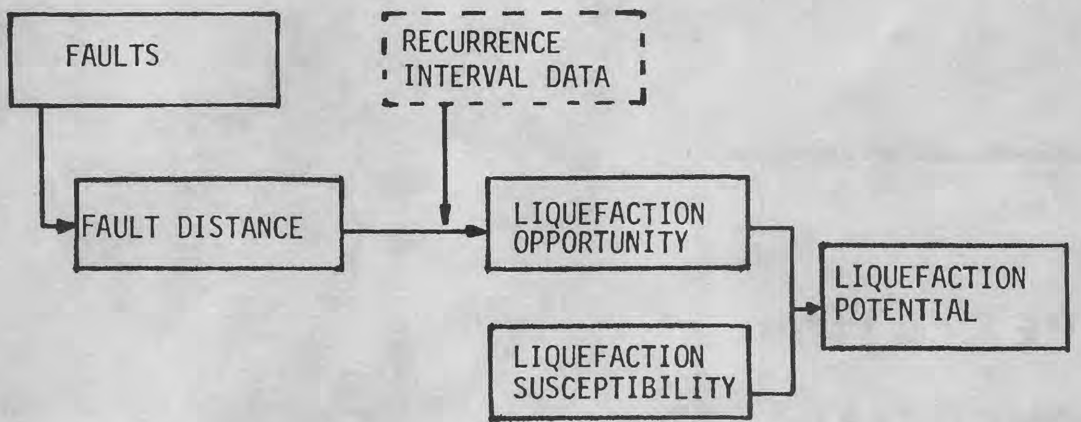
COVERAGE: All nine Bay Area counties

March 1980
Hectare resolution

SOURCE: The hazard map file on liquefaction susceptibility and the basic data map file on faults are combined to produce this map using data on:

- o the relative susceptibility
- o the liquefaction opportunity (the frequency of earthquakes)
- o a formula relating magnitude to distance from fault for liquefaction

DIAGRAM OF COMPONENTS:



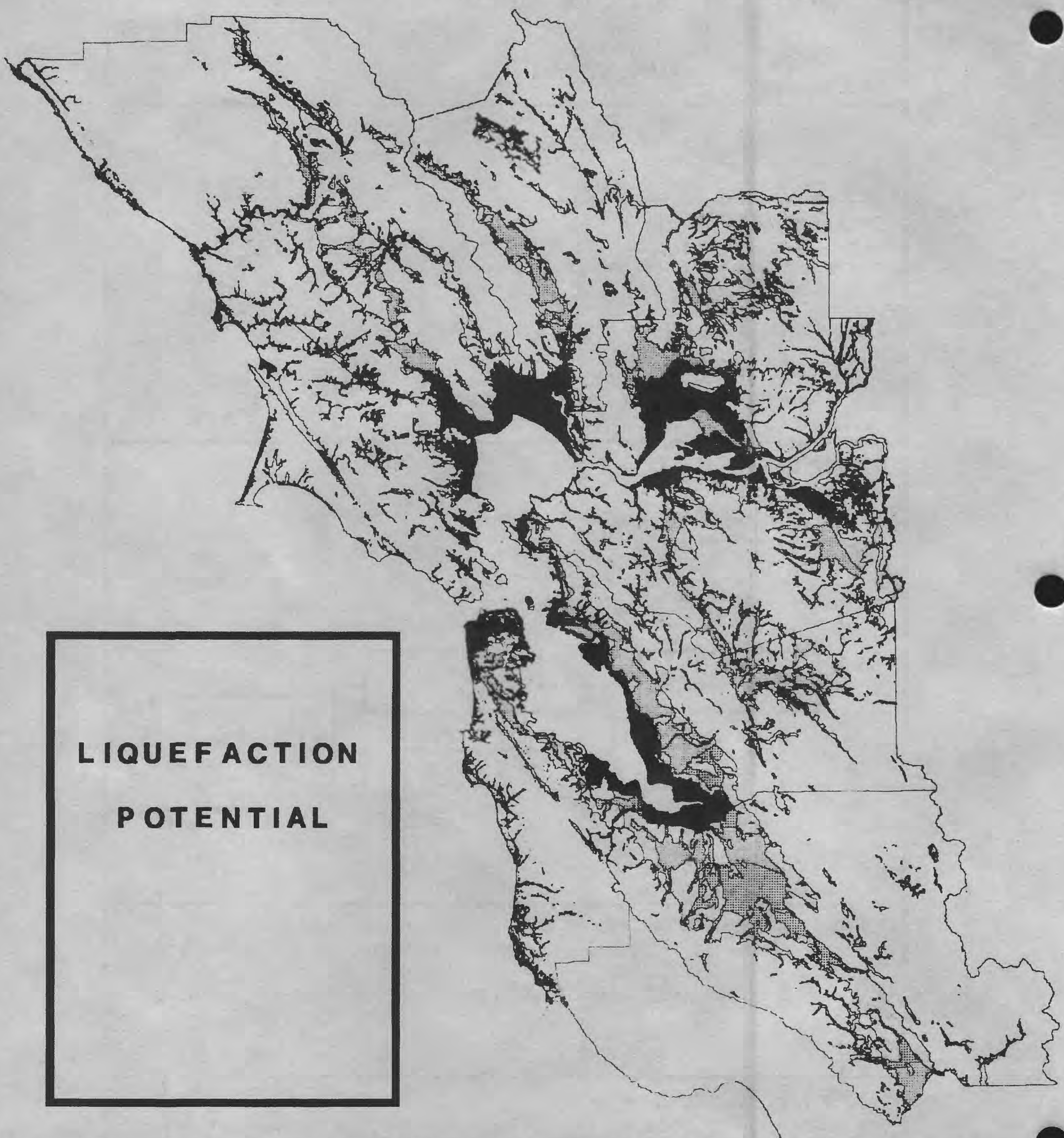
FURTHER INFORMATION ON THIS FILE IS CONTAINED IN:

- o Working Paper #4: Liquefaction Potential Mapping

The method is based on several publications of Les Youd and others of U.S.G.S.

LIMITATIONS AND FUTURE PLANS:

The difference in the detail of geology information between San Mateo County and the rest of the region does not affect this file. Any improvements in the liquefaction susceptibility map would obviously improve this hazard map as well. The formula used to relate magnitude to distance from a fault for liquefaction is currently being revised. Better information on earthquake recurrence intervals would improve the reliability of this file.



BASIS BAY AREA SPATIAL INFORMATION SYSTEM

RAINFALL-INDUCED LANDSLIDE SUSCEPTIBILITY

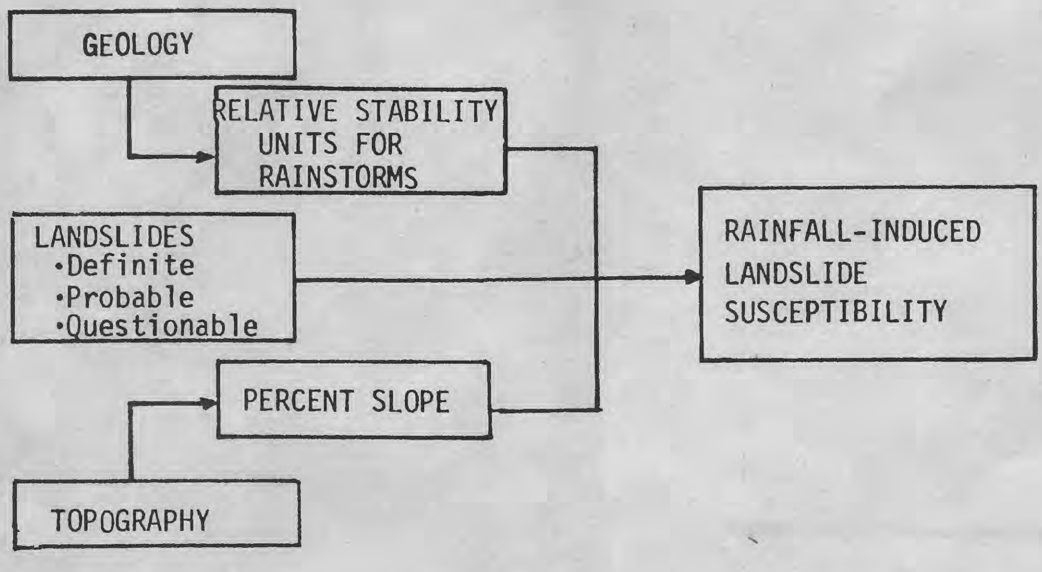
HAZARD MAP FILE

COVERAGE: San Mateo County only

SOURCE: The basic data map files on geology, landslides and topography (slope) are combined to produce this map using data on:
o the surface extent of each geologic unit that has failed by landsliding
o data on percent slope prior to failure

March 1980
Hectare resolution

DIAGRAM OF COMPONENTS:



FURTHER INFORMATION ON THIS FILE IS CONTAINED IN:
o Working Paper #5: Slope Stability Mapping

The method is based on U.S.G.S. Miscellaneous Field Studies Map MF-360 (Brabb and others)

LIMITATIONS AND FUTURE PLANS:
This file currently is available only for San Mateo County. The three basic map files used to create this file will be expanded to include fifteen 7-1/2 minute quadrangles in 1980 and early 1981. If the method of combining these files can be applied beyond San Mateo County, this file could be expanded as well. The landslide susceptibility mapping of Nilsen and others (U.S.G.S. Professional Paper 943) is available in BASIS but at 1/4 sq. km. resolution.

RAINFALL INDUCED LANDSLIDE SUSCEPTIBILITY

BASIS

EARTHQUAKE-INDUCED LANDSLIDE SUSCEPTIBILITY

HAZARD MAP FILE

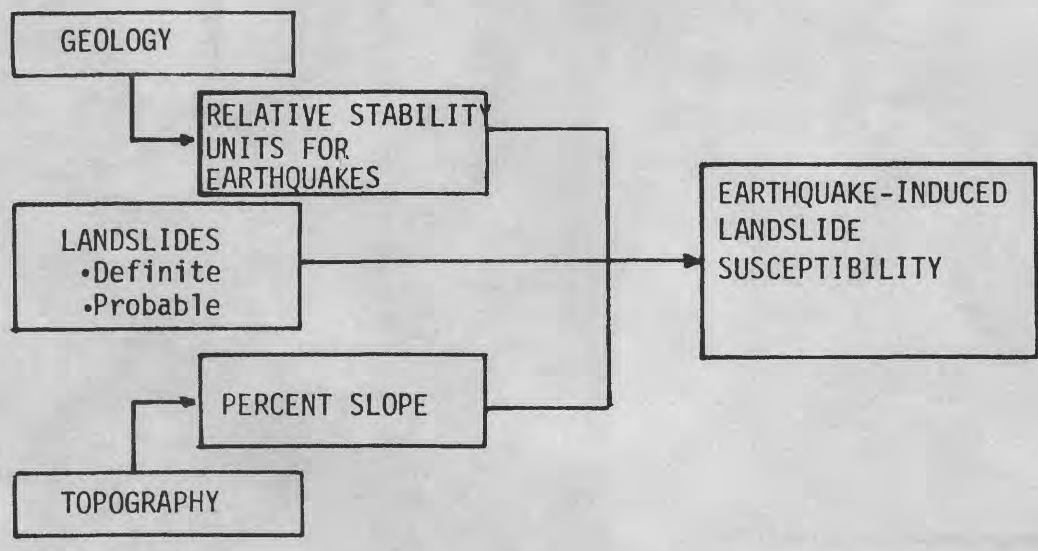
COVERAGE: San Mateo County only

SOURCE: The basic data map files on geology, landslides and topography (slope) are combined to produce this map using data on:

- o physical properties of the geologic units (largely relative cohesion)
- o data on historic failures
- o data on saturation characteristics

March 1980
Hectare resolution

DIAGRAM OF COMPONENTS:



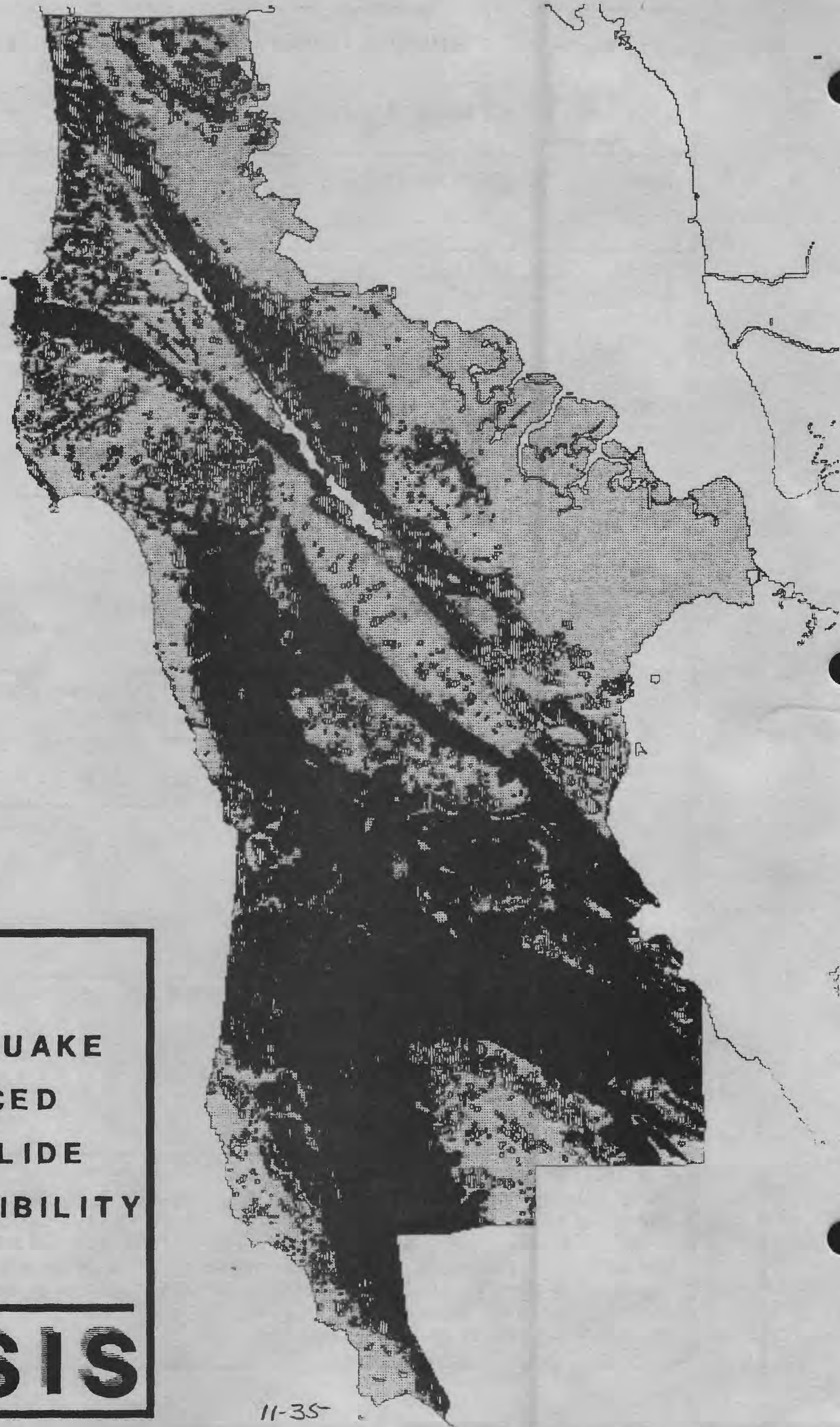
FURTHER INFORMATION ON THIS FILE IS CONTAINED IN:

o Working Paper #5: Slope Stability Mapping

The method is based on current research of Gerry Wieczorek and others of U.S.G.S.

LIMITATIONS AND FUTURE PLANS:

This file currently is available only for San Mateo County. The three basic map files used to create this file will be expanded to include fifteen 7-1/2 minute quadrangles in 1980 and early 1981. If the method of combining these files can be applied beyond San Mateo County, this file could be expanded as well. At the present time, insufficient data is available on landslide opportunity to enable a landslide potential map to be created.



EARTHQUAKE INDUCED LANDSLIDE SUSCEPTIBILITY

BASIS

FAULT SURFACE RUPTURE

HAZARD MAP FILE

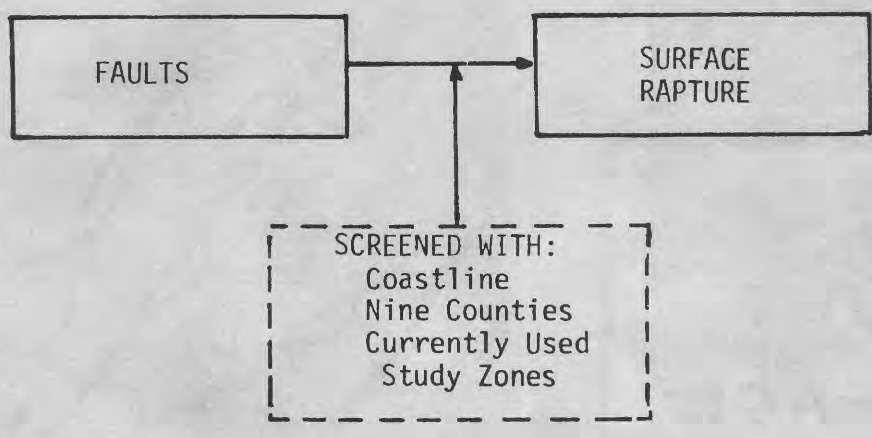
COVERAGE: All nine Bay Area counties

SOURCE: The basic data map file on faults is modified using data on:

- o fault activity from U.S.G.S. and C.D.M.G.
- o local government requirements

March 1980
Hectare resolution

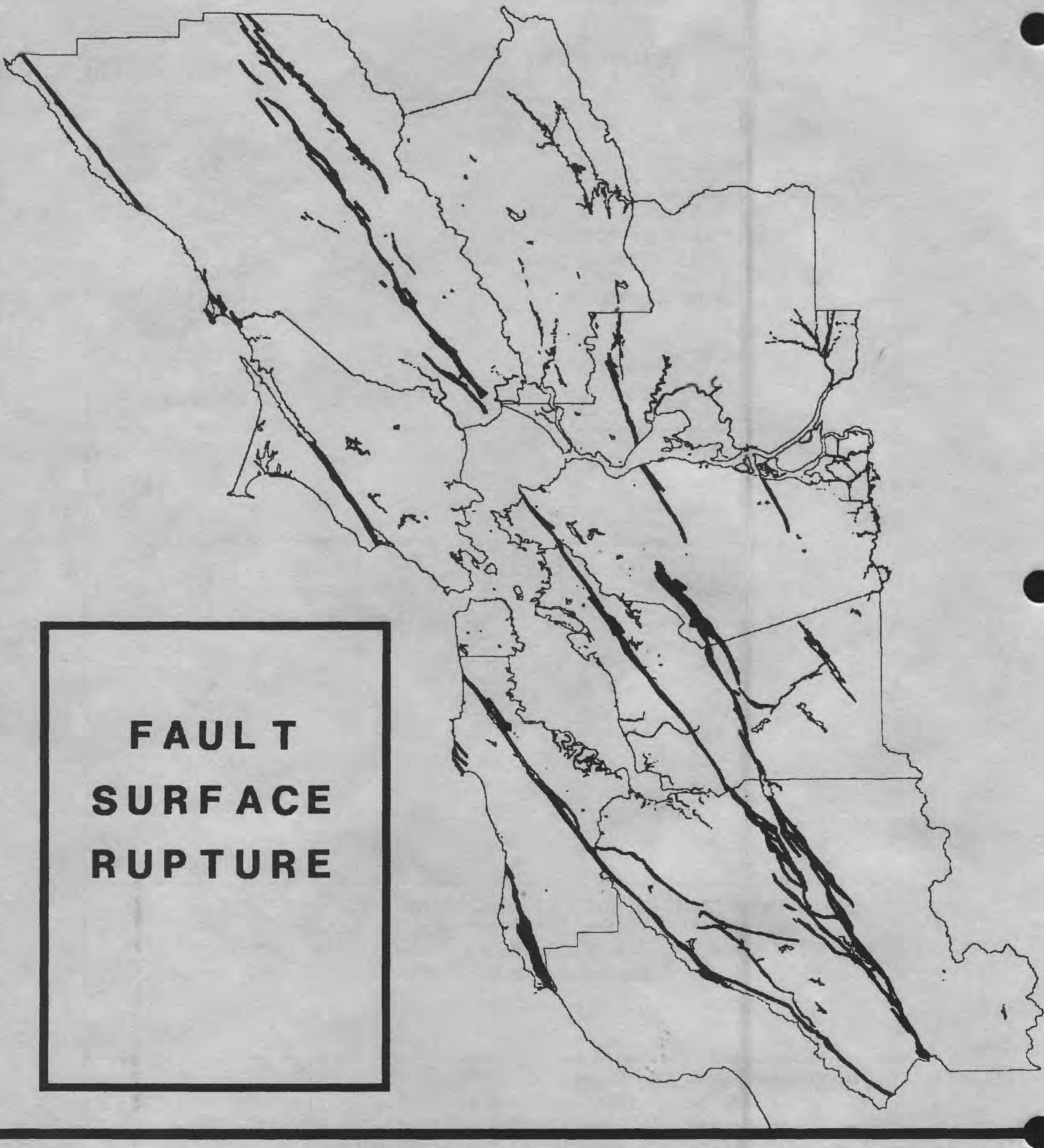
DIAGRAM OF COMPONENTS:



FURTHER INFORMATION ON THIS FILE IS CONTAINED IN:

- o Working Paper #1: Faults and Ground Shaking Intensity
- o Working Paper #9: Earthquake Map Applications for Composite Earthquake Hazard Mapping

LIMITATIONS AND FUTURE PLANS:
As new information on fault activity becomes available, both U.S.G.S. and C.D.M.G. staff will modify the maps used as a basis for this file. The hazard file will be modified accordingly.



FAULT SURFACE RUPTURE

BASIS BAY AREA SPATIAL INFORMATION SYSTEM

TSUNAMI HAZARD AREAS

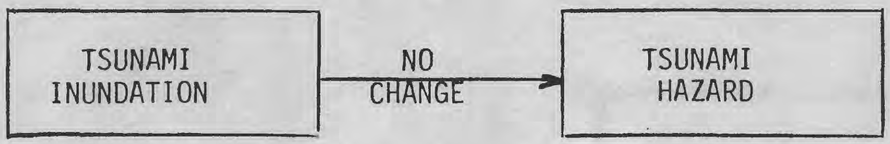
HAZARD MAP FILE

COVERAGE: All nine Bay Area counties

SOURCE: The basic data map file on tsunami inundation areas is currently the map of tsunami hazard areas. This file is included separately to emphasize that the file could have been created with information on topography and runup.

March 1980
Hectare resolution

DIAGRAM OF COMPONENTS:

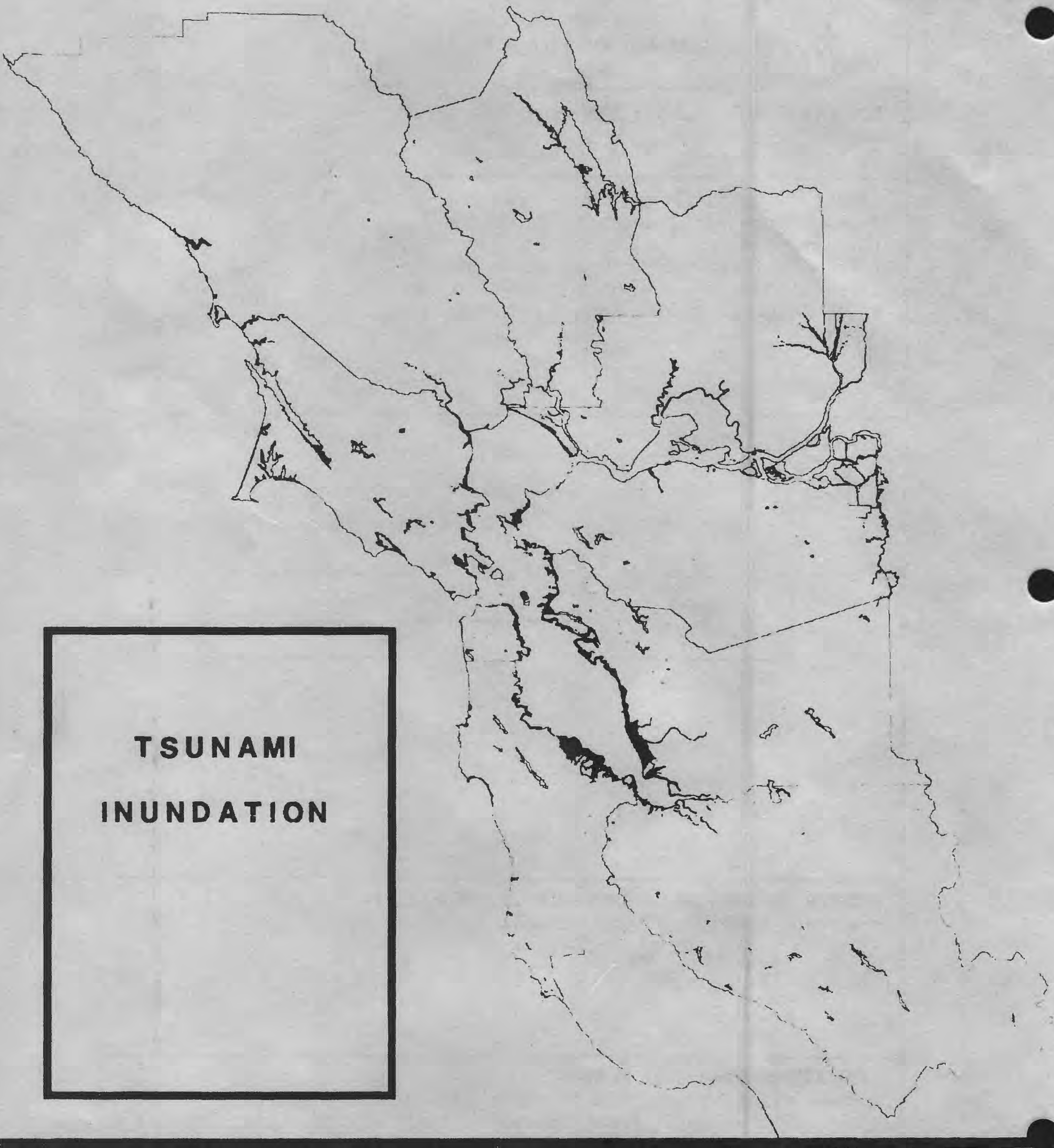


FURTHER INFORMATION ON THIS FILE IS CONTAINED IN:

o Working Paper #6: Tsunami Inundation Areas

LIMITATIONS AND FUTURE PLANS:

A more detailed map showing depth of inundation currently is not available in a usable form. However, special studies being done in conjunction with the Federal Flood Insurance Program should be available by early 1981. This file may be replaced with a file that combines data on runup, tsunami, recurrence, and elevation.



TSUNAMI INUNDATION

BASIS

BAY AREA SPATIAL INFORMATION SYSTEM

DAM FAILURE HAZARD AREAS

HAZARD MAP FILE

COVERAGE: All nine Bay Area counties

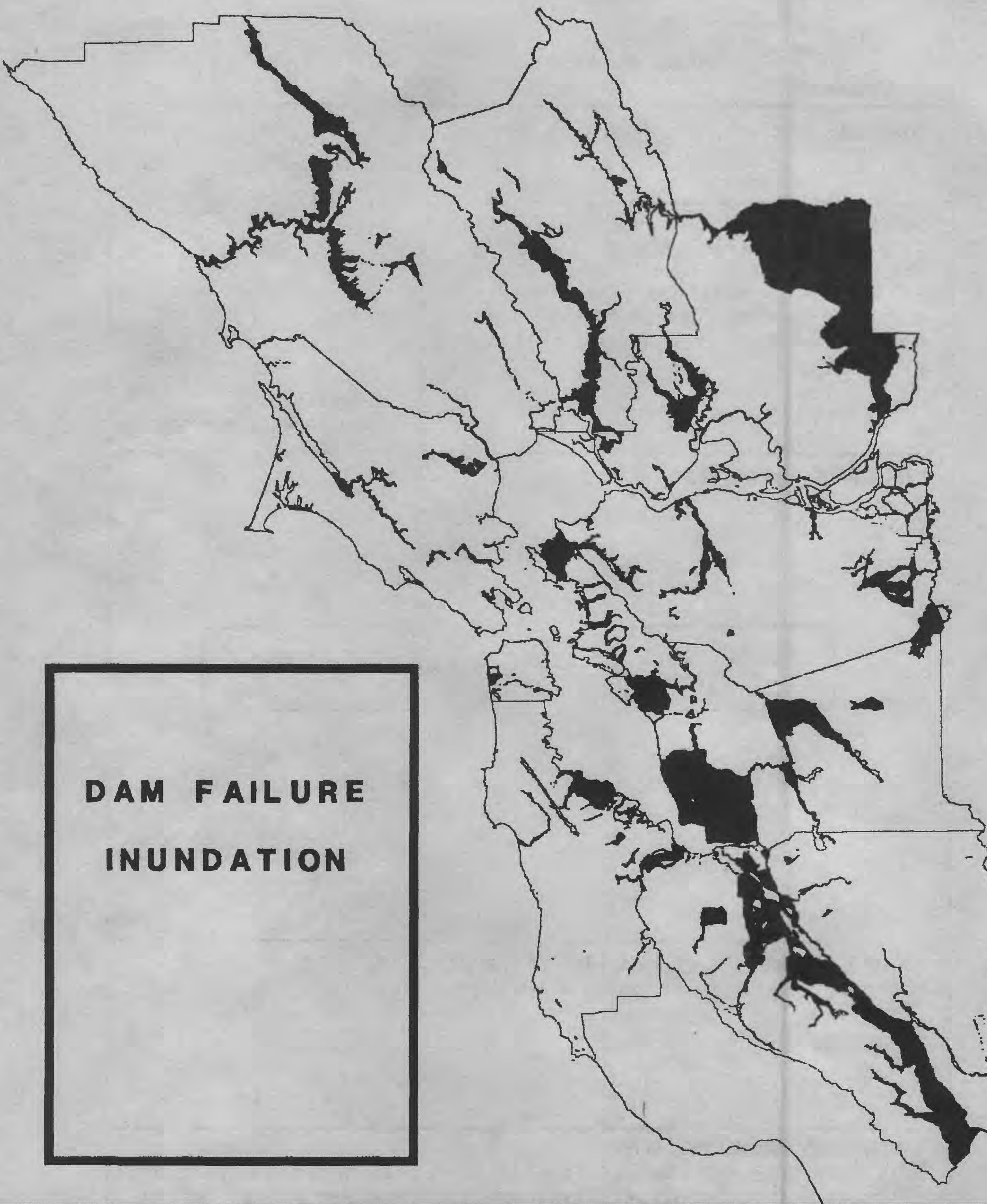
SOURCE: The basic data map file on dam failure inundation areas is currently the map of dam failure hazard areas. This file is included separately to emphasize that the file could have been created with more basic information.

March 1980
Hectare resolution

DIAGRAM OF COMPONENTS:

FURTHER INFORMATION ON THIS FILE IS CONTAINED IN:
o Working Paper #7: Dam Failure Inundation Areas

LIMITATIONS AND FUTURE PLANS:
This file does not contain information on depth of inundation although this information is available from some dam owners. At the present time, little is known on the statistical recurrence of failure of dams, although one would expect that being exposed to earthquakes would increase this rate.



DAM FAILURE

INUNDATION

BASIS BAY AREA SPATIAL INFORMATION SYSTEM

MAP FILE APPLICATIONS

As of March 1980, these map files can be manipulated for three different types of applications:

- o computer assisted environmental assessment
- o production of composite hazard maps
- o assessment of property and population at risk

Each of the following sheets consists of five major sections describing various aspects of the applications on the front and a sample of an application product on the back. The five sections include:

- o Coverage - the area of the region covered (including a map) and the resolution of the data
- o Source files - a list of the basic data map files and the hazard map files used
- o Description of product
- o Further information on this file is contained in - a list of the working papers further describing the map application
- o Limitations and future plans - limitations in coverage or accuracy are described, together with future plans to improve ABAG's ability to produce the products described

COMPUTER ASSISTED ENVIRONMENTAL ASSESSMENT

MAP FILE APPLICATION

COVERAGE: All nine Bay Area counties with in San Mateo County in more detail

March 1980
Hectare resolution

SOURCE FILES: Geology; Faults; Topography; Landslides; Tsunami Inundation Areas; Dam Failure Inundation Areas; Maximum Ground Shaking Intensity; Risk of Ground Shaking Damage; Liquefaction Susceptibility; Liquefaction Potential; Rainfall and Earthquake-Induced Landslide Susceptibility; Fault Surface Rupture

DESCRIPTION OF PRODUCT:
This application will produce a background document for development proposals that can be incorporated into the Environmental Impact Report (EIR). This document, as currently envisioned, will have ten parts, each focusing on a different environmental concern. The part dealing with earthquake hazards is "Geology and Soils-- Hazards and Resources". Each section, including the one on geology and soils, contains three parts--setting, impacts, and mitigation. The setting section contains information on five data items: topography, faults, landslides, geologic materials, and soil associations. The impacts section contains information on: rainfall-induced landslide susceptibility, earthquake-induced landslide susceptibility, liquefaction potential, tsunami inundation areas, dam failure inundation areas, maximum earthquake intensities, and earthquake intensity damage and risk. The mitigation section would include those items to be required of the developer by the city or county, including requirements for further study. The information for each section is presented on a single page. A copy of the impacts section for a hypothetical development is reproduced on the back of this sheet.

FURTHER INFORMATION ON THIS FILE IS CONTAINED IN:
o Working Paper #8: Earthquake Map Applications for Automated Environmental Impact Assessment

LIMITATIONS AND FUTURE PLANS:
At the present time, because of the limited coverage of the topography, landslide, and landslide susceptibility files, a complete report can be produced only for San Mateo County. The coverage will be expanded to include fifteen 7-1/2 minute quandrangles of high development potential in 1980 and early 1981. The file also could be expanded should a city or county request the service and provide funds for file development.

GEOLOGY AND SOILS - HAZARDS AND RESOURCES

IMPACTS

SLOPE STABILITY

RAINFALL-INDUCED
LANDSLIDE SUSCEPTIBILITY
AREA (IN HECTARES)

STABLE	61
*	0
*	0
TO	0
*	0
*	0
UNSTABLE	0

EARTHQUAKE-INDUCED
LANDSLIDE SUSCEPTIBILITY
AREA (IN HECTARES)

STABLE	61
*	0
*	0
UNSTABLE	0

TSUNAMI INUNDATION AREAS
AREA (IN HECTARES

INSIDE	0
OUTSIDE	61

LIQUEFACTION POTENTIAL
AREA (IN HECTARES)

LOW	0
*	0
TO	37
*	0
*	24
HIGH	0

DAM FAILURE INUNDATION AREAS

DAM	AREA
NONE	

MAXIMUM EARTHQUAKE INTENSITY
AREA (IN HECTARES)

A (4)-VERY VIOLENT	0
B (3)-VIOLENT	24
C (2)-VERY STRONG	37
D (1)-STRONG	0
E (0)-WEAK	0
NEGLIGIBLE	0

EARTHQUAKE INTENSITY -- DAMAGE AND RISK

FAULT	MAXIMUM MAGNITUDE	RECURRENCE (IN YEARS)	AVE. INTENSITY FOR AVE. ROCK
SAN ANDREAS	8.4(7.2)	1000(100)	E
CALAVERAS	7.3(6.7)	500(100)	E
SAN GREGORIO	7.1	200	E
HAYWARD	6.9	200	E
CONCORD/GRN. VAL.	7.0	200	E
HEALDSBURG/ROD. CR.	6.8	200	E
MAACAMA	7.1	500	E

INTENSITY INCREASES (OR DECREASES) FOR GEOLOGIC MATERIALS ON SITE

BAY MUD 2.9 ARTIFICIAL FILL 1.5

****EXPECTED DAMAGE (PER EVENT) AT VARIOUS INTENSITIES FOR ****
BUILDING TYPES PROPOSED FOR SITE

INTENSITY	BUILDING TYPES: WOOD-FRAME
A (4)	16 %
B (3)	12 %
C (2)	5 %
D (1)	2 %
E (0)	0.2%
<E	0 %

COMPOSITE HAZARD MAPS

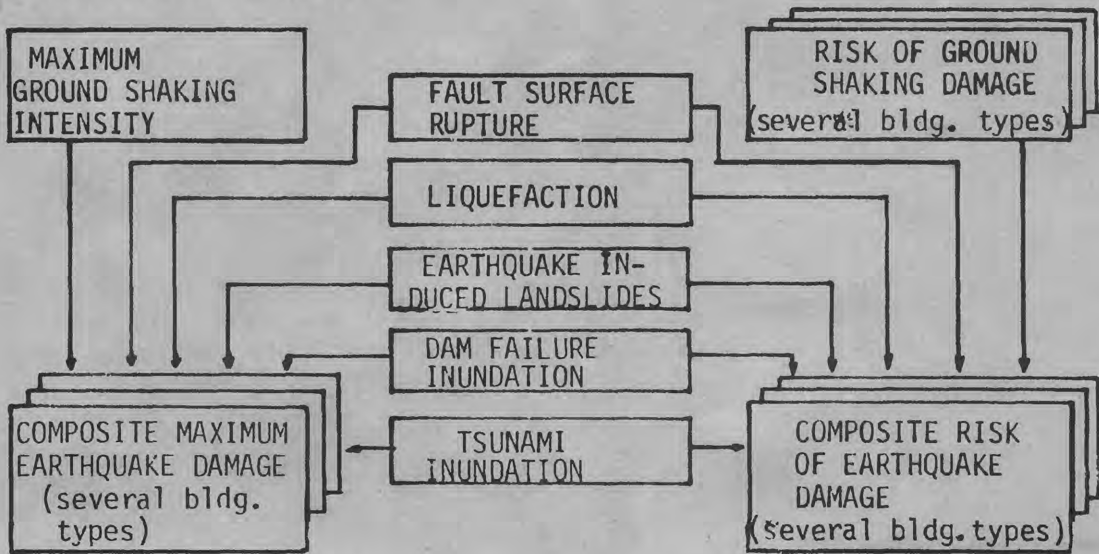
MAP FILE APPLICATION

COVERAGE: All nine Bay Area counties with San Mateo County in more detail

SOURCE FILES: Maximum Ground Shaking Intensity; Risk of Ground Shaking Damage; Fault Surface Rupture; Liquefaction Susceptibility and Potential; Earthquake-Induced Landslide Susceptibility (and Potential when available); Tsunami Hazard Areas; and Dam Failure Hazard Areas

March 1980
Hectare resolution

DESCRIPTION OF PRODUCT:



An example of a composite map appears on the reverse of this sheet.

FURTHER INFORMATION ON THIS FILE IS CONTAINED IN:

- o Working Paper #9: Earthquake Map Applications for Composite Earthquake Hazard Mapping

LIMITATIONS AND FUTURE PLANS:

Any composite maps that are produced at this time have two limitations. First, the landslide susceptibility file is only available for San Mateo County. Second, the lack of information on landslide opportunity in earthquakes makes the production of a landslide potential map impractical. The current data on damage associated with both landslides and liquefaction make composite maps hypothetical at best.


COMPOSITE RISK OF EARTHQUAKE DAMAGE
WOOD FRAME DWELLINGS
BASIS

ASSESSMENT OF PROPERTY AND POPULATION AT RISK

MAP FILE APPLICATION

COVERAGE: All nine Bay Area counties with San Mateo County in more detail

March 1980
Hectare resolution

SOURCE FILES: This application can use any of the basic data map files or hazard map files together with the land use jurisdiction and census tract files.

DESCRIPTION OF PRODUCT:
This application can produce tables of the amount of land in each hazard category on each hazard map file by:

- o Census tract
- o City sphere of influence
- o County
- o Land Use

An example of these types of tables is reproduced on the back of this sheet. Census tract data could be disaggregated by using the land use data to produce statistics on population at risk. This application will be investigated during 1980.

FURTHER INFORMATION ON THIS FILE IS CONTAINED IN:
o Working Paper #10: Earthquake Map Applications for Automated Assessment of Property and Population at Risk

LIMITATIONS AND FUTURE PLANS:
At the present time, the land use file is available only for San Mateo County so some of the more sophisticated applications only can be performed for that area. In addition, the extent of coverage of the data files may limit those areas where tables can be produced.

AREA (IN HECTARES) FOR CATEGORIES OF
MAXIMUM GROUND SHAKING INTENSITY
BY JURISDICTION

JURISDICTION	SAN FRANCISCO INTENSITY SCALE					
	<E	E	D	C	B	A
Cities						
ATHERTON	0.	0.	573.	711.	10.	0.
BELMONT	0.	129.	785.	283.	21.	9.
BRISBANE	0.	130.	7.	427.	0.	0.
BURLINGAME	0.	0.	123.	342.	638.	114.
COLMA	0.	0.	6.	389.	86.	0.
DALY CITY	0.	161.	54.	677.	746.	572.
FOSTER CITY	0.	0.	0.	921.	72.	6.
HALF MOON BAY	871.	802.	1531.	2022.	548.	0.
HILLSBOROUGH	0.	0.	866.	675.	122.	19.
MENLO PARK	0.	4.	806.	1494.	698.	0.
MILLBRAE	0.	0.	0.	58.	579.	208.
PACIFICA	0.	686.	1078.	804.	525.	331.
PORTOLA VALLEY	0.	4.	244.	1120.	831.	1108.
REDWOOD CITY	0.	16.	1077.	3137.	1606.	43.
SAN BRUNO	0.	0.	8.	267.	543.	708.
SAN CARLOS	0.	95.	1061.	581.	20.	3.
SAN MATEO	0.	21.	1060.	2203.	263.	10.
SOUTH SAN FRANCISCO	0.	122.	157.	1155.	752.	307.
WOODSIDE	0.	0.	1060.	2107.	1058.	1249.
Counties						
ALAMEDA	39296.	50523.	42469.	25213.	33543.	0.
CONTRA COSTA	54370.	69843.	33027.	13644.	16528.	0.
MARIN	8125.	57824.	40531.	14608.	9295.	4383.
NAPA	141612.	33736.	10281.	9430.	388.	0.
SAN FRANCISCO	21.	1216.	1090.	7643.	2091.	0.
SAN MATEO	1308.	21422.	36739.	32231.	18267.	6356.
SANTA CLARA	100607.	44197.	87339.	60875.	37206.	4340.
SOLANO	72112.	93703.	16815.	21528.	11245.	0.
SONOMA	94519.	147883.	88234.	38634.	35104.	6005.
Regional Total						
BAY AREA	511970.	520347.	356525.	223806.	163667.	21084.

WORKING PAPERS

The working papers referenced in this guide are not automatically included in this document. They can be ordered from ABAG's offices at a charge of $1.00 for the first copy and $1.00 for each additional copy or different working paper. This user's guide, complete with all Working Papers, has automatically been forwarded to the planning director in each city and county in the Bay Area.

The available working papers include:

#1 - Faults and Ground Shaking Intensity -- a description of those faults from which significant ground shaking could originate, including source of mapping, length, character of motion, maximum magnitude, maximum intensity, relative slip rate and recurrence intervals for various earthquakes

#2 - Attenuation, Geologic Materials and Ground Shaking -- a description of an attenuation relationship between intensity and distance from faults for a standard geologic material, a method of combining geologic materials into groups with similar responses to earthquake ground shaking, and intensity increments to be added to the standard intensity for each of the seismically distinct groups of geologic materials

#3 - Damage and Ground Shaking Intensity -- a description of how experience from past earthquakes can be used to estimate the damage different types of buildings would experience when subjected to various intensities of ground shaking; also a description of how damage data, the intensity maps, and recurrence interval information can be used to produced maps of risk of ground shaking damage for various building types

#4 - Liquefaction Potential Mapping -- a description of the likelihood of finding cohesionless sediments within a geologic map unit, the likelihood that those sediments (when saturated) would be susceptible to liquefaction, the likelihood of finding those sediments saturated, and liquefaction opportunity (based on recurrence intervals of earthquakes and the distance from various faults at which liquefaction can occur)

#5 - Slope Stability Mapping -- a description of how slope, geology and existing landslides can be used to estimate landslide susceptibility in an earthquake and under more normal circumstances

#6 - Tsunami Inundation Areas -- a description of the data used to develop a tsunami hazard map and of the relative risk associated with tsunamis

#7 - Dam Inundation Areas -- a description of dam inundation mapping and of the relative risk associated with dam failure

#8 - Earthquake Map Applications for Automated Environmental Impact Assessment -- a description of how hazard map files can be used to produce a background document for development proposals that can be incorporated into an Environmental Impact Report

#9 - Earthquake Map Applications for Composite Earthquake Hazard Mapping -- a description of how the various hazard maps can be combined to yield two types of hazard maps of total earthquake associated damage

#10 - Earthquake Map Applications for Automated Assessment of Property and Population at Risk -- a description of how tables of area in cities, counties, census tracts and land use can be created for each hazard map category, as well as some sample tables with a discussion of the conclusions that can be formed. In addition, the feasibility of disaggregating census tract data on population using land use to create data on population at risk in various hazard categories is discussed.