SEISMIC HAZARD ZONE REPORT 090

SEISMIC HAZARD ZONE REPORT FOR THE NEWARK 7.5-MINUTE QUADRANGLE, ALAMEDA COUNTY, CALIFORNIA

2003

DEPARTMENT OF CONSERVATION
California Geological Survey

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EXECUTIVE SUMMARY

This report summarizes the methods and sources of information used to prepare the Seismic Hazard Zone Map for the Newark 7.5-Minute Quadrangle, Alameda County, California. The map displays the boundaries of zones of required investigation for liquefaction and earthquake-induced landslides over an area of approximately 60 square miles at a scale of 1 inch = 2,000 feet.

Most of the Newark Quadrangle consists of alluvial flatlands, tidal marshes and salt evaporation ponds along the eastern margin of San Francisco Bay. The Hayward Hills, which reach 1,133 feet above sea level in the map area, extend into the northeastern corner of the quadrangle. The narrow, linear ridge of the Coyote Hills rises above the marshlands of the San Francisco Bay National Wildlife Refuge in the western part of the quadrangle. Alameda Creek, the largest creek in the area, flows from Niles Canyon, east of the map area, across the east bay plain to San Francisco Bay. Several tidal sloughs cross marshy areas along San Francisco Bay, including Coyote Hills Slough and Newark Slough. Most of the flatlands in the map area are developed for residential, commercial and industrial uses, including portions of the cities of Newark, Hayward, Union City, and Fremont. Hillsides are sparsely developed. Access is via Interstate Highway 880 and State Highway 84, which crosses the Dumbarton Bridge in the southwestern corner of the map area where a small portion of San Mateo County lies within the bay. The Bay Area Rapid Transit also serves this region. Several parks and recreational areas are scattered throughout the quadrangle.

The map is prepared by employing geographic information system (GIS) technology, which allows the manipulation of three-dimensional data. Information considered includes topography, surface and subsurface geology, borehole data, historical ground-water levels, existing landslide features, slope gradient, rock-strength measurements, geologic structure, and probabilistic earthquake shaking estimates. The shaking inputs are based upon probabilistic seismic hazard maps that depict peak ground acceleration, mode magnitude, and mode distance with a 10 percent probability of exceedance in 50 years.

In the Newark Quadrangle the liquefaction zone of required investigation is spread across most of the lowland terrain. Only the hills and a portion of the map area near the center of the eastern boundary are outside the zone. Scattered areas of the earthquake-induced landslide zone cover about 2 percent of the quadrangle and are concentrated in the Hayward Hills and the Coyote Hills.

How to view or obtain the map

Seismic Hazard Zone Maps, Seismic Hazard Zone Reports and additional information on seismic hazard zone mapping in California are available on the California Geological Survey's Internet page: http://www.conservation.ca.gov/CGS/index.htm

Paper copies of Official Seismic Hazard Zone Maps, released by CGS, which depict zones of required investigation for liquefaction and/or earthquake-induced landslides, are available for purchase from:

BPS Reprographic Services
945 Bryant Street
San Francisco, California 94105
(415) 512-6550

Seismic Hazard Zone Reports (SHZR) summarize the development of the hazard zone map for each area and contain background documentation for use by site investigators and local government reviewers. These reports are available for reference at CGS offices in Sacramento, San Francisco, and Los Angeles. **NOTE: The reports are not available through BPS Reprographic Services.**

INTRODUCTION

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation (DOC), Division of Mines and Geology (DMG) [now called California Geological Survey (CGS)] to delineate seismic hazard zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the seismic hazard zone maps in their land-use planning and permitting processes. They must withhold development permits for a site within a zone until the geologic and soil conditions of the project site are investigated and appropriate mitigation measures, if any, are incorporated into development plans. The Act also requires sellers (and their agents) of real property within a mapped hazard zone to disclose at the time of sale that the property lies within such a zone. Evaluation and mitigation of seismic hazards are to be conducted under guidelines adopted by the California State Mining and Geology Board (SMGB) (DOC, 1997). The text of this report is on the Internet at http://gmw.consrv.ca.gov/shmp/webdocs/sp117.pdf

The Act also directs SMGB to appoint and consult with the Seismic Hazards Mapping Act Advisory Committee (SHMAAC) in developing criteria for the preparation of the seismic hazard zone maps. SHMAAC consists of geologists, seismologists, civil and structural engineers, representatives of city and county governments, the state insurance commissioner and the insurance industry. In 1991 SMGB adopted initial criteria for delineating seismic hazard zones to promote uniform and effective statewide implementation of the Act. These initial criteria provide detailed standards for mapping regional liquefaction hazards. They also directed CGS to develop a set of probabilistic seismic maps for California and to research methods that might be appropriate for mapping earthquake-induced landslide hazards.

In 1996, working groups established by SHMAAC reviewed the prototype maps and the techniques used to create them. The reviews resulted in recommendations that 1) the process for zoning liquefaction hazards remain unchanged and 2) earthquake-induced landslide zones be delineated using a modified Newmark analysis.

This Seismic Hazard Zone Report summarizes the development of the hazard zone map. The process of zoning for liquefaction uses a combination of Quaternary geologic mapping, historical ground-water information, and subsurface geotechnical data. The process for zoning earthquake-induced landslides incorporates earthquake loading, existing landslide features, slope gradient, rock strength, and geologic structure. Probabilistic seismic hazard maps, which are the underpinning for delineating seismic hazard zones, have been prepared for peak ground acceleration, mode magnitude, and mode distance with a 10 percent probability of exceedance in 50 years (Petersen and others, 1996) in accordance with the mapping criteria.

This report summarizes seismic hazard zone mapping for potentially liquefiable soils and earthquake-induced landslides in the Newark 7.5-Minute Quadrangle.

SECTION 1
LIQUEFACTION EVALUATION REPORT

Liquefaction Zones in the Newark 7.5-Minute Quadrangle, Alameda County, California

By
Jacqueline D. J. Bott and Keith L. Knudsen

California Department of Conservation
California Geological Survey

PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation (DOC), Division of Mines and Geology (DMG) [now called California Geological Survey (CGS)] to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use seismic hazard zone maps developed by CGS in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within seismic hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines adopted by the California State Mining and Geology Board (SMGB) (DOC, 1997). The text of this report is on the Internet at http://gmw.consrv.ca.gov/shmp/webdocs/sp117.pdf

Following the release of DMG Special Publication 117 (DOC, 1997), agencies in the Los Angeles metropolitan region sought more definitive guidance in the review of geotechnical investigations addressing liquefaction hazards. The agencies made their request through the Geotechnical Engineering Group of the Los Angeles Section of the American Society of Civil Engineers (ASCE). This group convened an implementation committee under the auspices of the Southern California Earthquake Center (SCEC).

The committee, which consisted of practicing geotechnical engineers and engineering geologists, released an overview of the practice of liquefaction analysis, evaluation, and mitigation techniques (SCEC, 1999). This text is also on the Internet at: http://www.scec.org/

This section of the evaluation report summarizes seismic hazard zone mapping for potentially liquefiable soils in the Newark 7.5-Minute Quadrangle. Section 2 (addressing earthquake-induced landslides) and Section 3 (addressing potential ground shaking) complete the report, which is one of a series that summarizes production of similar seismic hazard zone maps within the state (Smith, 1996). Additional information on seismic hazards zone mapping in California is on CGS's Internet web page: http://www.conservation.ca.gov/CGS/index.htm

BACKGROUND

Liquefaction-induced ground failure historically has been a major cause of earthquake damage in northern California. During the 1989 Loma Prieta and 1906 San Francisco earthquakes, significant damage to roads, utility pipelines, buildings, and other structures in the San Francisco Bay area was caused by liquefaction-induced ground displacement (Youd and Hoose, 1978; Tinsley and others, 1998).

Sites most susceptible to liquefaction-induced damage are underlain by loose, water-saturated, granular sediment within 40 feet of the ground surface. These geological and ground-water conditions are widespread in the San Francisco Bay Area, most notably in some densely populated valley regions and alluviated floodplains. In addition, the potential for strong earthquake ground shaking is high because of the many nearby active faults. The combination of these factors constitutes a significant seismic hazard, especially in areas marginal to the bay, including areas in the Newark Quadrangle.

METHODS SUMMARY

Characterization of liquefaction hazard presented in this report requires preparation of maps that delineate areas underlain by potentially liquefiable sediment. The following were collected or generated for this evaluation:

- Existing geologic maps were used to provide an accurate representation of the spatial distribution of Quaternary deposits in the study area. Geologic units that generally are susceptible to liquefaction include late Quaternary alluvial and fluvial sedimentary deposits and artificial fill

- Construction of shallow ground-water maps showing the historically highest known ground-water levels

- Quantitative analysis of geotechnical data to evaluate liquefaction potential of deposits

- Information on potential ground shaking intensity based on CGS probabilistic shaking maps

The data collected for this evaluation were processed into a series of geographic information system (GIS) layers using commercially available software. The liquefaction zone map was derived from a synthesis of these data and according to criteria adopted by the SMGB (DOC, 2000).

SCOPE AND LIMITATIONS

Evaluation for potentially liquefiable soils generally is confined to areas covered by Quaternary (less than about 1.6 million years) sedimentary deposits. Such areas within the Newark Quadrangle consist mainly of gently sloping alluvial fans, areas bordering larger streams and low-lying shoreline regions. CGS's liquefaction hazard evaluations are based on information on earthquake ground shaking, surface and subsurface lithology, geotechnical soil properties, and ground-water depth, which is gathered from various sources. Although selection of data used in this evaluation was rigorous, the quality of the data used varies. The State of California and the Department of Conservation make no representations or warranties regarding the accuracy of the data obtained from outside sources.

Liquefaction zone maps are intended to prompt more detailed, site-specific geotechnical investigations, as required by the Act. As such, liquefaction zone maps identify areas where the potential for liquefaction is relatively high. They do not predict the amount or direction of liquefaction-related ground displacements, or the amount of damage to facilities that may result from liquefaction. Factors that control liquefaction-induced ground failure are the extent, depth, density, and thickness of liquefiable materials, depth to ground water, rate of drainage, slope gradient, proximity to free faces, and intensity and duration of ground shaking. These factors must be evaluated on a site-specific basis to assess the potential for ground failure at any given project site.

Information developed in the study is presented in two parts: physiographic, geologic, and hydrologic conditions in PART I, and liquefaction and zoning evaluations in PART II.

PART I

PHYSIOGRAPHY

Study Area Location and Physiography

The Newark 7.5-Minute Quadrangle covers approximately 60 square miles, most of which is in Alameda County. A small area in the southwestern corner within San

Francisco Bay is within San Mateo County. The city of Newark and parts of the cities of Union City, Fremont and Hayward lie within the Newark Quadrangle.

Gently sloping alluviated plains and low-lying shoreline regions bordering San Francisco Bay cover the majority of the quadrangle. The alluvial plains slope west to southwestward toward the bay. The northeastern corner of the quadrangle is occupied by moderately to steeply sloping terrain of the Hayward Hills, which rise to an elevation just over 1,100 ft at the highest point. The Coyote Hills, a linear north-northwesterly trending bedrock ridge about 4 miles long, rise to an elevation of nearly 300 feet above the alluvial plains in the west-central portion of the quadrangle. Major streams in the area are Dry Creek and Alameda Creek, both of which flow westward into the bay. Dry Creek flows out of the Hayward Hills and is formed from several small coalescing drainages, one of which has been dammed forming Jordon Pond in Garin Regional Park. Dry Creek flows into the Alameda Creek channel at the distal edge of the Dry Creek fan. The alluvial fan built at the foot of the hills by Dry Creek is steeper than that of the much larger Alameda Creek, which flows across the Hayward Hills within a steep-walled canyon and drains both the Livermore and Sunol valleys to the east of the hills. Alameda Creek no longer flows along its original more northerly course into the bay. It is now confined to a man-made channel and slough that curves gently from east to west across the quadrangle. The channel passes the northern end of the Coyote Hills and empties into the bay to the west of the Newark Quadrangle within the Redwood Point Quadrangle.

Most of the gently sloping alluvial plains within the Newark Quadrangle have been developed for residential and commercial uses except for a strip of land along the margin of San Francisco Bay. This strip of land has been reclaimed from the bay and is protected from tidal flooding by levees. Salt evaporation ponds have been developed to utilize the flat-lying marshy region along the bay margin. The central and northern Coyote Hills are included within the Coyote Hills Regional Park, which includes an area of flat-lying marshy land on the eastern side of the hills. A quarry is located near the southern end of the Coyote Hills where Franciscan red chert is mined for road aggregate (E.J. Helley, personal communication). Most of the hillside region in the northeastern corner of the quadrangle has been designated as the Dry Creek Pioneer Regional Park, so this area has little residential development except on the lower western flank of the hills. Some large abandoned gravel quarries within Fremont, just north of the Alameda Creek channel, also have been developed as the Quarry Lakes Regional Recreation Area.

There is only one major highway in the map area, Interstate Highway 880, which crosses southeasterly across the center of the quadrangle. State Highway 84 provides a westward route from Interstate Highway 880 to San Mateo County across the bay via the Dumbarton Bridge, the east side of which is located in the southwestern corner of the quadrangle. The Bay Area Rapid Transit also serves this region, and is located to the east of and parallel to Interstate Highway 880.

GEOLOGY

Bedrock and Surficial Geology

Geologic units that generally are susceptible to liquefaction include late Quaternary alluvial and fluvial sedimentary deposits and artificial fill. To evaluate the areal and vertical distribution of shallow Quaternary deposits and to provide information on subsurface geologic, lithologic and engineering properties of the units in the Newark Quadrangle, an unpublished Quaternary geologic map by J. M. Sowers and a bedrock map by Graymer and others (1996) were obtained from the U.S. Geological Survey in digital form. These GIS maps were combined, with minor modifications along the contact between the bedrock and the Quaternary units, to form a single, 1:24,000-scale geologic map of the Newark Quadrangle. The distribution of Quaternary deposits on this map (summarized on Plate 1.1) was used in combination with other data, discussed below, to evaluate liquefaction susceptibility and develop the liquefaction zones of required investigation.

Other geologic maps and reports were reviewed, including Trask and Rolston (1951), Radbruch (1959), Goldman (1961), Atwater and others (1977), Helley and others (1979), Bull (1991), Sloan and Aubrey (1991), Rogers and Figuers (1992), Lienkamper (1992), Sloan (1992), Koltermann and Gorelick (1992), Koltermann (1994), Graymer and others (1996), Helley and Graymer (1997), and Knudsen and others (2000). Limited field reconnaissance was conducted to confirm the location of geologic contacts, observe properties of near-surface deposits, and characterize the surface expression of individual geologic units.

The Quaternary geologic mapping methods used by Sowers in her mapping of the Newark Quadrangle are the same as described by Knudsen and others (2000). The methods consist of interpretation of topographic maps, aerial photographs, and soil surveys, as well as compiled published and unpublished geologic maps. The ages of deposits are estimated using landform shape, relative geomorphic position, crosscutting relationships, superposition, depth and degree of surface dissection, and relative degree of soil-profile development. Table 1.1 compares stratigraphic nomenclature used in Knudsen and others (2000) and the CGS GIS database, with that of several previous studies performed in northern California.

Approximately two thirds of the flat-lying onshore region of the Newark Quadrangle is covered by Holocene or latest Pleistocene to early Holocene alluvial fan and associated deposits. Holocene Bay Mud (Qhbm) or artificial fill overlying Bay Mud (afbm) covers the rest of the flat-lying region that borders San Francisco Bay. Bedrock of Jurassic-Cretaceous age is exposed in the Coyote Hills and rocks of Cretaceous to Miocene age are exposed in the northeastern corner of the map. There are significant stretches of engineered levees (alf) that divide evaporation ponds, flank artificial drainage channels (ac), and protect low-lying marshy regions from tidal flooding. There are a few small bodies of mapped engineered fill (af) underlying some freeway intersections and artificial fill has been used to fill in old Holocene meandering stream channels.

Holocene alluvial fan deposits have been subdivided into the following units: Qhc, Qhfy, Qhly, Qhty, Qhf, Qhf1, Qhff, and Qhl. Active stream-channel deposits (Qhc) are mapped along the beds of the Dry Creek and Alameda Creek by Sowers (unpublished mapping). Historically inundated alluvial fan deposits (Qhfy) are mapped along and to the south of the historical Alameda Creek channel. Young levee deposits (Qhly) are only mapped along Alameda Creek, mainly on either side of the historical channel. Young stream terrace deposits (Qhty) are mapped near the eastern edge of the map flanking the historical Alameda Creek channel. Sowers (unpublished mapping) mapped some small areas of undivided Holocene alluvial fan deposits (Qhf) and a geomorphically distinct subset of these (Qhf1). Fine-grained fan deposits (Qhff) are exposed at the distal parts of the Alameda Creek and Dry Creek fans. Branching Holocene levee deposits (Qhl) are mapped on Alameda Creek and Dry Creek alluvial fans. Undifferentiated Holocene alluvium has been mapped along the Holocene stream channels (Qha) within the Hayward Hills. The majority of the Dry Creek fan and the southernmost part of the Alameda Creek fan have been mapped as latest Pleistocene to Holocene alluvial fan deposits (Qf), though these appear to have a veneer of Holocene deposits based on the interpretation of subsurface geotechnical data. There are levee deposits (Ql) of similar age mapped in this area by Sowers (unpublished mapping). Some small outcrops of latest Pleistocene stream terrace deposits (Qpt) are mapped flanking the Dry Creek channel to the east of the Hayward Fault.

Pleistocene alluvial fan deposits (Qpf) have not been mapped in the Newark Quadrangle by Sowers (unpublished mapping), but have been interpreted within the subsurface during this study. Similarly, Holocene and latest Pleistocene basin deposits (Qhb, Qb and Qpb) have also been interpreted in the subsurface based on the geotechnical borehole data.

Bedrock exposed in the Coyote Hills consists of Late Jurassic to Early Cretaceous Franciscan Complex rocks (KJf, KJflg, KJfm, and KJfmw). In the northeastern corner of the quadrangle, Late Cretaceous sedimentary rocks of the Great Valley Sequence (KJkc, KJk, KJkv, Ko, Kp, and Kr), and middle to late Miocene sediments (Tbr, Tcs, Tor and Ttss) and volcanics (Tv) are exposed. See the earthquake induced landslide portion (Section 2) of this report for additional description of bedrock units.

UNIT	Knudsen and others (2000)	Helley and Graymer (1997)	Helley and others (1979)	CGS GIS database
Artificial fill	af	af		af
Artificial fill over Holocene Bay mud	afbm			afbm
Artificial fill, levee	alf	alf		alf
Artificial stream channel	ac	Qhasc		ac
Modern stream channel deposits	Qhc	Qhsc	Qhsc	Qhc
Latest Holocene alluvial fan deposits	Qhfy	Qhaf1		Qhfy
Latest Holocene alluvial fan levee deposits	Qhly			Qhly
Latest Holocene stream terrace deposits	Qhty	Qhfp1,2		Qhty
Holocene San Francisco Bay mud	Qhbm	Qhbm	Qhbm	Qhbm
Holocene alluvial fan deposits	Qhf, Qhf1	Qhaf	Qham, Qhac	Qhf
Holocene alluvial fan deposits, fine-grained facies	Qhff		Qhaf	Qhff
Holocene alluvial fan levee deposits	Qhl	Qhl		Qhl
Holocene alluvium, undifferentiated	Qha	Qhaf		Qha
Latest Pleistocene to Holocene alluvial fan deposits	Qf			Qf
Latest Pleistocene to Holocene alluvial fan levee deposits	Ql			Ql
Latest Pleistocene stream terrace deposits	Qpt			Qpt
bedrock	br			br

Table 1.1. Correlation Chart of Quaternary Stratigraphic Nomenclatures Used in Previous Studies. For this study, CGS has adopted the nomenclature of Knudsen and others (2000).

Structural Geology

The Newark Quadrangle is within the active San Andreas Fault system, which distributes shearing across a complex system of primarily northwest-trending, right-lateral, strike-slip faults that include the San Andreas, Hayward, and Calaveras faults. The Hayward Fault is located close to the foot of the Hayward Hills in the northeastern corner of the quadrangle, and is within about 8 miles of most onshore areas within the Newark Quadrangle.

ENGINEERING GEOLOGY

Information on subsurface geology and engineering characteristics of flatland deposits was obtained from borehole logs collected from reports on geotechnical and environmental projects. For this investigation, over 200 borehole logs were collected from files of the cities of Newark, Union City, Hayward and Fremont, and also from Caltrans, the U. S. Geological Survey and the Alameda County Water District. Data from 212 borehole logs were entered into a CGS geotechnical GIS database (Table 1.2).

Standard Penetration Tests (SPTs) provide a standardized measure of the penetration resistance of geologic deposits and commonly are used as an index of soil density. This in-field test consists of counting the number of blows required to drive a split-spoon sampler (1.375-inch inside diameter) one foot into the soil at the bottom of a borehole. The driving force is provided by dropping a 140-pound hammer weight 30 inches. The SPT method is formally defined and specified by the American Society for Testing and Materials in test method D1586 (ASTM, 1999). Recorded blow counts for non-SPT geotechnical sampling where the sampler diameter, hammer weight or drop distance differ from those specified for an SPT (ASTM D1586), are converted to SPT-equivalent blow counts. The actual and converted SPT blow counts are normalized to a common-reference, effective-overburden pressure of one atmosphere (approximately one ton per square foot) and a hammer efficiency of 60 percent using a method described by Seed and Idriss (1982) and Seed and others (1985). This normalized blow count is referred to as $(N_1)_{60}$.

Geotechnical and environmental borehole logs provided information on lithologic and engineering characteristics of Quaternary deposits within the study area. Geotechnical characteristics of the Quaternary map units are generalized in Table 1.2 and their composition by soil type in Table 1.3. These analyses reveal that: 1) Holocene materials are generally less dense and more readily penetrated than Pleistocene materials, especially the coarse-grained components; 2) latest Pleistocene alluvial fan deposits (Qpf) have higher dry density measurements than Holocene alluvial fan deposits (Qhf); 3) latest Pleistocene alluvial fan deposits (Qpf) contain more gravel and are coarser grained than Holocene alluvial fan deposits (Qhf); 4) Holocene alluvial units are predominantly fine grained, but have silt and sand lenses throughout that have the potential to liquefy; and 5) most units have a wide range in their dry density and penetration resistance values.

GEOLOGIC MAP UNIT		DRY DENSITY (pounds per cubic foot)						STANDARD PENETRATION RESISTANCE (blows per foot, $(N_1)_{60}$)					
Unit (1)	Texture (2)	Number of Tests	Mean	C (3)	Median	Min	Max	Number of Tests	Mean	C (3)	Median	Min	Max
f	ine	37	106.6	).1[illegible]	108.0	66.0	[illegible]1	58	24	).7[illegible]	18	[illegible]	7[illegible]
	oarse	11	117.3	).1[illegible]	114.0	92.0	[illegible]4	28	26	).8[illegible]	19	[illegible]	[illegible]
alf	Fine	-	-	-	-	-	-	4	26	0.14	27	20	28
	Coarse	-	-	-	-	-	-	-	-	-	-	-	-
)hf	ine	20	103.7	).0[illegible]	104.1	87.0	5	41	19	).6[illegible]	14	[illegible]	7[illegible]
	oarse	1	88.1	-	-	-	-	1	7	-	-	-	-
Qhly	Fine	7	95.7	0.09	95.0	84.0	110.0	11	14	0.65	10	6	28
	Coarse	1	89.6	-	-	-	-	4	5	0.30	5	4	8
)ht	ine	21	90.0	).2[illegible]	98.0	51.0	4	33	9	).5[illegible]	9	[illegible]	2[illegible]
	oarse	-	-	-	-	-	-	3	4	).0[illegible]	4	[illegible]	4
Qhf(4)	Fine	120	101.2	0.10	102.0	56.0	132.0	244	14	0.69	11	1	75
	Coarse	36	104.9	0.07	103.0	85.0	121.0	157	12	0.66	10	3	49
)hf	ine	29	99.0	).0[illegible]	100.0	81.0	6	44	17	).5[illegible]	17	[illegible]	3[illegible]
	oarse	-	-	-	-	-	-	-	-	-	-	-	-
Qhb	Fine	18	96.2	0.14	97.1	56.0	111.3	63	11	0.52	10	3	37
	Coarse	-	-	-	-	-	-	1	17	-	-	-	-
)hl	ine	11	102.9	).0[illegible]	103.0	87.5	6	28	15	).7[illegible]	12	[illegible]	4[illegible]
	oarse	-	-	-	-	-	-	8	9	).4[illegible]	8	[illegible]	1[illegible]
Qf	Fine	87	106.7	0.07	106.0	86.0	131.0	193	14	0.61	12	3	50
	Coarse	21	108.8	0.07	108.0	100.0	134.1	60	21	0.62	17	4	70
)b	ine	-	-	-	-	-	-	12	9	).3[illegible]	8	[illegible]	1[illegible]
	oarse	-	-	-	-	-	-	-	-	-	-	-	-
Qpf	Fine	107	107.3	0.06	108.0	79.0	128.0	90	17	0.53	16	3	44
	Coarse	44	114.5	0.08	114.1	99.0	139.0	150	27	0.60	25	1	87
)pt	ine	-	-	-	-	-	-	3	10	).5[illegible]	10	[illegible]	1[illegible]
	oarse	-	-	-	-	-	-	-	-	-	-	-	-

Notes:
(1) See Table 1.3 for names of the units listed here.
(2) Fine soils (silt and clay) contain a greater percentage passing the #200 sieve (<.074 mm); coarse soils (sand and gravel) contain a greater percentage not passing the #200 sieve.
(3) C = coefficient of variation (standard deviation divided by the mean)
(4) Includes Qhf1

Table 1.2. Summary of Geotechnical Characteristics for Quaternary Geological Units in the Newark 7.5-Minute Quadrangle.

Geologic Unit (1)	Description	Length of boreholes penetrating map unit (feet)	Composition by Soil Type (2) (Percent of total sediment column logged)	Depth to ground water (feet) (3) and liquefaction susceptibility category assigned to geologic unit			
				<10	10 to 30	30 to 40	>40
af	Artificial fill (4)	670	CL 35%; ML 22%; Other 43%	VH-L	H-L	M-L	VL
afbm	Artificial fill over Holocene Bay mud	-	n/a	VH	H	M	VL
alf	Artificial fill, levee	22	CL 95%; GC 5%	VH-L	H-L	M-L	VL
ac	Artificial channel	-	n/a	VH-L	H	M	VL
Qhc	Modern stream channel deposits	-	n/a	VH	H	M	VL
Qhfy	Latest Holocene alluvial fan deposits	245	CL 77%; ML 20%; Other 3%	VH	H	M	VL
Qhly	Latest Holocene alluvial fan levee deposits	100	CL 48%; ML 38%; Other 14%	VH	H	M	VL
Qhty	Latest Holocene stream terrace deposits	-	n/a	VH	H	M	VL
Qhbm	Holocene San Francisco Bay mud	282	CL 57%; CH 34%; Other 9%	H	M	L	VL
Qhf(6)	Holocene alluvial fan deposits	2316	CL 43%; ML 20%; SM 17%; Other 20%	H	M	L	VL
Qhff	Holocene alluvial fan deposits, fine grained facies	230	CL 66%; CH 29%; Other 5%	M	M	L	VL
Qhb	Holocene basin deposits	510	CL 77%; CH 15%; Other 8%	M	M	L	VL
Qhl	Holocene alluvial fan levee deposit	241	CL 42%; ML 30%; SM 16%; Other 12%	H	M	L	VL
Qha	Holocene alluvium, undifferentiated	-	n/a	M	M	L	VL
Qf	Latest Pleistocene to Holocene alluvial fan deposits	143	CL 62%; ML 12%; SM 9%; Other 17%	M	L	L	VL
Ql	Latest Pleistocene to Holocene alluvial fan deposits	-	n/a	M	L	L	VL
Qpbm	Pleistocene Bay Mud deposits	15	ML-CL 100%	L	L	VL	VL
Qb	Latest Pleistocene to Holocene basin deposits	77	CL 95%; Other 5%	L	L	VL	VL
Qpf	Latest Pleistocene alluvial fan deposits	3104	CL 32%; GW 13%; SP 10%; SW 10%; Other 35%	L	L	VL	VL
Qpb	Latest Pleistocene basin deposits	14	CL 78%; CH 22%	L	L	VL	VL

Notes:

(1) Susceptibility assignments are specific to the materials within the Newark 7.5-Minute Quadrangle.
(2) Unified Soil Classification System

(3) Based on the Simplified Procedure (Seed and Idriss, 1971; Youd and Idriss, 1997) and a small number of borehole analyses for some units.
(4) The liquefaction susceptibility of artificial fill ranges widely, depending largely on the nature of the fill, its age, and whether it was compacted during emplacement.
(5) n/a = not applicable
(6) Includes Qhf1

Table 1.3. Liquefaction Susceptibility for Quaternary Map Units within the Newark 7.5-Minute Quadrangle. Units indicate relative susceptibility of deposits to liquefaction as a function of material type and ground-water depth within that deposit. VH = very high, H = high, M = moderate, L = low, and VL = very low to none.

GROUND WATER

Liquefaction hazard may exist in areas where depth to ground water is 40 feet or less. CGS uses the highest known ground-water levels because water levels during an earthquake cannot be anticipated because of the unpredictable fluctuations caused by natural processes and human activities. A historical-high ground-water map differs from most ground-water maps, which show the actual water table at a particular time. Plate 1.2 depicts a hypothetical ground-water surface within alluviated areas.

Ground-water conditions were investigated in the Newark Quadrangle to evaluate the depth to saturated, potentially liquefiable materials. Saturation reduces the effective normal stress, thereby increasing the likelihood of earthquake-induced liquefaction (Youd, 1973). The ground-water evaluation was based on first-encountered water noted in monitoring wells and geotechnical borehole logs acquired from the Regional Water Quality Control Board and the cities of Newark, Union City, Fremont, and Hayward. Additional borehole data were obtained from Caltrans and the Alameda County Water District. The depths to first-encountered unconfined ground water were plotted onto a map of the project area to constrain the estimate of historically shallowest ground water. Water depths from boreholes known to penetrate confined aquifers were not utilized.

Ground-water levels are currently at or near their historical highs in many areas surrounding the San Francisco Bay. Regional ground-water contours on Plate 1.2 show historically high water depths, as interpreted from borehole logs from investigations between 1955 and the 2001.

Depths to first-encountered water in alluviated areas of the Newark Quadrangle range from one to 68 feet below the ground surface, although most of the area has ground-water levels within 40 feet of the ground surface (Plate 1.2). Plate 1.2 also shows that depth to ground water over much of the flat-lying area along the shore of the San Francisco Bay is less that 5 feet. Only on the upper part of the Dry Creek alluvial fan and on part of the Alameda Creek fan just west of the Hayward do ground-water depths exceed 40 feet. The Hayward Fault acts as a ground-water barrier and ground water is generally shallower to the east of the fault as determined in the adjacent Niles Quadrangle to the east (work in progress) and Hayward Quadrangle to the north (Rosinski and Wiegers, 2002).

PART II

LIQUEFACTION POTENTIAL

Liquefaction may occur in water-saturated sediment during moderate to great earthquakes. Liquefied sediment loses strength and may fail, causing damage to buildings, bridges, and other structures. Many methods for mapping liquefaction hazard have been proposed. Youd (1991) highlights the principal developments and notes some of the widely used criteria. Youd and Perkins (1978) demonstrate the use of geologic criteria as a qualitative characterization of liquefaction susceptibility and introduce the mapping technique of combining a liquefaction susceptibility map and a liquefaction opportunity map to produce a liquefaction potential map. Liquefaction susceptibility is a function of the capacity of sediment to resist liquefaction. Liquefaction opportunity is a function of the potential seismic ground shaking intensity.

The method applied in this study for evaluating liquefaction potential is similar to that of Tinsley and others (1985). Tinsley and others (1985) applied a combination of the techniques used by Seed and others (1983) and Youd and Perkins (1978) for their mapping of liquefaction hazards in the Los Angeles region. CGS's method combines geotechnical analyses, geologic and hydrologic mapping, and probabilistic earthquake shaking estimates, but follows criteria adopted by the SMGB (DOC, 2000).

LIQUEFACTION SUSCEPTIBILITY

Liquefaction susceptibility reflects the relative resistance of a soil to loss of strength when subjected to ground shaking. Physical properties of soil such as sediment grain-size distribution, compaction, cementation, saturation, and depth govern the degree of resistance to liquefaction. Some of these properties can be correlated to a sediment's geologic age and environment of deposition. With increasing age, relative density may increase through cementation of the particles or compaction caused by the weight of the overlying sediment. Grain-size characteristics of a soil also influence susceptibility to liquefaction. Sand is more susceptible than silt or gravel, although silt of low plasticity is treated as liquefiable in this investigation. Cohesive soils generally are not considered susceptible to liquefaction. Such soils may be vulnerable to strength loss with remolding and represent a hazard that is not addressed in this investigation. Soil characteristics and processes that result in higher measured penetration resistances generally indicate lower liquefaction susceptibility. Thus, blow count and cone penetrometer values are useful indicators of liquefaction susceptibility.

Saturation is required for liquefaction, and the liquefaction susceptibility of a soil varies with the depth to ground water. Very shallow ground water increases the susceptibility to liquefaction (soil is more likely to liquefy). Soils that lack resistance (susceptible soils) typically are saturated, loose and sandy. Soils resistant to liquefaction include all soil types that are dry, cohesive, or sufficiently dense.

CGS's map inventory of areas containing soils susceptible to liquefaction begins with evaluation of geologic maps and historical occurrences, cross-sections, geotechnical test data, geomorphology, and ground-water hydrology. Soil properties and soil conditions such as type, age, texture, color, and consistency, along with historical depths to ground water are used to identify, characterize, and correlate susceptible soils. Because Quaternary geologic mapping is based on similar soil observations, liquefaction susceptibility maps typically are similar to Quaternary geologic maps. CGS's qualitative relations among susceptibility, geologic map unit and depth to ground water are summarized in Table 1.3.

Most Holocene materials where water levels are within 30 feet of the ground surface have susceptibility assignments of high (H) to very high (VH) (Table 1.3). Holocene basin deposits (Qhb) and Holocene alluvial fan fine-facies deposits (Qhff) primarily are composed of fine-grained material and have correspondingly lower susceptibility assignments. Undifferentiated Holocene alluvium also has been assigned moderate susceptibility. However, these units may contain lenses of material with higher liquefaction susceptibility. Latest Pleistocene to Holocene deposits have moderate to low liquefaction susceptibility where water levels are within 30 feet of the ground surface. All latest Pleistocene and older deposits at depths less than 30 feet have low (L) susceptibility assignments except latest Pleistocene to Holocene alluvial fan and levee deposits (Qf, Ql). These units have slightly lower densities and penetration resistance and contain lenses of potentially liquefiable material (Tables 1.2 and 1.3) and are, therefore, assigned a moderate susceptibility. Uncompacted artificial fill and latest Holocene stream channel, alluvial fan, alluvial fan levee and stream terrace deposits have moderate (M) susceptibility assignments at depths below 30 ft. All other units have low (L) to very low (VL) susceptibility assignments when 30 feet below the ground surface.

LIQUEFACTION OPPORTUNITY

Liquefaction opportunity is a measure, expressed in probabilistic terms, of the potential for strong ground shaking. Analyses of in-situ liquefaction resistance require assessment of liquefaction opportunity. The minimum level of seismic excitation to be used for such purposes is the level of peak ground acceleration (PGA) with a 10 percent probability of exceedance over a 50-year period (DOC, 2000). The earthquake magnitude used in CGS's analysis is the magnitude that contributes most to the calculated PGA for an area.

For the Newark Quadrangle, PGAs of 0.52 to 0.88 g, resulting from earthquakes of magnitude 7.1 to 7.9 were used for liquefaction analyses. The PGA and magnitude values were based on de-aggregation of the probabilistic hazard at the 10 percent in 50-year hazard level (Petersen and others, 1996). See the ground motion portion (Section 3) of this report for additional discussion of potential ground motions.

Quantitative Liquefaction Analysis

CGS performs quantitative analysis of geotechnical data to evaluate liquefaction potential using the Seed-Idriss Simplified Procedure (Seed and Idriss, 1971; Seed and others, 1983; National Research Council, 1985; Seed and others, 1985; Seed and Harder, 1990; Youd and Idriss, 1997). Using the Seed-Idriss Simplified Procedure one can calculate soil resistance to liquefaction, expressed in terms of cyclic resistance ratio (CRR), based on SPT results, ground-water level, soil density, moisture content, soil type, and sample depth. CRR values are then compared to calculated earthquake-generated shear stresses expressed in terms of cyclic stress ratio (CSR). The Seed-Idriss Simplified Procedure requires normalizing earthquake loading relative to a M7.5 event for the liquefaction analysis. To accomplish this, CGS's analysis uses the Idriss magnitude-scaling factor (MSF) (Youd and Idriss, 1997). It is convenient to think in terms of a factor of safety (FS) relative to liquefaction, where: FS = (CRR / CSR) * MSF. FS, therefore, is a quantitative measure of liquefaction potential. CGS uses a factor of safety of 1.0 or less, where CSR equals or exceeds CRR, to indicate the presence of potentially liquefiable soil. While an FS of 1.0 is considered the "trigger" for liquefaction, for a site specific analysis an FS of as much as 1.5 may be appropriate depending on the vulnerability of the site and related structures.

The CGS liquefaction analysis program calculates an FS for each geotechnical sample where blow counts were collected. Typically, multiple samples are collected for each borehole. The program then independently calculates an FS for each non-clay layer that includes at least one penetration test using the minimum $(N_1)_{60}$ value for that layer. The minimum FS value of the layers penetrated by the borehole is used to determine the liquefaction potential for each borehole location. The reliability of FS values varies according to the quality of the geotechnical data. FS, as well as other considerations such as slope, presence of free faces, and thickness and depth of potentially liquefiable soil, are evaluated in order to construct liquefaction potential maps, which are then used to make a map showing zones of required investigation.

Of the 212 geotechnical borehole logs reviewed in this study (Plate 1.2), 148 include blow-count data from SPTs or from penetration tests that allow reasonable blow count translations to SPT-equivalent values. Non-SPT values, such as those resulting from the use of 2-inch or 2½-inch inside-diameter ring samplers, were translated to SPT-equivalent values if reasonable factors could be used in conversion calculations. The reliability of the SPT-equivalent values varies. Therefore, they are weighted and used in a more qualitative manner. Few borehole logs, however, include all of the information (e.g. soil density, moisture content, sieve analysis, etc.) required for an ideal Seed-Idriss Simplified Procedure analysis. For boreholes having acceptable penetration tests, liquefaction analysis is performed using recorded density, moisture, and sieve test values or using averaged test values of similar materials.

The Seed-Idriss Simplified Procedure for liquefaction evaluation was developed primarily for clean sand and silty sand. As described above, results depend greatly on accurate evaluation of in-situ soil density as measured by the number of soil penetration blow counts using an SPT sampler. However, many of the Holocene alluvial deposits in the study area contain a significant amount of gravel. In the past, gravelly soils were considered not to be susceptible to liquefaction because the high permeability of these soils presumably would allow the dissipation of pore pressures before liquefaction could occur. However, liquefaction in gravelly soils has been observed during earthquakes, and recent laboratory studies have shown that gravelly soils are susceptible to liquefaction (Ishihara, 1985; Harder and Seed, 1986; Budiman and Mohammadi, 1995; Evans and Zhou, 1995; and Sy and others, 1995). SPT-derived density measurements in gravelly soils are unreliable and generally too high. They are likely to lead to overestimation of the density of the soil and, therefore, result in an underestimation of the liquefaction susceptibility. To identify potentially liquefiable units where the N values appear to have been affected by gravel content, correlations were made with boreholes in the same unit where the N values do not appear to have been affected by gravel content.

LIQUEFACTION ZONES

Criteria for Zoning

Areas underlain by materials susceptible to liquefaction during an earthquake were included in liquefaction zones using criteria developed by the Seismic Hazards Mapping Act Advisory Committee and adopted by the SMGB (DOC, 2000). Under those guideline criteria, liquefaction zones are areas meeting one or more of the following:

1. Areas known to have experienced liquefaction during historical earthquakes

2. All areas of uncompacted artificial fill containing liquefaction-susceptible material that are saturated, nearly saturated, or may be expected to become saturated

3. Areas where sufficient existing geotechnical data and analyses indicate that the soils are potentially liquefiable

4. Areas where existing geotechnical data are insufficient

In areas of limited or no geotechnical data, susceptibility zones may be identified by geologic criteria as follows:

a) Areas containing soil deposits of late Holocene age (current river channels and their historic floodplains, marshes and estuaries), where the M7.5-weighted peak acceleration that has a 10 percent probability of being exceeded in 50 years is greater than or equal to 0.10 g and the water table is less than 40 feet below the ground surface; or

b) Areas containing soil deposits of Holocene age (less than 11,000 years), where the M7.5-weighted peak acceleration that has a 10 percent probability of being exceeded in 50 years is greater than or equal to 0.20 g and the historical high water table is less than or equal to 30 feet below the ground surface; or

c) Areas containing soil deposits of latest Pleistocene age (11,000 to 15,000 years), where the M7.5-weighted peak acceleration that has a 10 percent probability of being exceeded in 50 years is greater than or equal to 0.30 g and the historical high water table is less than or equal to 20 feet below the ground surface.

Application of SMGB criteria to liquefaction zoning in the Newark Quadrangle is summarized below.

Areas of Past Liquefaction

Knudsen and others (2000) compiled data from Tinsley and others (1998) and Youd and Hoose (1978) for earthquakes in the San Francisco Bay region. Tinsley and others (1998) compiled observations of evidence for liquefaction for the 1989 Loma Prieta earthquake. Youd and Hoose (1978) compiled them for earlier earthquakes, including 1868 Hayward and 1906 San Francisco earthquakes. The Knudsen and others (2000) digital database differs from earlier compilation efforts in that the observations were located on a 1:24,000-scale base map versus the smaller-scale base maps used in the earlier publications. Sites were reevaluated and some single sites were broken into two or more where the greater base-map scale allowed.

Within the Newark Quadrangle, Youd and Hoose (1978) identified two main liquefaction sites from the 1906 San Francisco earthquake (Plate 1.2). Areas along the old Alameda Creek channel near Alvarado (Union City) hosted numerous liquefaction effects including ground settlement, sand boils, and lateral spreading towards the creek; a fire-engine house moved 2 feet laterally in this area (site 170, Plate 1.2). Bluish-gray sand, along with large volumes of water, was ejected along many of the ground cracks. The foundation of the Alvarado pumping station, which was located about a mile west of Alvarado in the marshy land by the bay, settled about 2 feet causing all pipe connections to be severed. Sand boils, disturbed wells and ground cracks were observed along a railroad track, about a mile north of Newark including a 1.5-mile-long fissure, 8 to12 inches wide from which water gushed (site 168). Some old wells in the area were reported to have water spouting up to 12 feet into the air. An absence of ground failure was noted along the length of the Sunol aqueduct and 3.6-inch diameter pipeline on the east side of the bay (site 144) (Youd and Hoose, 1979). No ground failures due to liquefaction were identified within the Newark Quadrangle from the 1989 Loma Prieta earthquake (Tinsley and others, 1998).

Artificial Fills

In the Newark Quadrangle, artificial fill areas large enough to show at the scale of mapping consist of engineered fill for river levees and elevated freeways. Since these fills are considered to be properly engineered, zoning for liquefaction in such areas depends on soil conditions in underlying strata. Non-engineered fills are commonly loose and uncompacted, and the material varies in size and type.

Areas with Sufficient Existing Geotechnical Data

Borehole logs that include penetration test data and sufficiently detailed lithologic descriptions were used to evaluate liquefaction potential. These areas with sufficient geotechnical data were evaluated for zoning based on the liquefaction potential determined by the Seed-Idriss Simplified Procedure. In Holocene alluvial deposits that cover much of the area within the Newark Quadrangle, most of the borehole logs that were analyzed using the Seed-Idriss Simplified Procedure contain sediment layers that may liquefy under the expected earthquake loading. These areas containing saturated potentially liquefiable material are included in the zone of required investigation.

Based on geologic interpretation of the thickness of Holocene alluvial fan deposits across the Alameda Creek and Dry Creek alluvial fans and presence of shallow ground water, most of the flatlands within the Newark Quadrangle are included within the liquefaction zone of required investigation. The majority of boreholes in this region were found to contain potentially liquefiable material. The edge of the zone on the eastern side of the map was defined where Pleistocene alluvial fan deposits are saturated but overlying Holocene deposits are not. Pleistocene fan deposits are interpreted to be less susceptible to liquefaction than Holocene deposits when saturated, being more dense and compacted (Tables 1.2 and 1.3). Areas where depth to the top of the Pleistocene deposits is less than the depth to the highest historical ground water (thus, Holocene deposits are not saturated) were not included in the zone of required investigation

Areas with Insufficient Existing Geotechnical Data

Undifferentiated Holocene alluvium (Qha) and Holocene channel deposits (Qhc) could not be characterized adequately from available geotechnical data. These deposits were included within the zone for reasons presented in criterion 4. The ground-water depth is not known along Dry Creek to the east of the Hayward Fault, but in both the Hayward and Niles quadrangles, ground water is documented to be shallower on the east side of the fault than to the west. Thus, in the Newark Quadrangle ground water and forecast ground motions are sufficiently high to include these Holocene units within the liquefaction zone. The Holocene undifferentiated alluvium and Holocene channel deposits, mapped along the parts of Dry and Alameda creeks, are likely to contain loose, granular material that is saturated because of the proximity to the active stream channel.

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SECTION 2
EARTHQUAKE-INDUCED LANDSLIDE EVALUATION REPORT

Earthquake-Induced Landslide Zones in the Newark 7.5-Minute Quadrangle, Alameda County, California

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California Geological Survey

PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation (DOC), Division of Mines and Geology (DMG) [now called California Geological Survey (CGS)] to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use seismic hazard zone maps prepared by CGS in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (DOC, 1997). The text of this report is on the Internet at http://gmw.consrv.ca.gov/shmp/webdocs/sp117.pdf

Following the release of DMG Special Publication 117 (DOC, 1997), agencies in the Los Angeles metropolitan region sought more definitive guidance in the review of geotechnical investigations addressing landslide hazards. The agencies made their request through the Geotechnical Engineering Group of the Los Angeles Section of the American Society of Civil Engineers (ASCE). This group convened an implementation committee in 1998 under the auspices of the Southern California Earthquake Center (SCEC). The committee, which consisted of practicing geotechnical engineers and engineering geologists, released an overview of the practice of landslide analysis, evaluation, and mitigation techniques (SCEC, 2002). This text is also on the Internet at: http://www.scec.org/

This section of the evaluation report summarizes seismic hazard zone mapping for earthquake-induced landslides in the Newark 7.5-Minute Quadrangle. Section 1 (addressing liquefaction) and Section 3 (addressing earthquake shaking) complete the report, which is one of a series that summarizes the preparation of seismic hazard zone maps within the state (Smith, 1996). Additional information on seismic hazard zone mapping in California can be accessed on the California Geological Survey's Internet page: http://gmw.consrv.ca.gov/shmp/webdocs/sp117.pdf

BACKGROUND

Landslides triggered by earthquakes historically have been a significant cause of earthquake damage. In California, large earthquakes such as the 1971 San Fernando, 1989 Loma Prieta, and 1994 Northridge earthquakes triggered landslides that were responsible for destroying or damaging numerous structures, blocking major transportation corridors, and damaging life-line infrastructure. Areas that are most susceptible to earthquake-induced landslides are steep slopes in poorly cemented or highly fractured rocks, areas underlain by loose, weak soils, and areas on or adjacent to existing landslide deposits. These geologic and terrain conditions exist in many parts of California, including numerous hillside areas that have already been developed or are likely to be developed in the future. The opportunity for strong earthquake ground shaking is high in many parts of California because of the presence of numerous active faults. The combination of these factors constitutes a significant seismic hazard throughout much of California, including the hillside areas of the Newark Quadrangle.

METHODS SUMMARY

The mapping of earthquake-induced landslide hazard zones presented in this report is based on the best available terrain, geologic, geotechnical, and seismological data. If unavailable or significantly outdated, new forms of these data were compiled or generated specifically for this project. The following were collected or generated for this evaluation:

- Digital terrain data were used to provide an up-to-date representation of slope gradient and slope aspect in the study area.

- Geologic mapping was used to provide an accurate representation of the spatial distribution of geologic materials in the study area. In addition, a map of existing landslides, whether triggered by earthquakes or not, was prepared.

- Geotechnical laboratory test data were collected and statistically analyzed to quantitatively characterize the strength properties and dynamic slope stability of geologic materials in the study area.

- Seismological data in the form of CGS probabilistic shaking maps and catalogs of strong-motion records were used to characterize future earthquake shaking within the mapped area.

The data collected for this evaluation were processed into a series of GIS layers using commercially available software. A slope stability analysis was performed using the Newmark method of analysis (Newmark, 1965), resulting in a map of landslide hazard potential. The earthquake-induced landslide hazard zone was derived from the landslide hazard potential map according to criteria developed in a CGS pilot study (McCrink and Real, 1996; McCrink, 2001) and adopted by the State Mining and Geology Board (DOC, 2000).

SCOPE AND LIMITATIONS

The methodology used to make this map is based on earthquake ground-shaking estimates, geologic material-strength characteristics and slope gradient. These data are gathered from a variety of outside sources. Although the selection of data used in this evaluation was rigorous, the quality of the data is variable. The State of California and the Department of Conservation make no representations or warranties regarding the accuracy of the data gathered from outside sources.

Earthquake-induced landslide zone maps are intended to prompt more detailed, site-specific geotechnical investigations as required by the Act. As such, these zone maps identify areas where the potential for earthquake-induced landslides is relatively high. Due to limitations in methodology, it should be noted that these zone maps do not necessarily capture all potential earthquake-induced landslide hazards. Earthquake-induced ground failures that are not addressed by this map include those associated with ridge-top spreading and shattered ridges. It should also be noted that no attempt has been made to map potential run-out areas of triggered landslides. It is possible that such run-out areas may extend beyond the zone boundaries. The potential for ground failure resulting from liquefaction-induced lateral spreading of alluvial materials, considered by some to be a form of landsliding, is not specifically addressed by the earthquake-induced landslide zone or this report. See Section 1, Liquefaction Evaluation Report for the Newark Quadrangle, for more information on the delineation of liquefaction zones.

The remainder of this report describes in more detail the mapping data and processes used to prepare the earthquake-induced landslide zone map for the Newark Quadrangle. The information is presented in two parts. Part I covers physiographic, geologic and engineering geologic conditions in the study area. Part II covers the preparation of landslide hazard potential and landslide zone maps.

PART I

PHYSIOGRAPHY

Study Area Location and Physiography

The Newark 7.5-Minute Quadrangle map covers approximately 60 square miles on the eastern side of San Francisco Bay. Most of the map area is occupied by alluvial flatlands, tidal marshes and salt evaporation ponds along the eastern margin of San Francisco Bay. The Hayward Hills extend into the northeastern portion of the quadrangle. The Hayward Hills, which reach 1,133 feet above sea level in the map area, have some slopes greater than 2:1 (horizontal to vertical). The narrow ridge of the Coyote Hills, with about 275 feet of relief, rises above the marshlands of the San Francisco Bay National Wildlife Refuge in the southwestern part of the quadrangle.

Alameda Creek is the largest creek in the map area. It flows from Niles Canyon, east of the map area, and extends across the east bay plain to San Francisco Bay. Several tidal sloughs cross marshy areas along San Francisco Bay, including Coyote Hills Slough and Newark Slough.

Most of the flatlands in the map area are developed for residential, commercial and industrial uses. Major developed areas in the Newark Quadrangle include portions of the Alameda County cities of Newark, Hayward, Union City, and Fremont. Most of the hillsides are sparsely developed, although a couple of residential areas in Hayward extend into the hills. Major highways include Interstate Highway 880 (Nimitz Freeway) and State Highway 84, which crosses the Dumbarton Bridge in the southwest corner of the map area where a small portion of San Mateo County extends into the quadrangle. The Bay Area Rapid Transit also serves this region, and is located to the east and parallel to Interstate Highway 880. There is a large rock quarry in the Coyote Hills and some inactive gravel pits near Alameda Creek at the eastern edge of the map area. The gravel pits are now used as ground-water recharge ponds. Some have been developed as the Quarry Lakes Regional Recreation Area.

Digital Terrain Data

The calculation of slope gradient is an essential part of the evaluation of slope stability under earthquake conditions. An accurate slope gradient calculation begins with an up-to-date map representation of the earth's surface in the form of a digital topographic map. Within the Newark Quadrangle, a Level 2 digital elevation model (DEM) was obtained from the USGS (U.S. Geological Survey, 1993). This DEM was prepared from the 7.5-minute quadrangle topographic contours generated from 1947 aerial photographs by photogrammetric methods and plane-table surveys. The DEM has a 10-meter horizontal resolution and a 7.5-meter vertical accuracy.

A slope map was made from the DEM using a third-order, finite difference, center-weighted algorithm (Horn, 1981). The DEM also was used to make a slope aspect map.

The manner in which the slope and aspect maps were used to prepare the zone map will be described in subsequent sections of this report.

GEOLOGY

Bedrock and Surficial Geology

The primary source of bedrock geologic mapping used in this slope stability evaluation was the "Preliminary geologic map emphasizing bedrock formations in Alameda County, California: a digital database" (Graymer and others, 1996). This digital geologic database was prepared at a resolution scale of 1:24,000 from a compilation of previously published reports and from new mapping and field checking by the authors. Sowers (unpublished) map of Quaternary surficial geology at a scale of 1:24,000 was also used.

Geologists at the CGS merged the surficial and bedrock geologic maps. Contacts between surficial and bedrock units were modified in some areas to resolve differences between the two maps. Geologic field reconnaissance was performed to assist in adjusting contacts and to review the lithology and structure of the various geologic units.

Bedrock in the Newark Quadrangle is characterized by two highly deformed Mesozoic basement assemblages that are unconformably overlain by deformed Tertiary sedimentary rocks and relatively undeformed Quaternary sediments. These two Mesozoic basement complexes are the Great Valley Complex and the Franciscan Complex (Graymer and others, 1996). In the map area, the two basement complexes are separated by the Hayward Fault, which extends through the northeastern part of the map area.

The Great Valley Complex is exposed in the Hayward Hills on the northeastern side of the Hayward Fault. It includes the Coast Range Ophiolite, which is composed of serpentinite, gabbro, diabase, basalt and keratophyre (altered silicic volcanic rock), and the Great Valley Sequence, which is composed of sandstone, conglomerate and shale of Jurassic and Cretaceous age (Graymer and others, 1996). The ophiolitic rocks are the remnants of arc-related oceanic crust. The Great Valley Sequence consists of turbidites that were deposited on top of the oceanic crustal rocks. Ophiolitic rocks are not exposed in the Newark Quadrangle; however, several units of the Great Valley Sequence are exposed. The Great Valley Sequence rocks are unconformably overlain by Tertiary marine and non-marine sedimentary units in the Newark Quadrangle.

The Franciscan Complex is composed of weakly to strongly metamorphosed graywacke, basalt, argillite, chert and other rocks (Graymer and others, 1996). The Franciscan Complex was accreted beneath the Great Valley Complex by subduction. During subduction, the Franciscan rocks were intensely sheared and tectonically mixed, producing a melange of small to large blocks of various rock types embedded in a matrix of crushed rock material. Franciscan rocks underlie thick Quaternary deposits on the southwestern side of the Hayward Fault and also are exposed in the Coyote Hills.

The following paragraphs describe the rock types exposed in the map area in more detail. Description of the rock units is based on the work of Graymer and others (1996).

Franciscan rocks are exposed only in the Coyote Hills. Franciscan Complex melange (KJfm) of Cretaceous and/or Late Jurassic age consists of sheared argillite, graywacke and green tuff with blocks of graywacke, chert, shale, greenstone basalt, and high-grade metamorphic blocks (glaucophane schist, amphibolite and eclogite) (Graymer and others, 1996). Individual blocks are mapped locally, including marble (fl) and chert (fc). Greenstone (KJflg) of the Franciscan Complex consists of metamorphosed basalt that is generally pervasively altered and that locally exhibits well-defined pillow structure. Undivided graywacke and metagraywacke (KJfmw) is also mapped in the Coyote Hills.

Several units of the Great Valley Sequence are mapped in the Hayward Hills (Graymer and others, 1996). The Knoxville Formation (KJk) consists of silt and clay shale with thin interbeds of sandstone. The lower part contains thick pebble to cobble conglomerate beds (KJkc). This formation also contains beds of angular volcanoclastic breccia near the base (KJkv). The Oakland Sandstone (Ko) consists of medium- to coarse-grained sandstone with prominent lenses of pebble to cobble conglomerate. The proportion of conglomerate in this unit increases significantly to the north in the Oakland area. The Redwood Canyon Formation (Kr) consists of fine- to coarse-grained sandstone with thin interbeds of mica-rich siltstone. The Pinehust Shale (Kp) consists of siliceous shale with interbedded sandstone and siltstone.

There are several Tertiary rock units in the map area (Graymer and others, 1996). The Tolman Formation of Hall (1958) of Eocene(?) age (Ttss) consists of dark gray, glauconite-bearing lithic sandstone. The Claremont Shale of middle and late Miocene age (Tcs) consists to brown siliceous shale with minor interbedded chert. The Briones Formation of late Miocene age (Tbr) consists of gray and white, fine- to coarse-grained sandstone with shell breccia and pebble and cobble conglomerate lenses. The Orinda Formation of late Miocene age (To) consists of pebble to boulder conglomerate, conglomeratic sandstone and medium- to coarse-grained sandstone. Unnamed volcanic rocks of late Miocene and/or Pliocene age (Tv) consist of rhyolite, dacite, andesite tuff, breccia and basalt.

Quaternary surficial geologic units are discussed in detail in Section 1 of this report.

Structural Geology

The Hayward Fault is the primary geologic structure in the study area. It is an active right-lateral strike-slip fault with an estimated late Holocene slip rate of about 9 mm per year. The Hayward Fault is undergoing active creep in the Newark Quadrangle to the north and south, as manifested by offset curbs, streets, buildings and other structures in numerous locations (Lienkaemper, 1992). Lienkaemper (1992) has mapped in detail the inferred active trace of the Hayward Fault. A variety of additional traces are shown on earlier geologic maps (Radbruch-Hall, 1974; Smith, 1980). Associated with the main trace are numerous splays and subsidiary traces that may accommodate secondary movements or that may be slightly older abandoned traces. Bedrock units in the vicinity of the Hayward Fault zone have been complexly offset and juxtaposed by the main trace and it's associated subsidiary traces.

Northeast of the Hayward Fault, in the Hayward Hills, Cretaceous and Tertiary rocks are cut by numerous thrust faults. Folds are generally not preserved in the Cretaceous rocks in the vicinity of the study area; however, folds are preserved in Tertiary rocks, indicating evidence of Tertiary compressional deformation. The northern end of a synclinal axis preserved in Tertiary rocks extends into the northeastern part of the quadrangle. Almost all strata in the Hayward Hills within the map area dip more steeply than the hillslopes. As a result, very few areas of potentially adverse bedding are present, as discussed later in this report.

Franciscan rocks southwest of the Hayward Fault are chaotically deformed and pervasively sheared. Franciscan rocks exposed in the map area in the Coyote Hills do not exhibit folds or consistent bedding orientations.

Landslide Inventory

As a part of the geologic data compilation, an inventory of existing landslides in the Newark Quadrangle was prepared by field reconnaissance, analysis of stereo-paired aerial photographs and a review of previously published landslide mapping (Nilsen, 1975). Landslides were mapped at a scale of 1:24,000. For each landslide included on the map a number of characteristics (attributes) were compiled. These characteristics include the confidence of interpretation (definite, probable and questionable) and other properties, such as activity, thickness, and associated geologic unit(s). Landslides rated as definite and probable were carried into the slope stability analysis. Landslides rated as questionable were not carried into the slope stability analysis due to the uncertainty of their existence. The completed landslide map was digitized and the attributes for each landslide were compiled in a database. A version of this landslide inventory is included with Plate 2.1.

The distribution of landslides mapped for this study differs slightly from that of landslides mapped by Nilsen (1975). For example, Nilsen (1975) does not include source areas (amphitheater walls) within the landslides on his map and there is some difference between CGS's interpretation of individual landslides and that of Nilsen. Some additional landslides were identified in this inventory, which also includes several small reported historical landslides.

Within the Hayward Hills the majority of landslides occur on slopes underlain by the Knoxville Formation (KJk, KJkc), with some in the Briones Formation (Tbr) and Claremont Shale (Tcs). In the Coyote Hills, most of the landslides occur on slopes underlain by Franciscan melange (KJfm). Smaller, shallow earth or debris flow style landslides preferentially occur on southwest-facing slopes. Larger rock slides flank the northern and southern forks of Dry Creek within the Knoxville Formation conglomerate (KJkc).

Some smaller historical landslides occur in slopes underlain by Knoxville Formation conglomerate (KJkc). Landslides in this area range from shallow earth flows and debris slides, to deeper rotational rock slides. About half have occurred on southwest-facing slopes.

Because it is not within the scope of the Act to review and monitor grading practices to ensure that past slope failures have been properly mitigated, all documented slope failures, whether or not surface expression currently exists, are included in the landslide inventory.

ENGINEERING GEOLOGY

Geologic Material Strength

To evaluate the stability of geologic materials under earthquake conditions, the geologic map units described above were ranked and grouped on the basis of their shear strength. Generally, the primary source for shear-strength measurements is geotechnical reports prepared by consultants on file with local government permitting departments. Shear-strength data for the units identified on the Newark Quadrangle geologic map were obtained from the community development departments of the Cities of Hayward, Union City and Fremont and the County of Alameda (see Appendix A). The locations of rock and soil samples taken for shear testing within the Newark Quadrangle are shown on Plate 2.1. There were very few shear tests available for bedrock formations in the Newark Quadrangle because development in the hillside areas is sparse. As a result, shear tests from the adjoining or nearby Hayward, Oakland East and Niles quadrangles were used to augment data for many of the geologic units in the Newark Quadrangle.

Shear strength data gathered from the above sources were compiled for each geologic map unit. Geologic units were grouped on the basis of average angle of internal friction (average phi) and lithologic character. Average (mean or median) phi values for each geologic map unit and corresponding strength groups are summarized in Table 2.1. For each geologic strength group in the map area, the average shear strength value was assigned and used in our slope stability analysis. A geologic material strength map was made based on the groupings presented in Table 2.1 and Table 2.2. This map provides a spatial representation of material strength for use in the slope stability analysis.

Adverse Bedding Conditions

Adverse bedding conditions are an important consideration in slope stability analyses. Adverse bedding conditions occur where the dip direction of bedded sedimentary rocks is roughly the same as the slope aspect, and where the dip magnitude is less than the slope gradient. Under these conditions, landslides can slip along bedding surfaces due to a lack of lateral support.

To account for adverse bedding in our slope stability evaluation, we used geologic structural data in combination with digital terrain data to identify areas with potentially adverse bedding, using methods similar to those of Brabb (1983). The structural data, derived from the geologic map database, were used to categorize areas of common bedding dip direction and magnitude. The dip direction was then compared to the slope aspect and, if the same, the dip magnitude and slope gradient categories were compared. If the dip magnitude category was less than or equal to the slope gradient category, but greater than 25 percent (4:1 slope), the area was marked as a potential adverse bedding area.

The results of this analysis indicated that there are no significant areas of adverse bedding conditions in the map area. This is because: a) beds are consistently steeper than the topographic slopes in the map area, and b) Franciscan rocks exposed in the Coyote Hills are chaotically oriented and cannot be meaningfully analyzed for dip slope conditions using this approach.

Existing Landslides

As discussed later in this report, the criteria for landslide zone mapping state that all existing landslides that are mapped as definite or probable are automatically included in the landslide zone of required investigation. Therefore, an evaluation of shear strength parameters for existing landslides is not necessary for the preparation of the zone map. However, in the interest of completeness for the material strength map, to provide relevant material strength information to project plan reviewers, and to allow for future revisions of our zone mapping procedures, we have collected and compiled shear strength data considered representative of existing landslides within the quadrangle.

The strength characteristics of existing landslides (Qls) must be based on tests of the materials along the landslide slip surface. Ideally, shear tests of slip surfaces formed in each mapped geologic unit would be used. However, this amount of information is rarely available, and for the preparation of the earthquake-induced landslide zone map it has been assumed that all landslides within the quadrangle have the same slip surface strength parameters. We collect and use primarily “residual” strength parameters from laboratory tests of slip surface materials tested in direct shear or ring shear test equipment. Back-calculated strength parameters, if the calculations appear to have been performed appropriately, also have been used. For landslides within the Newark Quadrangle, a residual direct shear test from the Penetencia Creek landslide on the eastern side of San Jose was used as a characteristic residual strength value for landslides. This test was performed on a well-developed landslide slip surface that was obtained from a deep borehole in the landslide mass. This test yielded an internal friction of angle (phi value) of 12 degrees.

NEWARK QUADRANGLE
SHEAR STRENGTH GROUPS

	Formation Name	Number Tests	Mean/Median Phi (deg)	Mean/Median Group Phi (deg)	Mean/Median Group C (psf)	No Data: Similar Lithology	Phi Values Used in Stability Analyses
GROUP 1	KJk*	11	32.5/32.5	32/31.5	674/510	KJkc	32
	KJf***	5	31/31			KJflg	
	Ko*	9	34/35			KJkv	
	Kr*	3	28/33			Tv	
	Tbr***	14	32/32			fc	
	Tcs*	7	32/30			fl	
GROUP 2	Qhl*	2	28.5/28.5	27/28.5	542/500	Kpfl	28
	af*	31	26.8/28.5			Ttss	
						Qf	
						Qha	
						Qhc	
						Qhly	
						Qhty	
						Ql	
						Qpt	
						ac	
						alf	
GROUP 3	KJfm	9		23/23	759/675	Qhf1	23
	Qhf	7				Qhff	
GROUP 4	Tor**	20	19/17	19.3/17.5	750/612		18
	Qhbm	10	20/17.5				
GROUP 5	Qls	1	12	12	745		12

* includes tests from Hayward Quadrangle
** includes tests from Niles Quadrangle
*** includes tests from Oakland East Quadrangle

Formations for strength groups from USGS OF-96-252 (Graymer and others, 1996)

Table 2.1. Summary of the Shear Strength Statistics for the Newark Quadrangle.

Newark Quadrangle Strength Groups				
GROUP 1	GROUP 2	GROUP 3	GROUP 4	GROUP 5
KJf	Kp	KJfm	Tor	Qls
KJflg	Qf	KJfmw	Qhbm	
KJk	Qha	Qhf	afbm	
KJkc	Qhc	Qhfl		
KJkv	Qhfy	Qhff		
Ko	Qhl			
Kr	Qhly			
Tbr	Qhty			
Tcs	Ql			
Tv	Qpt			
fc	Ttss			
fl	ac			
	af			
	alf			

Table 2.2. Summary of Shear Strength Groups for the Newark Quadrangle.

PART II

EARTHQUAKE-INDUCED LANDSLIDE HAZARD POTENTIAL

Design Strong-Motion Record

The Newmark analysis used in delineating the earthquake-induced landslide zones requires the selection of a design earthquake strong-motion record. Because the active Hayward Fault traverses diagonally, northwest/southeast through the northeastern part of the Newark Quadrangle, the selection of a strong motion record was based on the desire to emulate a large earthquake on the Hayward Fault. The Hayward Fault is a right lateral strike-slip fault with a total length of approximately 86 kilometers, and an estimated maximum moment magnitude of 7.1 (Petersen and others, 1996). The hilly areas of the northeastern part of the Newark Quadrangle, which would be susceptible to earthquake-induced landsliding, range from zero to about 1.5 kilometers from the seismic source. Strong-motion records considered in the selection include: the CGS Strong Motion Instrumentation Program (SMIP) Corralitos record from the 1989 Loma Prieta earthquake; the Southern California Edison (SCE) Lucerne record from the 1992 Landers earthquake; and the Japan Meteorological Agency (JMA) Kobe City record from the 1995 Hyogoken-Nambu (Kobe) earthquake. The significant parameters for each of these earthquakes are listed below:

Strong-Motion Record	Moment Magnitude	Source to Site Distance (km)	PGA (g)
SMIP Corralitos	6.9	5.1	0.64
SCE Lucerne	7.3	1.1	0.80
JMA Kobe	6.9	0.6	0.82

The Corralitos record was eliminated because the fault motion was oblique, rather than purely strike-slip, and because of the relatively short rupture length. The Kobe record was eliminated because of uncertainties regarding the effects of topographic and basin-edge amplification at the recording site. Despite the slightly higher than expected magnitude, the Lucerne record from the 1992 Landers earthquake was used because it has many tectonic similarities to an earthquake on the Hayward Fault.

The selected strong-motion record was not scaled or otherwise modified prior to analysis.

Displacement Calculation

The design strong-motion record was used to develop a relationship between landslide displacement and yield acceleration (a_y), defined as the earthquake horizontal ground acceleration above which landslide displacements take place. This relationship was prepared by integrating the design strong-motion record twice for a given acceleration value to find the corresponding displacement, and the process was repeated for a range of acceleration values (Jibson, 1993). The resulting curve in Figure 2.1 represents the full spectrum of displacements that can be expected for the design strong-motion record. This curve provides the required link between anticipated earthquake shaking and estimates of displacement for different combinations of geologic materials and slope gradient, as described in the Slope Stability Analysis section below.

The amount of displacement predicted by the Newmark analysis provides an indication of the relative amount of damage that could be caused by earthquake-induced landsliding. Displacements of 30, 15 and 5 cm were used as criteria for rating levels of earthquake-induced landslide hazard potential based on the work of Youd (1980), Wilson and Keefer (1983), and a CGS pilot study for earthquake-induced landslides (McCrink and Real, 1996; McCrink, 2001). Applied to the curve in Figure 2.1, these displacements correspond to yield accelerations of 0.14, 0.18 and 0.24g. Because these yield acceleration values are derived from the design strong-motion record, they represent the ground shaking opportunity thresholds that are significant in the Newark Quadrangle.

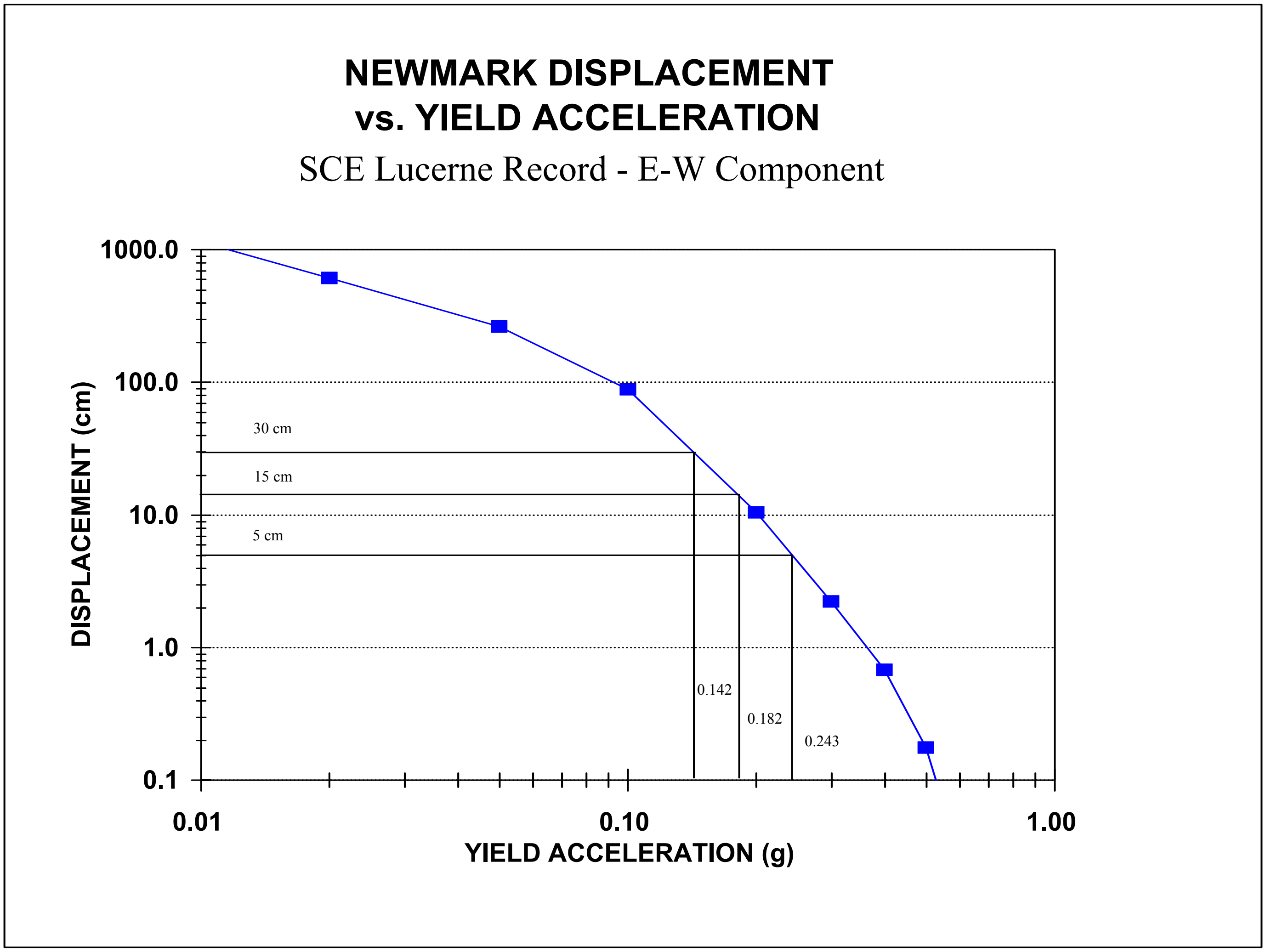

Figure 2.1. Yield Acceleration vs. Newmark Displacement for the Lucerne Record for the 1992 Landers Earthquake.

Slope Stability Analysis

A slope stability analysis was performed for each geologic material strength group at slope increments of 1 degree. An infinite-slope failure model under unsaturated slope conditions was assumed. A factor of safety was calculated first, followed by the calculation of yield acceleration from Newmark's (1965) equation:

$$a_y = (FS - 1)g \sin \alpha$$

where **FS** is the Factor of Safety, **g** is the acceleration due to gravity, and α is the direction of movement of the slide mass, in degrees measured from the horizontal, when displacement is initiated (Newmark, 1965). For an infinite slope failure α is the same as the slope angle.

The yield accelerations resulting from Newmark's equations represent the susceptibility to earthquake-induced failure of each geologic material strength group for a range of slope gradients. Based on the relationship between yield acceleration and Newmark displacement shown in Figure 2.1, hazard potentials were assigned as follows:

1. If the calculated yield acceleration was less than 0.14g, Newmark displacement greater than 30 cm is indicated, and a HIGH hazard potential was assigned (H on Table 2.3)

2. If the calculated yield acceleration fell between 0.14g and 0.18g, Newmark displacement between 15 cm and 30 cm is indicated, and a MODERATE hazard potential was assigned (M on Table 2.3)

3. If the calculated yield acceleration fell between 0.18g and 0.24g, Newmark displacement between 5 cm and 15 cm is indicated, and a LOW hazard potential was assigned (L on Table 2.3)

4. If the calculated yield acceleration was greater than 0.24g, Newmark displacement of less than 5 cm is indicated, and a VERY LOW potential was assigned (VL on Table 2.3)

Table 2.3 summarizes the results of the stability analyses. The earthquake-induced landslide hazard potential map was prepared by combining the geologic material-strength map and the slope map according to this table.

NEWARK QUADRANGLE HAZARD POTENTIAL MATRIX

Geologic Material Strength Group (Average Phi)	HAZARD POTENTIAL (Percent Slope)			
	Very Low	Low	Moderate	High
1 (32)	0 to 37%	37 to 42%	42 to 47%	> 47%
2 (28)	0 to 27%	27 to 33%	33 to 37%	> 37%
3 (23)	0 to 18%	18 to 23%	23 to 27%	> 27%
4 (18)	0 to 7%	7 to 14%	14 to 18%	> 18%
5 (12)	0%	0 to 3%	3 to 7%	> 7%

Table 2.3. Hazard Potential Matrix for Earthquake-Induced Landslides in the Newark Quadrangle. Values in the table show the range of slope gradient (expressed as percent slope) corresponding to calculated Newmark displacement ranges from the design earthquake for each material strength group.

EARTHQUAKE-INDUCED LANDSLIDE HAZARD ZONE

Criteria for Zoning

Earthquake-induced landslide zones were delineated using criteria adopted by the California State Mining and Geology Board (DOC, 2000). Under these criteria, earthquake-induced landslide hazard zones are defined as areas that meet one or both of the following conditions:

1. Areas that have been identified as having experienced landslide movement in the past, including all mappable landslide deposits and source areas as well as any landslide that is known to have been triggered by historic earthquake activity.

2. Areas where the geologic and geotechnical data and analyses indicate that the earth materials may be susceptible to earthquake-induced slope failure.

These conditions are discussed in further detail in the following sections.

Existing Landslides

Existing landslides typically consist of disrupted soils and rock materials that are generally weaker than adjacent undisturbed rock and soil materials. Previous studies indicate that existing landslides can be reactivated by earthquake movements (Keefer, 1984). Earthquake-triggered movement of existing landslides is most pronounced in steep head scarp areas and at the toe of existing landslide deposits. Although reactivation of deep-seated landslide deposits is less common (Keefer, 1984), a significant number of deep-seated landslide movements have occurred during, or soon after, several recent earthquakes. Based on these observations, all existing landslides with a definite or probable confidence rating are included within the earthquake-induced landslide hazard zone.

Geologic and Geotechnical Analysis

Based on the conclusions of a pilot study performed by CGS (McCrink and Real, 1996; McCrink, 2001), it has been concluded that earthquake-induced landslide hazard zones should encompass all areas that have a High, Moderate or Low level of hazard potential (see Table 2.3). This would include all areas where the analyses indicate earthquake displacements of 5 centimeters or greater. Areas with a Very Low hazard potential, indicating less than 5 centimeters displacement, are excluded from the zone.

As summarized in Table 2.3, all areas characterized by the following geologic strength group and slope gradient conditions are included in the earthquake-induced landslide hazard zone:

1. Geologic Strength Group 5 is included for all slope gradient categories. Strength Group 5 includes only existing landslides, which are included in the zone on the basis of the preceding criterion.

2. Geologic Strength Group 4 is included for all slopes steeper than 7 percent.

3. Geologic Strength Group 3 is included for all slopes steeper than 18 percent.

4. Geologic Strength Group 2 is included for all slopes steeper than 27 percent.

5. Geologic Strength Group 1 is included for all slopes greater than 37 percent.

This results in about 1.7 percent of the quadrangle lying within the earthquake-induced landslide hazard zone for the Newark Quadrangle. The earthquake-induced landslide hazard zones are concentrated in the Hayward Hills in the northeast corner of the quadrangle and in the Coyote Hills in the southwest part of the quadrangle.

ACKNOWLEDGMENTS

The authors would like to thank the following individuals and organizations for their assistance in obtaining the data necessary to complete this project. Gary Moore and Mary Anne Hubbard with the County of Alameda arranged access and provided assistance in retrieving geotechnical data from files maintained by Alameda County. Norman Payne with the City of Hayward arranged access and provided assistance in retrieving geotechnical data from files maintained by the City of Hayward. Dianna Rapposelli arranged access and provided assistance in retrieving geotechnical data from files maintained by the City of Fremont. At CGS, Terilee McGuire, Lee Wallinder and Bob Moscovitz provided GIS support. Robert Urban assisted in the shear test data collection and data entry. Barbara Wanish and Diane Vaughan prepared the final landslide hazard zone maps and the graphic displays for this report.

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APPENDIX A
SOURCE OF ROCK STRENGTH DATA

SOURCE	NUMBER OF TESTS SELECTED
County of Alameda	**56**
City of Hayward	**38**
City of Union City	**20**
City of Fremont	**14**
Total Number of Shear Tests	**128**

SECTION 3
GROUND SHAKING EVALUATION REPORT

Potential Ground Shaking in the Newark 7.5-Minute Quadrangle, Alameda County, California

By

Mark D. Petersen*, Chris H. Cramer*, Geoffrey A. Faneros, Charles R. Real, and Michael S. Reichle

California Department of Conservation
California Geological Survey
***Formerly with CGS, now with U.S. Geological Survey**

PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation (DOC), Division of Mines and Geology (DMG) [now called California Geological Survey (CGS)] to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the Seismic Hazard Zone Maps in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (DOC, 1997). The text of this report is on the Internet at http://gmw.consrv.ca.gov/shmp/webdocs/sp117.pdf

This section of the evaluation report summarizes the ground motions used to evaluate liquefaction and earthquake-induced landslide potential for zoning purposes. Included are ground motion and related maps, a brief overview on how these maps were prepared, precautionary notes concerning their use, and related references. The maps provided herein are presented at a scale of approximately 1:150,000 (scale bar provided on maps), and show the full 7.5-minute quadrangle and portions of the adjacent eight quadrangles. They can be used to assist in the specification of earthquake loading conditions ***for the analysis of ground failure*** according to the "Simple Prescribed Parameter Value" method (SPPV) described in the site investigation guidelines (DOC, 1997). Alternatively, they can be used as a basis for comparing levels of ground motion determined by other methods with the statewide standard.

This section and Sections 1 and 2 (addressing liquefaction and earthquake-induced landslide hazards) constitute a report series that summarizes development of seismic hazard zone maps in the state. Additional information on seismic hazard zone mapping in California can be accessed on the California Geological Survey's Internet page: http://www.conservation.ca.gov/CGS/index.htm

EARTHQUAKE HAZARD MODEL

The estimated ground shaking is derived from the statewide probabilistic seismic hazard evaluation released cooperatively by the California Department of Conservation, Division of Mines and Geology [California Geological Survey], and the U.S. Geological Survey (Petersen and others, 1996). That report documents an extensive 3-year effort to obtain consensus within the scientific community regarding fault parameters that characterize the seismic hazard in California. Fault sources included in the model were evaluated for long-term slip rate, maximum earthquake magnitude, and rupture geometry. These fault parameters, along with historical seismicity, were used to estimate return times of moderate to large earthquakes that contribute to the hazard.

The ground shaking levels are estimated for each of the sources included in the seismic source model using attenuation relations that relate earthquake shaking with magnitude, distance from the earthquake, and type of fault rupture (strike-slip, reverse, normal, or subduction). The published hazard evaluation of Petersen and others (1996) only considers uniform firm-rock site conditions. In this report, however, we extend the hazard analysis to include the hazard of exceeding peak horizontal ground acceleration (PGA) at 10 percent probability of exceedance in 50 years on spatially uniform conditions of rock, soft rock, and alluvium. These soil and rock conditions approximately correspond to site categories defined in Chapter 16 of the Uniform Building Code (ICBO, 1997), which are commonly found in California. We use the attenuation relations of Boore and others (1997), Campbell (1997), Sadigh and others (1997), and Youngs and others (1997) to calculate the ground motions.

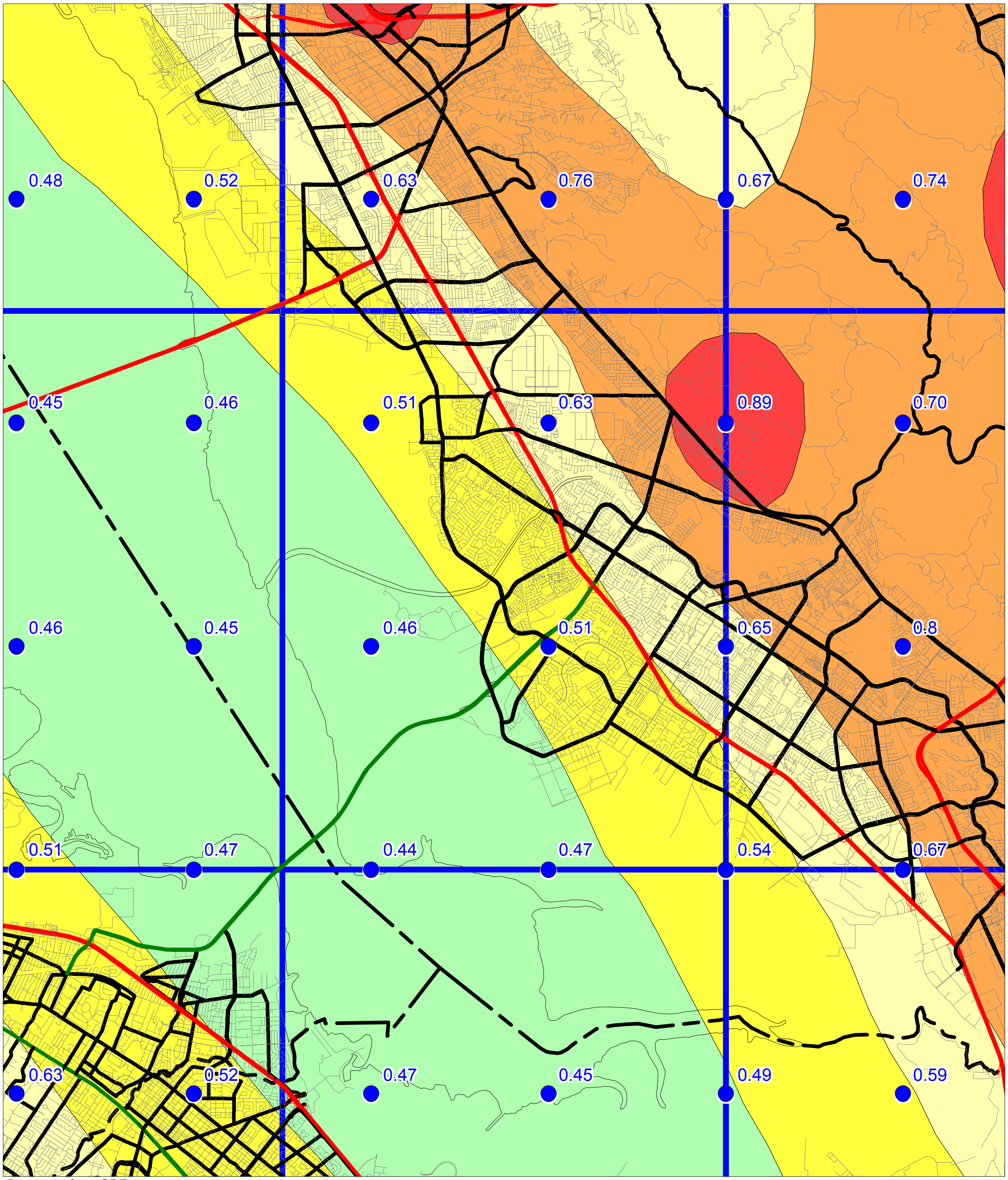
The seismic hazard maps for ground shaking are produced by calculating the hazard at sites separated by about 5 km. Figures 3.1 through 3.3 show the hazard for PGA at 10 percent probability of exceedance in 50 years assuming the entire map area is firm rock, soft rock, or alluvial site conditions respectively. The sites where the hazard is calculated are represented as dots and ground motion contours as shaded regions. The quadrangle of interest is outlined by bold lines and centered on the map. Portions of the eight

NEWARK 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

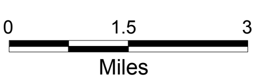
10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

FIRM ROCK CONDITIONS



Base map from GDT



Department of Conservation
California Geological Survey

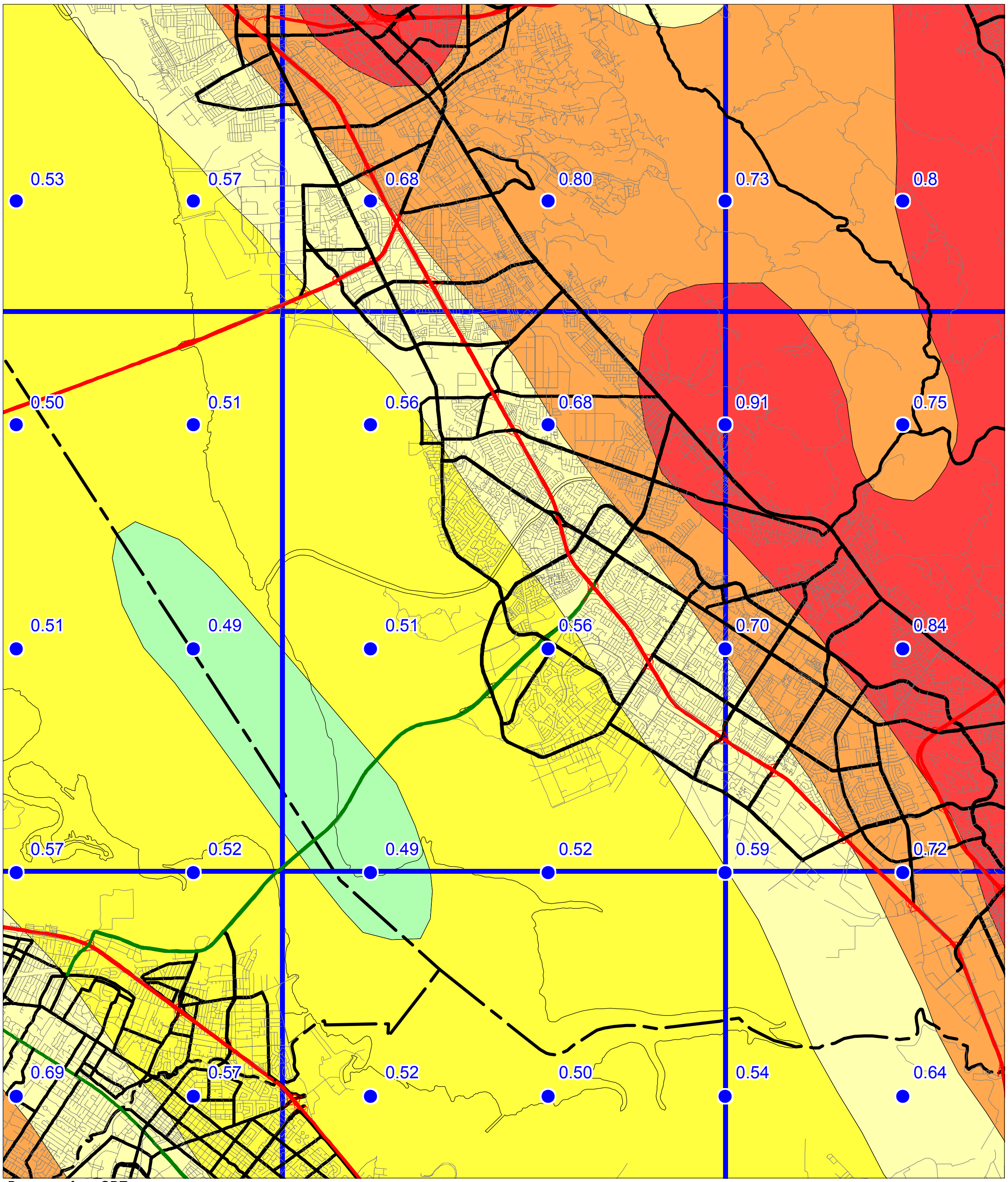
Figure 3.1

NEWARK 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

SOFT ROCK CONDITIONS



Base map from GDT

0 1.5 3
Miles

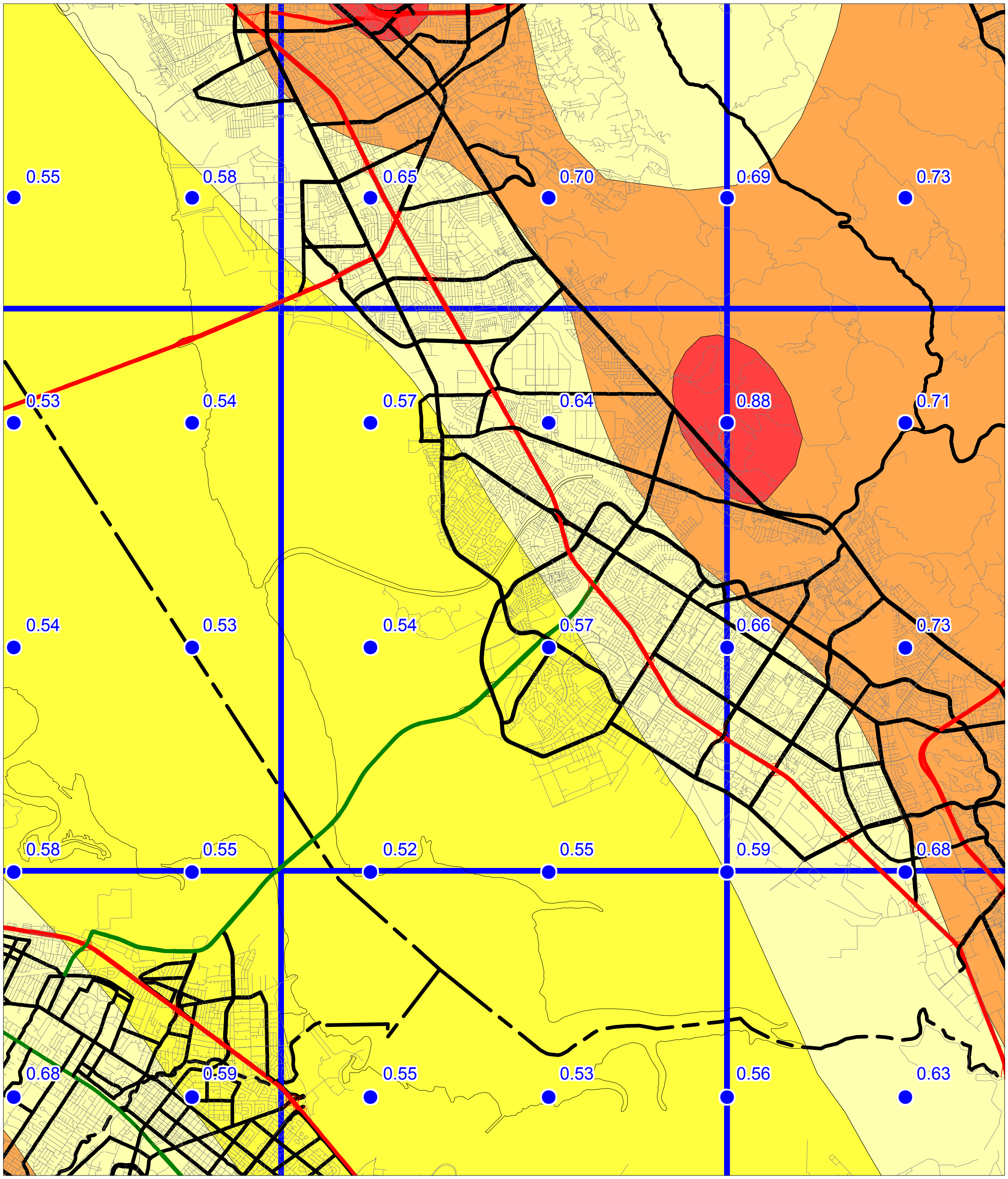
Department of Conservation
California Geological Survey

Figure 3.2

NEWARK 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)
1998

ALLUVIUM CONDITIONS



Base map from GDT

0 1.5 3
Miles

Department of Conservation
California Geological Survey

Figure 3.3

adjacent quadrangles are also shown so that the trends in the ground motion may be more apparent. We recommend estimating ground motion values by selecting the map that matches the actual site conditions, and interpolating from the calculated values of PGA rather than the contours, since the points are more accurate.

APPLICATIONS FOR LIQUEFACTION AND LANDSLIDE HAZARD ASSESSMENTS

Deaggregation of the seismic hazard identifies the contribution of each of the earthquakes (various magnitudes and distances) in the model to the ground motion hazard for a particular exposure period (see Cramer and Petersen, 1996). The map in Figure 3.4 identifies the magnitude and the distance (value in parentheses) of the earthquake that contributes most to the hazard at 10 percent probability of exceedance in 50 years on alluvial site conditions (*predominant earthquake*). This information gives a rationale for selecting a seismic record or ground motion level in evaluating ground failure. However, it is important to keep in mind that more than one earthquake may contribute significantly to the hazard at a site, and those events can have markedly different magnitudes and distances. For liquefaction hazard the predominant earthquake magnitude from Figure 3.4 and PGA from Figure 3.3 (alluvium conditions) can be used with the Youd and Idriss (1997) approach to estimate cyclic stress ratio demand. For landslide hazard the predominant earthquake magnitude and distance can be used to select a seismic record that is consistent with the hazard for calculating the Newmark displacement (Wilson and Keefer, 1983). When selecting the predominant earthquake magnitude and distance, it is advisable to consider the range of values in the vicinity of the site and perform the ground failure analysis accordingly. This would yield a range in ground failure hazard from which recommendations appropriate to the specific project can be made. Grid values for predominant earthquake magnitude and distance should **not** be interpolated at the site location, because these parameters are not continuous functions.

A preferred method of using the probabilistic seismic hazard model and the “simplified Seed-Idriss method” of assessing liquefaction hazard is to apply magnitude scaling probabilistically while calculating peak ground acceleration for alluvium. The result is a “magnitude-weighted” ground motion (liquefaction opportunity) map that can be used directly in the calculation of the cyclic stress ratio threshold for liquefaction and for estimating the factor of safety against liquefaction (Youd and Idriss, 1997). This can provide a better estimate of liquefaction hazard than use of predominate magnitude described above, because all magnitudes contributing to the estimate are used to weight the probabilistic calculation of peak ground acceleration (Real and others, 2000). Thus, large distant earthquakes that occur less frequently but contribute *more* to the liquefaction hazard are appropriately accounted for.

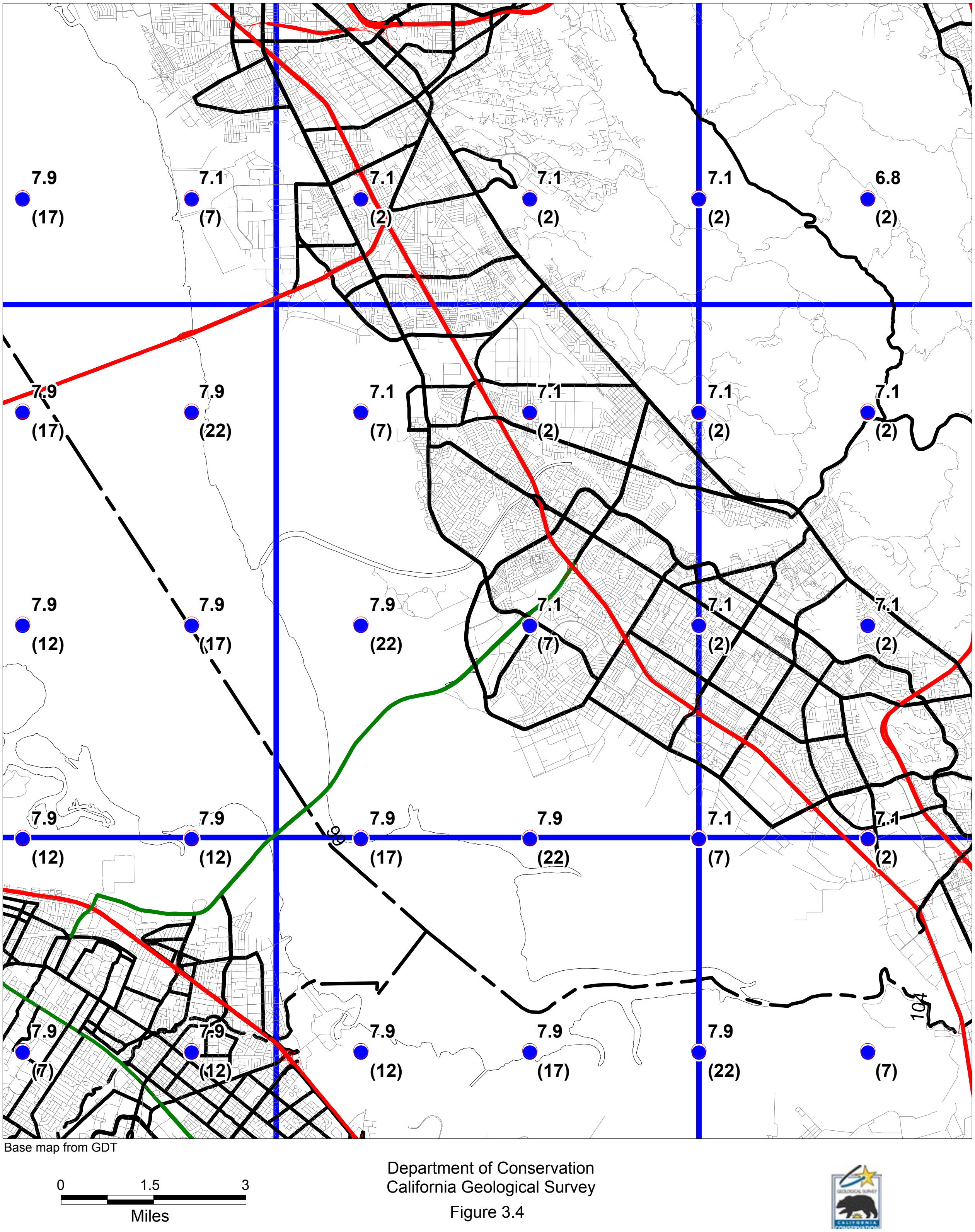
Figure 3.5 shows the magnitude-weighted alluvial PGA based on Idriss’ weighting function (Youd and Idriss, 1997). It is important to note that the values obtained from this map are pseudo-accelerations and should be used in the formula for factor of safety without any magnitude-scaling (a factor of 1) applied.

NEWARK 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION

1998

PREDOMINANT EARTHQUAKE
Magnitude (Mw)
(Distance (km))



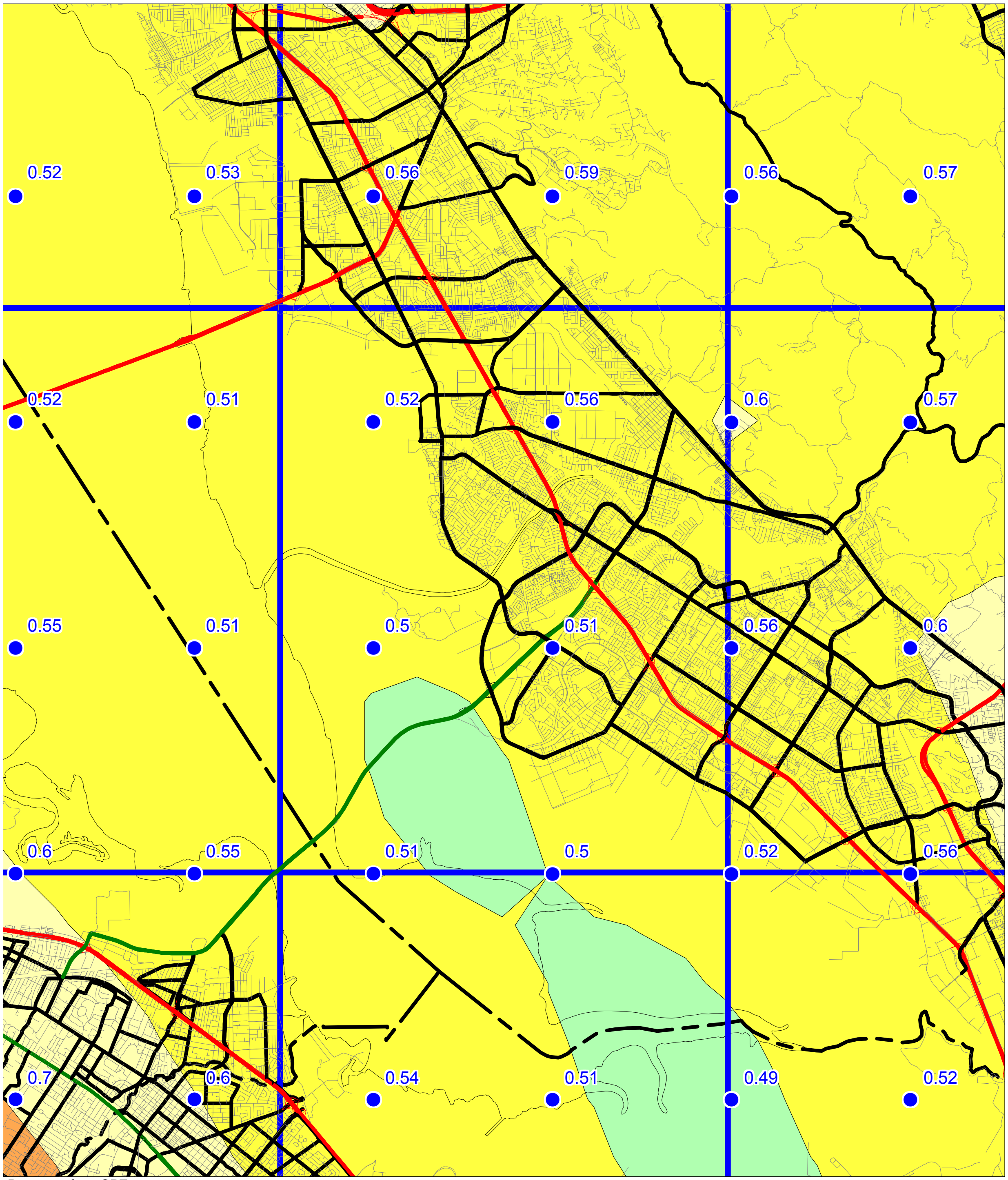
Department of Conservation
California Geological Survey
Figure 3.4

NEWARK 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS MAGNITUDE-WEIGHTED PSEUDO-PEAK ACCELERATION (g) FOR ALLUVIUM

1998

LIQUEFACTION OPPORTUNITY



Base map from GDT

0 1.5 3
Miles

Department of Conservation
California Geological Survey

Figure 3.5

USE AND LIMITATIONS

The statewide map of seismic hazard has been developed using regional information and is ***not appropriate for site specific structural design applications***. Use of the ground motion maps prepared at larger scale is limited to estimating earthquake loading conditions for preliminary assessment of ground failure at a specific location. We recommend consideration of site-specific analyses before deciding on the sole use of these maps for several reasons.

1. The seismogenic sources used to generate the peak ground accelerations were digitized from the 1:750,000-scale fault activity map of Jennings (1994). Uncertainties in fault location are estimated to be about 1 to 2 kilometers (Petersen and others, 1996). Therefore, differences in the location of calculated hazard values may also differ by a similar amount. At a specific location, however, the log-linear attenuation of ground motion with distance renders hazard estimates less sensitive to uncertainties in source location.

2. The hazard was calculated on a grid at sites separated by about 5 km (0.05 degrees). Therefore, the calculated hazard may be located a couple kilometers away from the site. We have provided shaded contours on the maps to indicate regional trends of the hazard model. However, the contours only show regional trends that may not be apparent from points on a single map. Differences of up to 2 km have been observed between contours and individual ground acceleration values. *We recommend that the user interpolate PGA between the grid point values rather than simply using the shaded contours*.

3. Uncertainties in the hazard values have been estimated to be about +/- 50 percent of the ground motion value at two standard deviations (Cramer and others, 1996).

4. Not all active faults in California are included in this model. For example, faults that do not have documented slip rates are not included in the source model. Scientific research may identify active faults that have not been previously recognized. Therefore, future versions of the hazard model may include other faults and omit faults that are currently considered.

5. A map of the predominant earthquake magnitude and distance is provided from the deaggregation of the probabilistic seismic hazard model. However, it is important to recognize that a site may have more than one earthquake that contributes significantly to the hazard. Therefore, in some cases earthquakes other than the predominant earthquake should also be considered.

Because of its simplicity, it is likely that the SPPV method (DOC, 1997) will be widely used to estimate earthquake shaking loading conditions for the evaluation of ground failure hazards. It should be kept in mind that ground motions at a given distance from an earthquake will vary depending on site-specific characteristics such as geology, soil properties, and topography, which may not have been adequately accounted for in the regional hazard analysis. Although this variance is represented to some degree by the recorded ground motions that form the basis of the hazard model used to produce Figures 3.1, 3.2, and 3.3, extreme deviations can occur. More sophisticated methods that take into account other factors that may be present at the site (site amplification, basin effects, near source effects, etc.) should be employed as warranted. The decision to use the SPPV method with ground motions derived from Figures 3.1, 3.2, or 3.3 should be based on careful consideration of the above limitations, the geotechnical and seismological aspects of the project setting, and the "importance" or sensitivity of the proposed building with regard to occupant safety.

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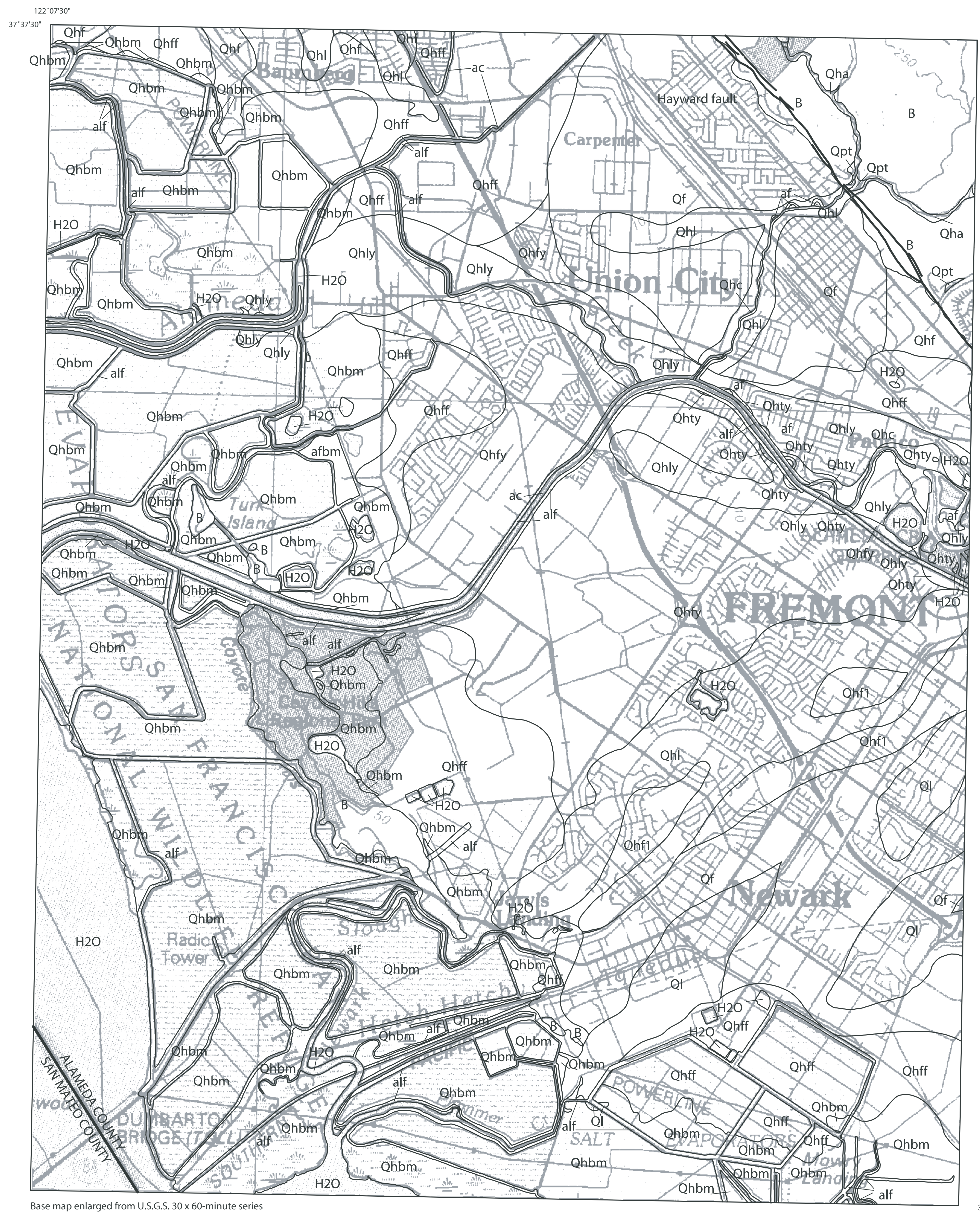
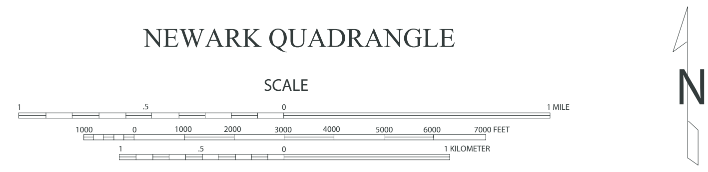


Base map enlarged from U.S.G.S. 30 x 60-minute series

NEWARK QUADRANGLE



Hayward Fault from Bryant and others (2001)

Lithologic contact

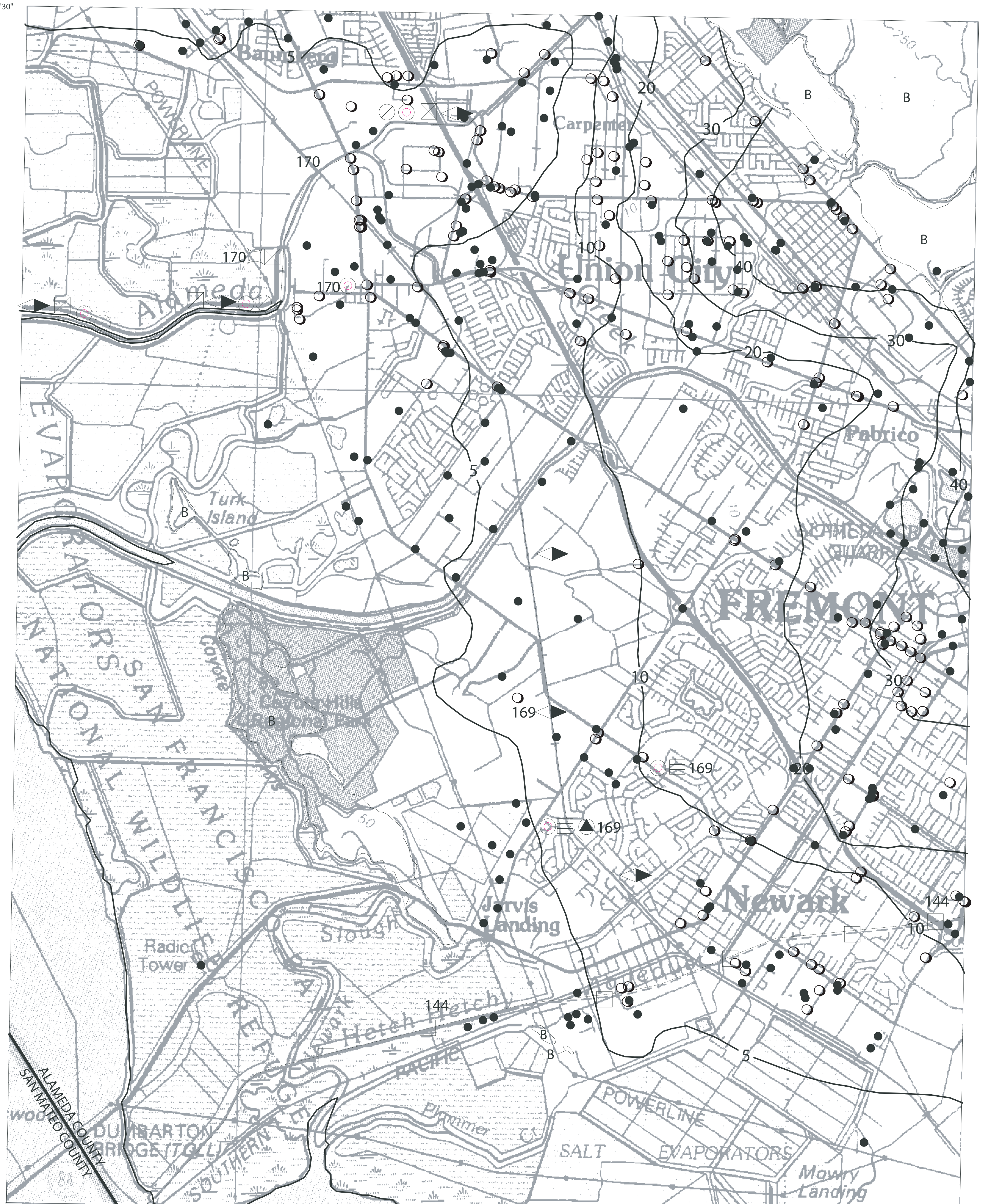
B = Pre-Quaternary bedrock

See "Bedrock and Surficial Geology" in Section 1 of report for descriptions of units.

Plate 1.1 Quaternary geologic map of the Newark 7.5-Minute Quadrangle, California.

Unpublished mapping by J. Sowers, William Lettis & Associates, Inc.

37°37' 30"
122°07'30"



Base map enlarged from U.S.G.S. 30 x 60-minute series

37°30'
122°00'

NEWARK QUADRANGLE

SCALE

1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
1 KILOMETER

N

Historical Ground Failures (modified from Knudsen and others, 2000)

- Miscellaneous effects
- Ground settlement
- Lateral spread
- Sand boil
- Disturbed well
- Absence of ground failures
- Ground cracks
- Streambank landslides including slumps
- Areas along which observations were recorded. Symbols show failure types.
- 172 Number assigned to ground failure site (adapted from Youd and Hoose (1978) and Tinsley and others (1998) by Knudsen and others (2000))
- B Pre-Quaternary bedrock. See "Bedrock and Surficial Geology" in Section 1 of report for descriptions of units.
- —10— Depth to ground water, in feet (5, 10, 20 foot contours)
- Geotechnical boreholes used in liquefaction evaluation
- Ground-water level data provided by the California State Water Resources Control Board

Plate 1.2 Historical liquefaction sites, depth to historically high ground water, and locations of boreholes used in this study, Newark 7.5-Minute Quadrangle, California

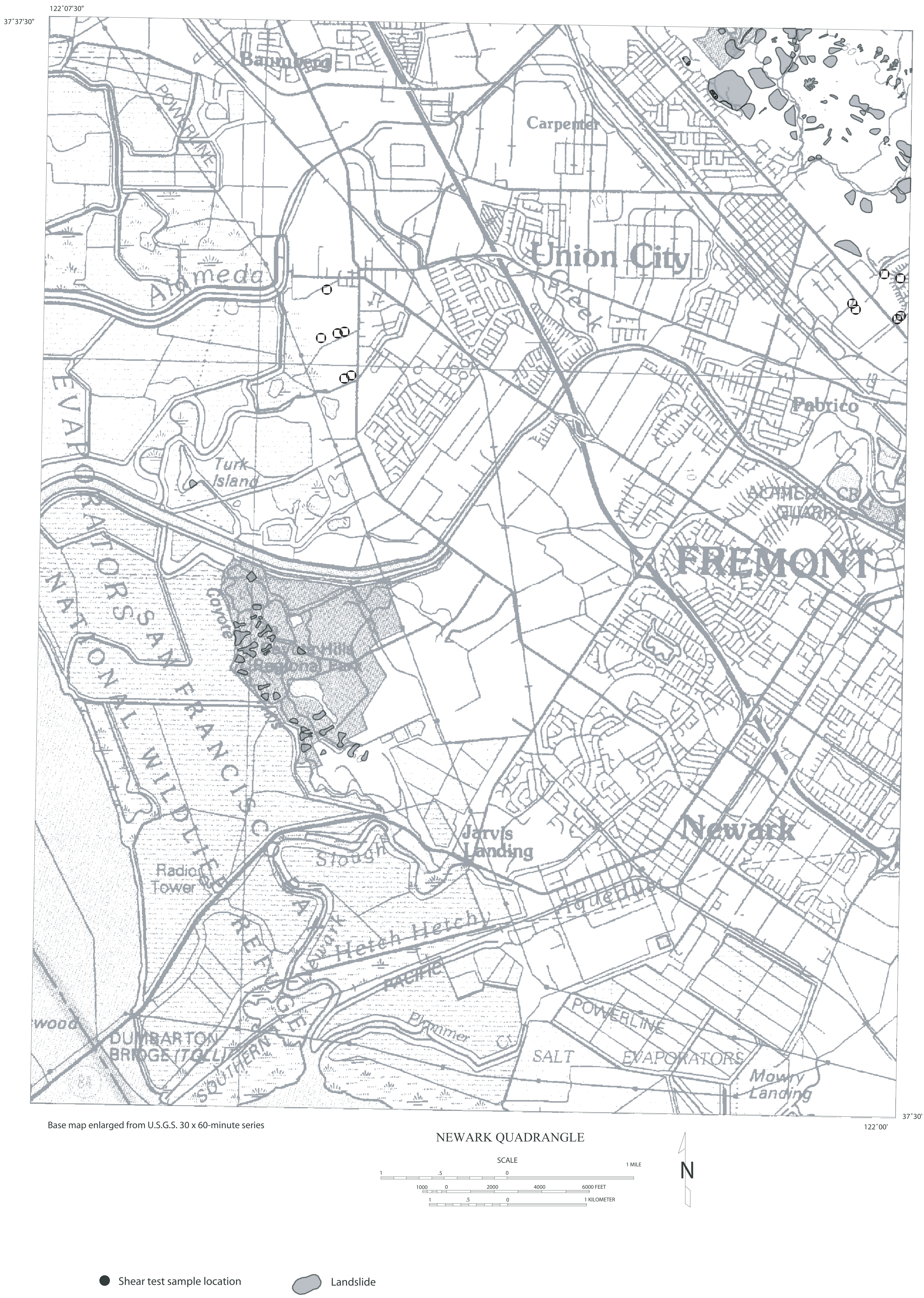


Plate 2.1 Landslide inventory and shear test sample locations, Newark 7.5-Minute Quadrangle, California.