SEISMIC HAZARD ZONE REPORT 079

SEISMIC HAZARD ZONE REPORT FOR THE REDWOOD POINT 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 Alameda County, California, portion of the Redwood Point 7.5-Minute Quadrangle. The map displays the boundaries of zones of required investigation for liquefaction over an area of approximately 5 square miles of Alameda County at a scale of 1 inch = 2,000 feet.

Although the Redwood Point 7.5-Minute Quadrangle covers approximately 60 square miles in Alameda and San Mateo counties on opposite sides of San Francisco Bay much of the area is covered by the Bay. Only the Alameda County portion of the quadrangle, which comprises approximately a third of the quadrangle and includes about five square miles of land, has been evaluated during this study. Parts of the cities of Hayward and Fremont occupy the onshore region, which consists of marshy flat-lying land adjacent to the bay, mostly less than 5 feet above the bay. The modern channel of Alameda Creek flows westward into the Bay along Coyote Slough, a man-made flood-control channel. The historical channel of Alameda Creek flows into the Bay north of the Coyote Slough. Most of the land has been reclaimed from the bay and is protected in places from tidal flooding by levees. Salt-evaporation ponds also have been developed along the bay margin. The San Mateo Bridge along State Route 92 crosses the bay from near the northeastern corner of 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.

The liquefaction zone covers all of the land in the Alameda County portion of the Redwood Point Quadrangle. No areas are designated as “zones of required investigation” for earthquake-induced landslides.

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.consrv.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
149 Second 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/SHMPsp117.asp

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 in the Redwood Point 7.5-Minute Quadrangle.

SECTION 1
LIQUEFACTION EVALUATION REPORT

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

By
Jacqueline D. J. Bott

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/SHMPsp117.asp

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 Redwood Point 7.5-Minute Quadrangle. Section 3 (addressing potential ground shaking) completes 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.consrv.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 Redwood Point 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 Redwood Point Quadrangle within Alameda County consist mainly of 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 Redwood Point 7.5-Minute Quadrangle covers approximately 60 square miles in Alameda and San Mateo counties on opposite sides of San Francisco Bay. Only the Alameda County portion of the quadrangle, which includes about five square miles of

land, has been evaluated during this study. Parts of the cities of Hayward and Fremont occupy the onshore region.

The onshore part of Alameda County consists of marshy flat-lying shoreline regions adjacent to the bay; most of the land is less than 5 feet in elevation. The modern channel of Alameda Creek flows westward into the Bay along Coyote Slough, a man-made flood-control channel. The historical channel of Alameda Creek flows into the Bay north of Coyote Slough. The historical channel of the Alameda Creek followed a northwestward route that passed close to Union City's Alvarado district (within the adjacent Newark Quadrangle), before flowing into the bay. Mt. Eden Creek also flows into the bay north of Alameda Creek. Alameda Creek is one of the largest streams entering the bay and its watershed includes both the Livermore and Sunol valleys, east of the Hayward Hills.

Most of the land along the shoreline within Alameda County has been reclaimed from the bay and is protected in places from tidal flooding by levees. Salt-evaporation ponds have been developed to utilize the flat-lying marshy region along the bay margin. The San Mateo Bridge along State Route 92 crosses the bay from near the northeastern corner of the quadrangle.

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 Redwood Point Quadrangle, recently completed maps of the nine-county San Francisco Bay Area showing Quaternary deposits (Knudsen and others, 2000) were obtained from the U.S. Geological Survey in digital form. These GIS maps were used to create a 1:24,000-scale geologic map of the Redwood Point 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 seismic hazard zones of required investigation.

Other geologic maps and reports were reviewed, including Trask and Rolston (1951), Treasher (1963), Goldman (1969), Atwater and others (1977), Helley and others (1979), Rogers and Figuers (1992), Sloan (1992), and Helley and Graymer (1997). Limited field reconnaissance was conducted to confirm the location of geologic contacts, map recently modified ground surfaces, observe properties of near-surface deposits, and characterize the surface expression of individual geologic units.

The Quaternary geologic mapping methods used by Knudsen and others (2000) 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.

Holocene San Francisco Bay mud deposits (Qhbm) cover most of the onshore region within Alameda County in the Redwood Point Quadrangle. There are numerous stretches of artificial levee fill (alf) that flank the creeks and protect evaporation ponds from tidal flooding. There is a small area covered by Holocene alluvial fan deposits (Qhf) in the northeastern corner of the map. The eastern end of the San Mateo Bridge is on artificial fill overlying Holocene San Francisco Bay mud deposits (afbm).

There is no bedrock exposed in Alameda County portion of the Redwood Point Quadrangle.

UNIT	Knudsen and others (2000)	Helley and Graymer (1997)	Helley and others (1979)	CGS GIS database
Artificial fill over Holocene bay mud	afbm			afbm
Artificial levee fill	alf	alf		alf
Holocene alluvial fan deposits	Qhf	Qhaf, Qhfp	Qham, Qhac	Qhf
Holocene bay mud	Qhbm	Qhbm	Qhbm	Qhbm

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 Redwood Point 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 the closest active fault and is located about 6 miles east of the study area.

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, a single borehole log was collected from

the City of Hayward. Data from the borehole log were entered into a CGS geotechnical GIS database.

Standard Penetration Tests (SPTs) provide a standardized measure of the penetration resistance of geologic deposits and are commonly 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 at chosen intervals while drilling. 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 that 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 borehole logs typically provide 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 based on the only available borehole (Plate 1.2).

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	-	-	-	-	-	·	3	32	0.16	35	[illegible]	35
	oarse	-	-	-	-	-	·	1	43	-	-	·	-
Qhf	Fine	-	-	-	-	-	-	3	12	0.26	14	8	14
	Coarse	-	-	-	-	-	-	-	-	-	-	-	-

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)

Table 1.2. Summary of Geotechnical Characteristics for Quaternary Geological Units in the Redwood Point 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
fbm	Artificial fill over Holocene Bay mud (3)	-	n/a(4)	VH	H	M	VL
alf	Artificial levee fill	-	n/a	VH-L	H-L	M-L	VL
Qhf	Holocene alluvial fan deposits	14.5	100% CL	H	M	L	VL
Qhbm	Holocene San Francisco Bay mud	-	n/a	H	M	L	VL

Notes:
(1) Susceptibility assignments are specific to the materials within the Redwood Point 7.5-Minute Quadrangle.
(2) Based on the Simplified Procedure (Seed and Idriss, 1971; Youd and Idriss, 1997) and a small number of borehole analyses for some units.
(3) 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.
(4) n/a = not applicable

Table 1.3. Liquefaction Susceptibility for Quaternary Map Units within the Redwood Point 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 due to the unpredictable fluctuations caused by natural processes and human activities.

Ground-water conditions were investigated in the Redwood Point Quadrangle to evaluate the depth to saturated materials. Saturated conditions reduce the effective normal stress, thereby increasing the likelihood of earthquake-induced liquefaction (Youd, 1973). The evaluation was based on first-encountered water noted in a geotechnical borehole log acquired from the City of Hayward and water wells from the Regional Water Quality Control Board.

Ground-water levels are at or near their historical highs in many areas around the bay. Wells to the east and north were used to interpret the regional depth to ground water. Ground water is very shallow within the Alameda County portion of the Redwood Point Quadrangle, with depths to first-encountered water ranging from 0 to about 5 feet below the ground surface.

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.

The artificial fill materials (afbm and alf) 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 alluvial fan deposits and Holocene San Francisco Bay mud deposits (Qhbm) have moderate (M) to high (H) susceptibility assignments within 30 feet of the ground surface. Despite the Holocene Bay mud being mostly fine-grained, it is soft with high water content and may contain lenses of material with higher liquefaction susceptibility (Trask and Rolston, 1951; Helley and others, 1979), especially near the mouth of creeks. Artificial fill and levee fill deposits have moderate (M) to very low (VL) susceptibility assignments where they are saturated between 30 and 40 feet.

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 Alameda County portion of the Redwood Point Quadrangle, a PGA of 0.53 to 0.60 g, resulting from earthquakes of magnitude 7.1 to 7.9, was computed. 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 motion.

Quantitative Liquefaction Analysis

The single geotechnical borehole record obtained from within the Redwood Point Quadrangle was comprised of fill over fine-grained Holocene alluvial fan deposits (100 percent clay) and thus a quantitative liquefaction analysis was not necessary. The borehole did not contain deposits that would liquefy under the predicted ground shaking and existing shallow ground-water conditions.

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 Redwood Point 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 scale of the base map allowed.

In the Redwood Point Quadrangle and just east of it, only one area of documented historical liquefaction is known. It is along the historical channel of Alameda Creek. Youd and Hoose (1978) cite information from the 1906 earthquake regarding liquefaction effects at a pumping station on the marshland near the shore of the Bay, one mile west of Alvarado, and along the creek. At the pumping station "the foundation settled about 2 feet, breaking all the pipe connections. During the quake the channel of the creek disappeared, its bottom being raised to the general level of the adjoining land" (Youd and Hoose, 1978, p.119). They also reported some irregular ground settlement by as much as 6 inches along piles supporting a 30-in diameter riveted iron force main water pipe, near the Alvarado pumping station.

Areas with Insufficient Existing Geotechnical Data

The single borehole available for the Redwood Point Quadrangle encountered Holocene alluvial fan deposits below 16 feet of artificial fill. The borehole did not encounter deposits that would liquefy under expected earthquake loading, being mostly fine-grained. Geotechnical data were not available for the rest of the area in the Redwood Point Quadrangle within Alameda County. However, the liquefaction zone includes all of this area due to the presence of shallow ground water (≤ 5 feet) and Holocene Bay Mud, artificial fills placed on Holocene Bay Mud and/or Holocene alluvial fan deposits. Historically, the latter two units have experienced earthquake-induced liquefaction.

ACKNOWLEDGMENTS

The author would like to thank the following individuals and organizations for their assistance in obtaining the data necessary to complete this project: Norman Payne with the City of Hayward and Kathleen Livermore with the City of Fremont. Thanks also go to all the staff in the building, engineering and planning departments who arranged access and provided assistance in retrieving geotechnical data from files maintained by the respective cities. Thanks go to the Regional Water Quality Control Board for ground-water data for Alameda County.

At CGS, special thanks to Keith Knudsen and Al Barrows for their technical review; Marvin Woods, Teri McGuire, Bob Moskovitz and Barbara Wanish for their GIS operations and database support; and Ross Martin for his help with preparation of the plates. Thanks go to Barbara Wanish and Ross Martin who prepared digital versions of the liquefaction hazard zone maps for this report.

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SECTION 2
EARTHQUAKE-INDUCED LANDSLIDE EVALUATION REPORT

NO LANDSLIDE HAZARDS ZONED

Within the Alameda County portion of the Redwood Point Quadrangle, no areas are designated as "zones of required investigation for earthquake-induced landslides." However, the potential for landslides may exist locally, particularly along stream banks, margins of drainage channels, and similar settings where steep banks or slopes occur. Such occurrences are of limited lateral extent or are too small and discontinuous to be depicted at 1:24,000 scale (the scale of Seismic Hazard Zone Maps). Within the liquefaction zones, some geologic settings may be susceptible to lateral spreading (a condition wherein low-angle landsliding is associated with liquefaction). Also, landslide hazards can be created during excavation and grading unless appropriate techniques are used.

SECTION 3
GROUND SHAKING EVALUATION REPORT

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

By

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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/SHMPsp117.asp

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) 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.consrv.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.

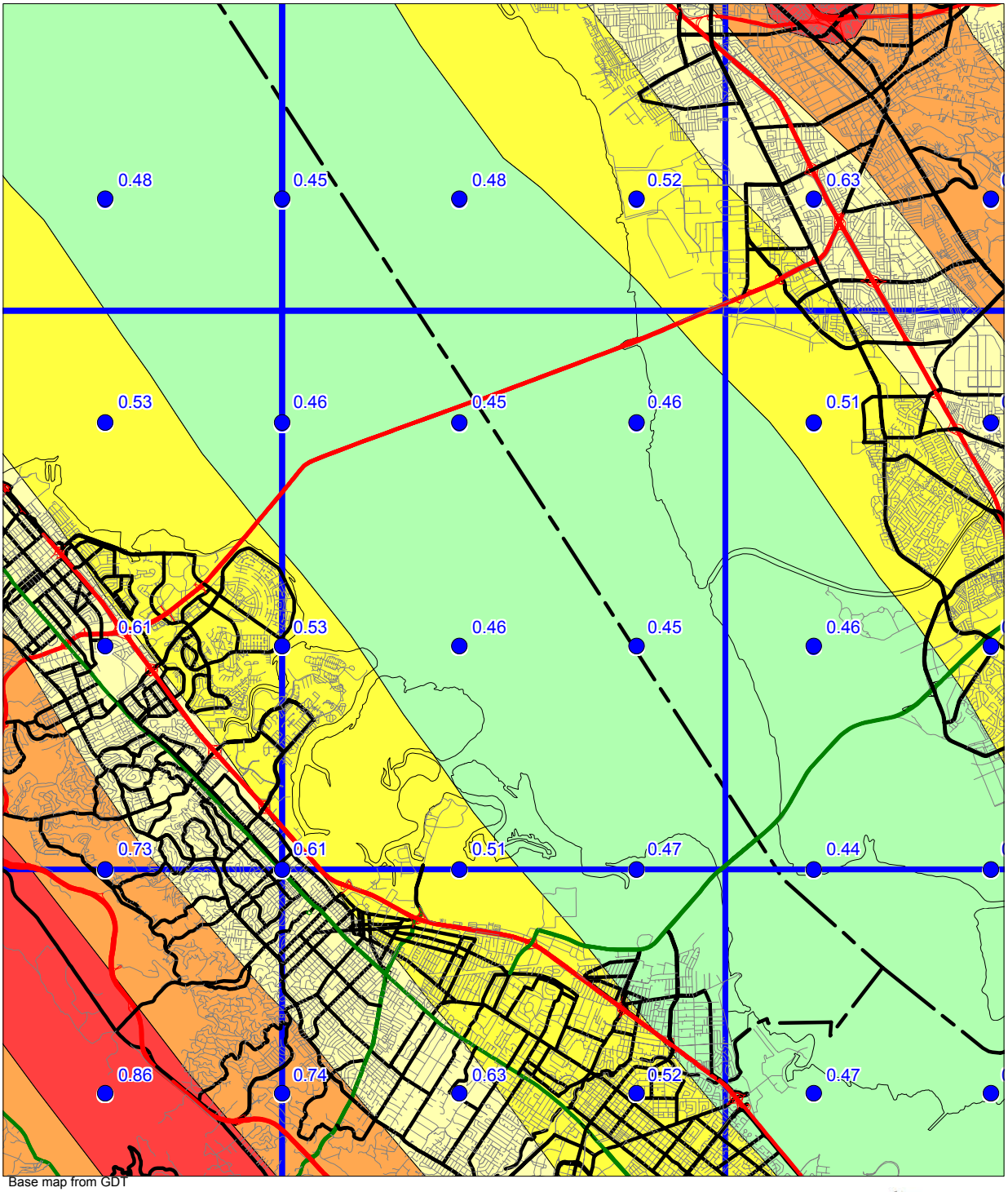
The seismic hazard maps for ground shaking are produced by calculating the hazard at sites separated by about 5 km. Figures 3.1 through 3.3 show the hazard for PGA at 10 percent probability of exceedance in 50 years assuming the entire map area is firm rock, soft rock, or alluvial site conditions respectively. 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

REDWOOD POINT 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

0 1.5 3
Miles

Department of Conservation
California Geological Survey

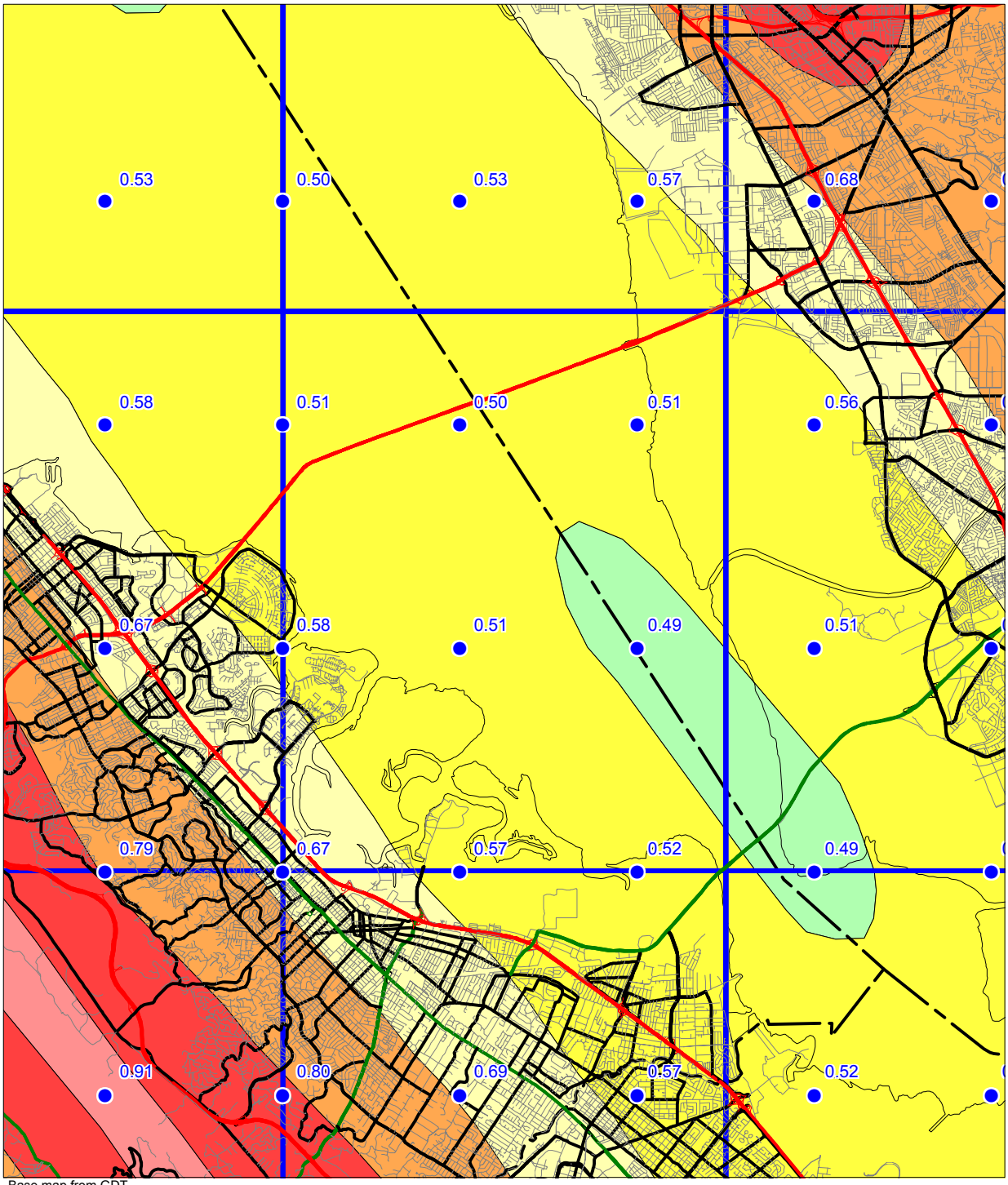
Figure 3.1

REDWOOD POINT 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

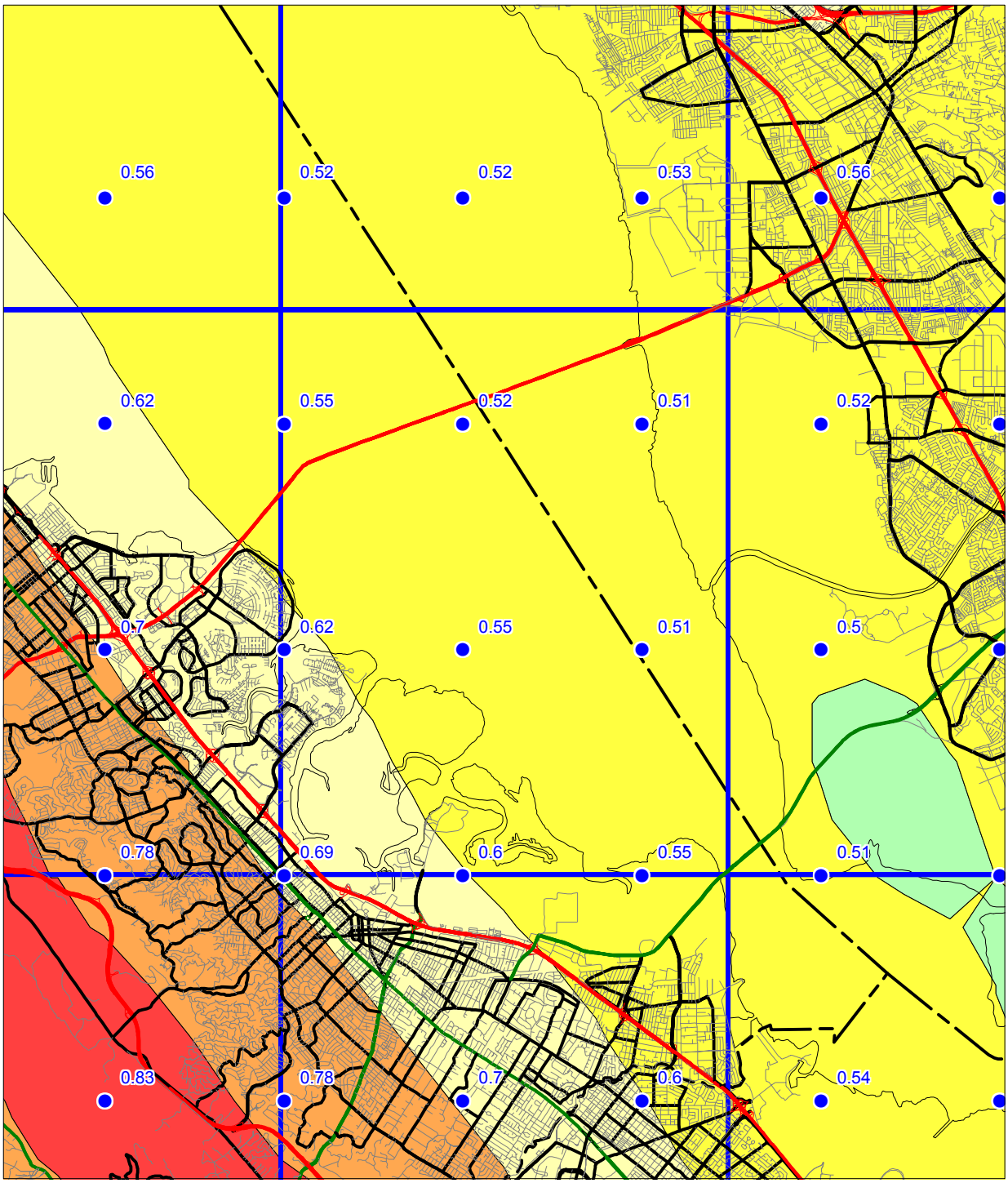
Figure 3.2

REDWOOD POINT 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

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.

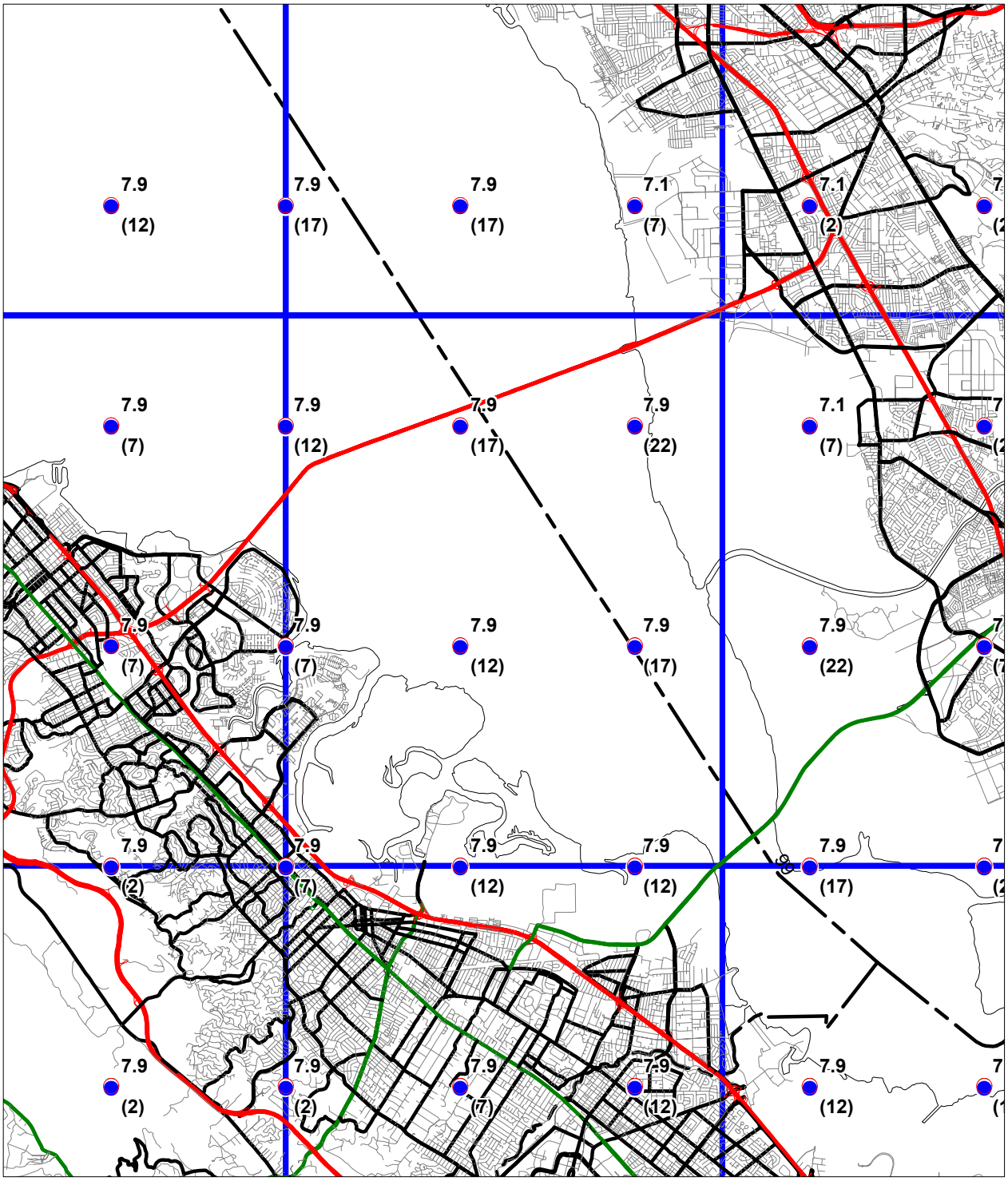
Figure 3.5 shows the magnitude-weighted alluvial PGA based on Idriss' weighting function (Youd and Idriss, 1997). It is important to note that the values obtained from this map are pseudo-accelerations and should be used in the formula for factor of safety without any magnitude-scaling (a factor of 1)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

REDWOOD POINT 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION

1998

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



Base map from GDT

0 1.5 3
Miles

Department of Conservation
California Geological Survey

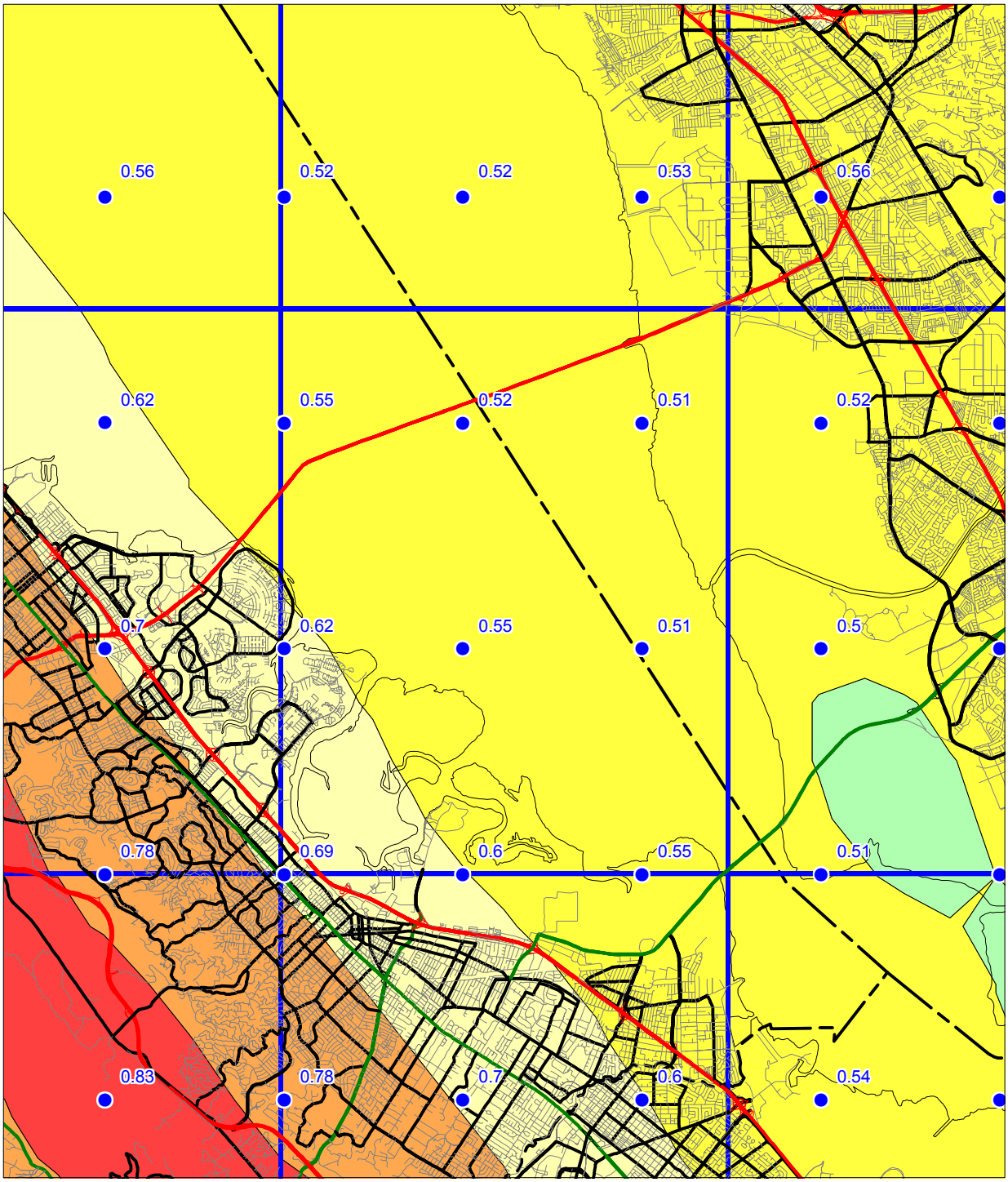
Figure 3.4

REDWOOD POINT 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 from U.S.G.S. 7.5-minute series

REDWOOD POINT QUADRANGLE

SCALE

1 .5 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 .5 0 1 KILOMETER

N

Lithologic contact

Plate 1.1 Quaternary geologic map of the Redwood Point 7.5-Minute Quadrangle from Knudsen and others (2000)

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

- Miscellaneous effects
- Ground settlement
- Lateral spread
- Sand boil
- 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))
- Geotechnical boreholes used in liquefaction evaluation

Plate 1.2 Historical liquefaction sites and location of borehole used in this study, Redwood Point 7.5-Minute Quadrangle, California