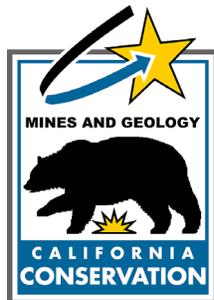


**SEISMIC HAZARD ZONE REPORT FOR THE
VENICE 7.5-MINUTE QUADRANGLE,
LOS ANGELES COUNTY, CALIFORNIA**

1998



DEPARTMENT OF CONSERVATION
Division of Mines and Geology

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SEISMIC HAZARD ZONE REPORT 036

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VENICE 7.5-MINUTE QUADRANGLE,
LOS ANGELES COUNTY, CALIFORNIA**

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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 Venice 7.5-minute Quadrangle, Los Angeles County, California. The map displays the boundaries of Zones of Required Investigation for liquefaction and earthquake-induced landslides over an area of approximately 34 square miles at a scale of 1 inch = 2,000 feet.

The Venice Quadrangle covers about 34 square miles of land adjacent to Santa Monica Bay. Coastal cities, from north to south, are Venice (part of Los Angeles), Marina Del Rey (Los Angeles County land), Playa del Rey, the Los Angeles International Airport, the City of El Segundo, and the City of Manhattan Beach. Inland are parts of Culver City and Westchester (part of Los Angeles). Small slivers of the cities of Inglewood, Hawthorne, and Redondo Beach lie along the eastern boundary of the quadrangle. The quadrangle includes the shoreline of Santa Monica Bay from Santa Monica south to Hermosa Beach. Venice was developed as a series of excavated canals east of the barrier beach. Culver City straddles Ballona Creek and extends up the slopes of the Baldwin Hills. Marina Del Rey was built by Los Angeles County at the mouth of Ballona Creek by dredging and modification of the wetlands. South of Ballona Creek, the land rises abruptly to a broad terrace up to 150 feet above sea level where Westchester, the Los Angeles International Airport, and parts of El Segundo and Manhattan Beach are located. South of Ballona Creek, hilly topography that consists of ancient sand dunes extends inland about two miles from the coast. The lowland areas of the Venice Quadrangle are covered with alluvial deposits, mostly of Holocene age. The terrace surface south of Ballona Creek is covered by older alluvial deposits and, locally, with a veneer of Pleistocene dune sand.

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% probability of exceedance in 50 years.

In the Venice Quadrangle the liquefaction zone coincides with the lowlands along the Ballona Creek drainage, the Marina Del Rey area, the Venice Plain to the north and the entire stretch of beach. Most of the quadrangle has low relief. The earthquake-induced landslide zone, therefore, is restricted to the steep erosional bluffs along the northwestern edge of Westchester, the steep faces of ancient sand dune near the coast and a few localities in the Baldwin Hills. The zone covers only about one percent of the quadrangle.

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 Division of Mines and Geology's Internet page: <http://www.conservation.ca.gov/CGS/index.htm>

Paper copies of Official Seismic Hazard Zone Maps, released by DMG, 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 DMG 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) 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 established by the California State Mining and Geology Board (DOC, 1997; also available 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 DMG 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% 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 Venice 7.5-minute Quadrangle.

SECTION 1

LIQUEFACTION EVALUATION REPORT

Liquefaction Zones in the Venice 7.5-Minute Quadrangle, Los Angeles County, California

By
Christopher J. Wills, Cynthia L. Pridmore, and Pamela J. Irvine

**California Department of Conservation
Division of Mines and Geology**

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) 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 DMG 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 (DOC, 1997; also available on the Internet at <http://gmw.consrv.ca.gov/shmp/webdocs/sp117.pdf>).

This section of the evaluation report summarizes seismic hazard zone mapping for potentially liquefiable soils in the Venice 7.5-minute Quadrangle. This section, along with Section 2 (addressing earthquake-induced landslides), and Section 3 (addressing potential ground shaking), form a report that 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 DMG'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 southern California. During the 1971 San Fernando and 1994 Northridge earthquakes, significant damage to roads, utility pipelines, buildings, and other structures in the Los Angeles area was caused by liquefaction-induced ground displacement.

Localities 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 exist in parts of southern California, 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 in the southern California region in general, including areas in the Venice 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 DMG 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 State Mining and Geology Board (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 Venice Quadrangle consist mainly of low-lying shoreline regions and floodplains. DMG'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

Although the Venice Quadrangle covers an area of about 62 square miles, it includes only about 34 square miles of land east of Santa Monica Bay in southwestern Los Angeles County. Located along the coast, from north to south, are Venice, which is part of Los Angeles, Marina Del Rey (Los Angeles County land), Playa del Rey, the Los Angeles International Airport, the City of El Segundo, and the City of Manhattan Beach. Inland, on the north are parts of the city of Culver City and the community of Westchester (part of Los Angeles). Small slivers of the cities of Inglewood, Hawthorne, and Redondo Beach lie along the eastern boundary of the quadrangle.

The quadrangle includes the shoreline of Santa Monica Bay from Santa Monica south to Hermosa Beach. Venice was developed on the coastal plain south of Santa Monica and includes a series of excavated canals east of the barrier beach. Culver City straddles

Ballona Creek and extends up the slopes of the Baldwin Hills. Marina Del Rey was created by Los Angeles County through dredging and modification of the wetlands at the mouth of Ballona Creek in the 1960's. South of Ballona Creek, the land rises abruptly to a broad terrace 100 to 150 feet above sea level. The Westchester area of the City of Los Angeles, the Los Angeles International Airport, and parts of the cities of El Segundo and Manhattan Beach are built on this surface. South of Ballona Creek, hilly topography that consists of ancient sand dunes extends inland about two miles from the coast.

The lowland areas of the Venice Quadrangle are covered with alluvial deposits, mostly of Holocene age. The terrace surface south of Ballona Creek is covered by older alluvial deposits and, locally, with a veneer of Pleistocene dune sand.

GEOLOGY

Surficial Geology

Geologic units that generally are susceptible to liquefaction include late Quaternary alluvial and fluvial sedimentary deposits and artificial fill. A digital map obtained from the U.S. Geological Survey (Tinsley, unpublished) was used as a base to prepare a geologic map of the Venice Quadrangle for this project. Additional detail was added from a digital map prepared by the Southern California Areal Mapping Project (SCAMP, unpublished), which was compiled primarily from mapping by Castle (1960a) and Poland and others (1959). Other geologic maps reviewed include Castle (1960b), Weber and others (1982), and CDWR (1961). Geologic contacts were modified using the sources listed above, air photos (Fairchild, 1927), and older topographic maps (USGS, 1934 and USGS, 1930). Stratigraphic nomenclature was revised to follow the format developed by SCAMP (Morton and Kennedy, 1989). The revised geologic map that was used in this study of liquefaction susceptibility is included as Plate 1.1.

The oldest geologic unit mapped in the Venice Quadrangle is the Pleistocene San Pedro Formation (Qsp), a predominantly marine sand and gravel deposit exposed in the Baldwin Hills in the northeast corner of the quadrangle. A resistant, locally pebbly and gravelly, silty sand (Qoa) overlies the San Pedro Formation and caps some of the ridges in this area. A more detailed description of the geology of the Baldwin Hills is presented in Section 2.

Pleistocene older marine (?) sediments (Qom?) forming the southernmost part of the Ocean Park plain extend into the Venice Quadrangle from Santa Monica. These deposits are composed of medium- to coarse-grained sand.

Quaternary sediments exposed on the elevated plain south of Ballona Creek include Pleistocene older alluvium (Qoa) composed of medium- to coarse-grained sand and gravel that interfingers with near-shore marine sediments of similar composition. These deposits are overlain by laterally extensive, stabilized, older eolian deposits (Qoe), which consist of well-sorted, medium- to coarse-grained sand.

Younger alluvium and floodplain deposits (Qya1 and Qya2) are exposed in the low-lying areas of Ballona Gap and Centinela Creek. They generally consist of very fine- to medium-grained sand intermixed with silt and clay.

Prior to the development of Marina Del Rey, extensive estuarine deposits (Qes) were present at the mouth of Ballona Creek. Remnants of these deposits, which consist of organic tidal mud interbedded with floodplain sediments, are mapped around the edges of the marina along with areas of artificial fill (af).

Modern eolian deposits (Qe) form a quarter- to half-mile-wide strip along the coastline adjacent to the modern beach. The eolian deposits are composed of very well-sorted, fine- to medium-grained sand. Modern beach deposits (Qm), which consist of well-sorted, medium- to coarse-grained sand, form the shoreline of Santa Monica Bay.

ENGINEERING GEOLOGY

The geologic units described above were primarily mapped from their surface expression, including interpretation of aerial photos and old topographic maps and soils properties described in soil surveys. The geomorphic mapping was compared with the subsurface properties described in over 180 borehole logs in the study area. Subsurface data used for this study includes the database compiled by John Tinsley for previous liquefaction studies (Tinsley and Fumal, 1985; Tinsley and others, 1985), a database of shear wave velocity measurements originally compiled by Walter Silva (Wills and Silva, 1998), and additional data collected for this study. Subsurface data were collected for this study at Caltrans, DMG files of seismic reports for hospital and school sites, and the Regional Water Quality Control Board. In general, the data gathered for geotechnical studies appear to be complete and consistent. Data from environmental geology reports filed with the Water Quality Control Board are well distributed areally and provide reliable data on water levels. Geotechnical data, particularly SPT blow counts, from environmental studies are sometimes less reliable however, due to the use of non-standard equipment and incomplete reporting of procedures.

Standard Penetration Test (SPT) data provide a standardized measure of the penetration resistance of a geologic deposit and commonly are used as an index of density. Many geotechnical investigations record SPT data, including the number of blows by a 140-pound drop weight required to drive a sampler of specific dimensions one foot into the soil. 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), were converted to SPT-equivalent blow count values and entered into the DMG GIS. The actual and converted SPT blow counts were normalized to a common reference effective overburden pressure of one atmosphere (approximately one ton per square foot) and a hammer efficiency of 60% using a method described by Seed and Idriss (1982) and Seed and others (1985). This normalized blow count is referred to as $(N_1)_{60}$.

Data from previous databases and additional borehole logs were entered into the DMG Geographic Information System (GIS) database. Locations of all exploratory boreholes

considered in this investigation are shown on Plate 1.2. Construction of cross sections from the borehole logs, using the GIS, enabled the correlation of soil types from one borehole to another and the outlining of areas of similar soils.

Descriptions of characteristics of geologic units recorded on the borehole logs are given below. These descriptions are necessarily generalized, but give the most commonly encountered characteristics of the units (see Table 1.1).

Older alluvium (Qoa), older eolian deposits (Qoe), and older marine deposits (Qom?)

Older alluvial and eolian deposits on the Venice Quadrangle cover up the large terrace south of the Ballona Creek channel. This terrace surface consists of older alluvial deposits with a veneer of older, largely stabilized dune sands. Ground water is deep throughout this area, so no extensive effort was made to collect subsurface data. Several logs of deep boreholes from the shear-wave velocity database and the Regional Water Quality Control Board files describe dense to very dense sands and silty sands.

Older marine deposits make up much of the terrace underlying the City of Santa Monica, north of the Venice Quadrangle. A small area of this unit extends onto the northwestern corner of the Venice Quadrangle. They also probably underlie the younger alluvium mapped as Qya1, described below. This material is dense to very dense sand and silty sand.

Younger alluvium (Qya1, Qya2)

Younger alluvium in the lowlands near the mouth of Ballona Creek was subdivided into “alluvium” and “floodplain” deposits by Castle (1960a). For this study these units are called Qya1 and Qya2 to be consistent with SCAMP nomenclature (Morton and Kennedy, 1989). Both of these units have soft clay and silt near the surface but the “alluvium” (Qya1) was described by Castle (1960a) as being a thin veneer over older deposits. This can clearly be seen in the subsurface where the Qya1 deposits are typically ten to 15 feet thick. These deposits consist of silts and clays with some silty sand, overlying dense sand and gravel. The “floodplain” deposits (Qya2) are a much thicker sequence of soft clay, silts and loose to moderately dense sand, commonly with a sand or sandy gravel deposit at 40 to 50 feet depth.

Estuarine deposits (Qes)

Estuarine, or marsh deposits, were mapped by Castle (1960a) in the Marina Del Rey area. These deposits typically include loose to moderately dense silt, sand and clayey sand.

Eolian deposits (Qe)

Eolian Deposits mapped immediately inland from the modern beach are composed of a very thin layer of fine sand, less than 10 feet thick on borehole logs that we were able to obtain. This deposit is typically underlain by dense to very dense sand of the older alluvial deposits.

Beach deposits (Qm)

Modern beach deposits are composed of coarse sand and gravelly sand, up to 23 feet thick on borehole logs we were able to obtain. This deposit is loose to moderately dense. Beach deposits are also typically underlain by dense to very dense sand of the older alluvial deposits.

Artificial fill (af)

Artificial fill on the Venice Quadrangle consists of “engineered” fill in the Marina Del Rey and Ballona Creek areas. Because the engineered fills are too thin to affect the liquefaction hazard, no effort was made to determine their subsurface characteristics.

Geologic Map Unit	Material Type	Consistency	Liquefaction Susceptibility
Qm, beach	Sand, gravelly sand	Loose	high
Qes, estuarine deposit	silty sand, sand	Loose	high
Qya2, younger alluvium	silty sand, sand, clay	loose-moderately dense	high
Qya1, young alluvium	Clay, silt, silty sand (thin)	Soft, loose-moderately dense	Low, locally high
Qoe, older dune sand	silt & silty sand	dense-very dense	low
Qoa, older alluvium	sand & gravel	dense-very dense	low
Qom?, older marine? terrace	sand & gravel	dense-very dense	low

Table 1.1. General Geotechnical Characteristics and Liquefaction Susceptibility of Younger Quaternary Units.

GROUND-WATER CONDITIONS

Liquefaction hazard may exist in areas where depth to ground water is 40 feet or less. DMG 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 table within alluviated areas.

Ground-water conditions were investigated in the Venice 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 relied heavily on turn-of-the-century water-well logs (Mendenhall, 1905) but

also included water measurements from borehole logs collected for this study. The depths to first-encountered unconfined ground water were plotted onto a map (Plate 1.2) 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. The map was compared to similar published maps for any discrepancies (Tinsley and others, 1985; Leighton and others, 1990).

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. This method combines geotechnical analyses, geologic and hydrologic mapping, and probabilistic earthquake shaking estimates, but follows criteria adopted by the State Mining and Geology Board (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.

DMG'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. A qualitative susceptible soil inventory is outlined below and summarized in Table 1.1.

Older alluvium (Qoa), older eolian deposits (Qoe), and older marine deposits (Qom?)

Older alluvial, eolian, and marine deposits are composed of dense to very dense sands and silty sands. Liquefaction susceptibility of these units is low.

Younger alluvium (Qya1, Qya2)

Young alluvium in the lowlands near the mouth of Ballona Creek was subdivided into "alluvium" and "floodplain" deposits by Castle (1960a). Qya1 is a thin deposit of silt and clay with some local layers of silty sand. Liquefaction susceptibility of the silty sand layers is high. Much of this unit is less than 10 feet thick, overlying dense older deposits. Where Qya1 is unsaturated because ground water is deeper than the thickness of the unit, liquefaction susceptibility is low. Qya2 consists of silt, clay and silty sand, which is loose to moderately dense and, commonly, saturated. Liquefaction susceptibility of this unit is high.

Estuarine deposits (Qes)

Estuarine deposits include loose to moderately dense silt, sand and clayey sand. In an area with a very shallow water table. Liquefaction susceptibility of this unit is high.

Eolian deposits (Qe)

Eolian deposits are composed of a very thin layer of fine sand, less than 10 feet thick. Because it is so thin, it is above the historically highest water table. This deposit is typically underlain by dense to very dense sand of older alluvial deposits. Liquefaction susceptibility of this unit is low.

Beach deposits (Qm)

Beach deposits include loose sand and gravelly sand. Liquefaction susceptibility of this unit is high.

Artificial fill (af)

Artificial fills commonly overlie young alluvial or estuarine deposits. Because the engineered fills are usually too thin to affect the liquefaction hazard, and the underlying estuarine deposits have a high liquefaction susceptibility, they are assumed to have a high susceptibility to liquefaction.

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% probability of exceedance over a 50-year period (DOC, 2000). The earthquake magnitude used in DMG's analysis is the magnitude that contributes most to the calculated PGA for an area.

For the Venice Quadrangle, PGAs of 0.44 g to 0.60 g, resulting from earthquakes ranging in magnitude from 6.6 to 7.3, were used for liquefaction analyses. The PGA and magnitude values were based on de-aggregation of the probabilistic hazard at the 10% in 50-year hazard level (Petersen and others, 1996; Cramer and Petersen, 1996). See the ground motion section (3) of this report for further details.

Quantitative Liquefaction Analysis

DMG 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, DMG'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. DMG 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 DMG liquefaction analysis program calculates an FS for each geotechnical sample for which blow counts

were collected. Typically, multiple samples are collected for each borehole. The lowest FS in each borehole is used for that location. FS values vary in reliability according to the quality of the geotechnical data used in their calculation. 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 183 geotechnical borehole logs reviewed in this study (Plate 1.2), 133 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. 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.

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 California State Mining and Geology Board (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% 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% 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% 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 Venice Quadrangle is summarized below.

Areas of Past Liquefaction

In the Venice Quadrangle, minor effects attributed to liquefaction were noted in Marina Del Rey following the 1994 Northridge earthquake, especially a modest concentration of pipe breakage between Washington Boulevard and Culver Boulevard (Stewart and others, 1994, p.129 and Figure 4.75). In addition, a sand fissure was reported by the Los Angeles County, Department of Harbors and Beaches (see Plate 1.2) in an artificial beach area at the marina near the intersection of Via Marina and Admiralty Way (Stewart and others, 1994).

In his discussion of the effects of the June 21, 1920, Inglewood earthquake, Taber described and pictured (1920, p. 140 and Plate 14, figure 2) a “low ridge about one and one half feet high and fifteen feet broad” that crossed the furrows in a farm field in the Centinela Creek Valley near the eastern boundary of the Venice 7.5-minute Quadrangle. He also described a depression that had developed between the ridge and another, parallel one about one hundred yards to the northeast. This feature is suggestive of differential settlement and may have been related to liquefaction in the creek valley sediments.

Artificial Fills

In the Venice Quadrangle artificial fill consists of engineered fill around the Marina Del Rey area. The engineered fills are generally too thin to have an impact on liquefaction but overlie estuarine deposits that are susceptible to liquefaction. Areas underlain by artificial fill have been included in liquefaction hazard zones.

Areas with Sufficient Existing Geotechnical Data

The older alluvium, marine deposits, and eolian deposits exposed in the Venice Quadrangle (Qoa, Qoe, and Qom?) have a dense consistency and deep ground water was encountered in boreholes in much of the area underlain by these units. Accordingly, these geologic units have not been included in a liquefaction hazard zone.

Younger eolian deposits are typically very thin, and, therefore, unsaturated. They are not included in liquefaction hazard zones.

Younger alluvial deposits (Qya1 and Qya2) commonly have layers of loose silty sand or sand. Where these deposits are saturated, they are included in a liquefaction hazard zone. The thickness of Qya1 is typically less than 10 feet, therefore areas underlain by Qya1 where the water table is at greater than 10 feet are not included in the liquefaction hazard zone.

Modern beach deposits are typically loose saturated sand. They are included in liquefaction hazard zones.

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SECTION 2 EARTHQUAKE-INDUCED LANDSLIDE EVALUATION REPORT

Earthquake-Induced Landslide Zones in the Venice 7.5-Minute Quadrangle, Los Angeles County, California

By

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Division of Mines and Geology**

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) 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 DMG 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; also available on the Internet at <http://gmw.consrv.ca.gov/shmp/webdocs/sp117.pdf>).

This section of the evaluation report summarizes seismic hazard zone mapping for earthquake-induced landslides in the Venice 7.5-minute Quadrangle. This section, along with Section 1 (addressing liquefaction), and Section 3 (addressing earthquake shaking), form a report that 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 DMG's Internet web page:
<http://www.conservation.ca.gov/CGS/index.htm>.

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 Venice 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 DMG 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 DMG pilot study (McCrink and Real, 1996) 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 Venice 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 Venice 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

Although the Venice Quadrangle covers an area of about 62 square miles, it includes only about 34 square miles of land east of Santa Monica Bay in southwestern Los Angeles County. Located along the coast, from north to south, are Venice, which is part of Los Angeles, Marina Del Rey (Los Angeles County land), Playa del Rey, the Los Angeles

International Airport, the City of El Segundo, and the City of Manhattan Beach. Inland, on the north are parts of the city of Culver City and the community of Westchester (part of Los Angeles). Small slivers of the cities of Inglewood, Hawthorne, and Redondo Beach lie along the eastern boundary of the quadrangle.

The quadrangle includes the shoreline of Santa Monica Bay from Santa Monica south to Hermosa Beach. Venice was developed on the coastal plain south of Santa Monica and includes a series of excavated canals east of the barrier beach. Culver City straddles Ballona Creek and extends up the slopes of the Baldwin Hills. Marina Del Rey was created by Los Angeles County through dredging and modification of the wetlands at the mouth of Ballona Creek in the 1960's. South of Ballona Creek, the land rises abruptly to a broad terrace 100 to 150 feet above sea level. The Westchester area of the City of Los Angeles, the Los Angeles International Airport, and parts of the cities of El Segundo and Manhattan Beach are built on this surface. South of Ballona Creek, hilly topography that consists of ancient sand dunes extends inland about two miles from the coast.

The lowland areas of the Venice Quadrangle are covered with alluvial deposits, mostly of Holocene age. The terrace surface south of Ballona Creek is covered by older alluvial deposits and, locally, with a veneer of Pleistocene dune sand.

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. Within the Venice Quadrangle, a Level 2 digital elevation model (DEM) was obtained from the USGS (U.S. Geological Survey, 1993). This DEM, which was prepared from the 7.5-minute quadrangle topographic contours that are based on 1963 aerial photography, 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 was also 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

A digital map obtained from the U.S. Geological Survey (Tinsley, unpublished) was used as a base to prepare a geologic map of the Venice Quadrangle for this project. Additional detail was added from a digital map prepared by the Southern California Areal Mapping Project (SCAMP, unpublished), which was compiled primarily from mapping by Castle (1960a) and Poland and others (1959). Other geologic maps reviewed include Castle (1960b), Weber and others (1982), and CDWR (1961). Geologic contacts were modified using the sources listed above, air photos (Fairchild, 1927), and older topographic maps (USGS, 1934 and USGS, 1930). In the field, observations were made of exposures,

aspects of weathering, and general surface expression of the geologic units. In addition, the relation of the various geologic units to development and abundance of landslides was noted.

Bedrock exposures in the Venice Quadrangle are limited to the northeast corner of the map where strata have been uplifted, folded, and faulted along the Newport-Inglewood structural zone to form the Baldwin Hills. The Baldwin Hills are primarily composed of marine sediments of Pleistocene age. Stratigraphic correlation of Plio-Pleistocene and Quaternary strata within the Los Angeles Basin is difficult because of rapid lateral facies changes resulting from fluctuations in the paleo-shoreline and the time-transgressive nature of the faunal assemblages (Quinn and others, 1997). Because of the current lack of well-defined Quaternary correlations and nomenclature, the formation designations used in this study for the Baldwin Hills area should be regarded as generalized and informal.

The oldest geologic unit mapped in the Venice Quadrangle is the Pleistocene San Pedro Formation (Qsp; "B" formation of Castle, 1960a and 1960b), which is exposed in the Baldwin Hills in the northeast corner of the quadrangle. The San Pedro Formation consists of poorly consolidated, fine- to coarse-grained sand interbedded with thin beds and lenses of gravel deposited in a near-shore marine environment ("Qc" in Weber and others, 1982). Also included in this unit are fluvial sand and gravel with local beds of clayey silt ("Qb" in Weber and others, 1982). A reddish brown, well-cemented and resistant, locally pebbly or gravelly, silty sand caps some of the ridges in the Baldwin Hills and is designated older alluvium (Qoa; "Qf" in Weber and others, 1982; "cap deposits" in Castle, 1960a and 1960b).

Quaternary sediments that cover the remainder of the Venice Quadrangle include older marine deposits (Qom) extending into the northwest corner from Santa Monica, older alluvium (Qoa) and older eolian deposits (Qoe) on the elevated plain south of Ballona Creek, modern eolian deposits (Qe) and beach sand (Qm) fringing the coastline, modern estuarine deposits (Qes) in the Ballona Creek and Marina Del Rey area, and younger alluvial-fan and floodplain deposits (Qya1 and Qya2) in the northern part of the quadrangle on the margins of the Baldwin Hills, and along Ballona Gap and Centinela Creek. Small, surficial landslides (Qls and Qls?) have occurred along the bluffs on the south side of Ballona Creek and on steeper slopes in the Baldwin Hills. Modern man-made (artificial) fills (af) are also mapped in some areas. A more detailed discussion of the Quaternary deposits in the Venice Quadrangle can be found in Section 1.

Landslide Inventory

As a part of the geologic data compilation, an inventory of existing landslides in the Venice Quadrangle was prepared (Irvine, unpublished) by using previous work done in the area (Weber and others, 1979; Weber and others, 1982) and by combining field observations, analysis of aerial photos, and interpretation of landforms on current and older topographic maps. The following aerial photos were used for landslide interpretation: Fairchild (1927) and USGS (1994a; 1994b). Landslides were mapped and digitized 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 hand-drawn landslide map was scanned, digitized, and the attributes were compiled in a database. A version of this landslide inventory is included with Plate 2.1.

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 rock shear-strength measurements is geotechnical reports prepared by consultants on file with local government permitting departments. Shear-strength data for the rock units identified on the Venice Quadrangle geologic map were obtained from the City of Los Angeles, Department of Building and Safety and from CDMG documents (see Appendix A). The locations of rock and soil samples taken for shear testing by consultants are shown on Plate 2.1. When available, shear tests from adjacent quadrangles were used to augment data for geologic formations that had little or no shear test information. For the Venice Quadrangle, shear test values used to characterize rock strength were borrowed from adjacent quadrangles. Shear tests for Qya were obtained from the Inglewood Quadrangle and additional values for Qsp were obtained from the Hollywood Quadrangle. No shear tests were available for af, Qm, Qom?, Qes, and Qya1. These geologic units were added to existing groups on the basis of lithologic and stratigraphic similarities.

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 and median) phi values for each geologic map unit and corresponding strength group are summarized in Table 2.1. For most of the geologic strength groups in the map area, a single 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 Tables 2.1 and 2.2, and this map provides a spatial representation of material strength for use in the slope stability analysis.

Existing Landslides

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, have also been used.

VENICE QUADRANGLE SHEAR STRENGTH GROUPINGS							
	Formation Name	Number Tests	Mean/Median Phi	Mean/Median (Group phi) (deg)	Group Mean/Median C (psf)	No Data: Similar Geologic Strength	Phi Values Used in Stability Analysis
GROUP 1	Qoe	54	31.1/31	30.2/31	251/215	af Qom? Qes	30.2
	Qoa	41	29.8/31				
	Qe?	3	29/27				
	Qsp	30	28.2/30				
	Qe	1	27/27				
GROUP 2	Qya2	3	26.3/26	26.3/26	300/300	Qya1	26
GROUP 3	Qls	-	-	-	-	-	15

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

SHEAR STRENGTH GROUPS FOR THE VENICE QUADRANGLE		
GROUP 1	GROUP 2	GROUP 3
af	Qya1	Qls
Qe	Qya2	
Qes		
Qe?		
Qm		
Qoa		
Qoe		
Qom?		
Qsp		

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

PART II

EARTHQUAKE-INDUCED LANDSLIDE HAZARD POTENTIAL

Design Strong-Motion Record

To evaluate earthquake-induced landslide hazard potential in the study area, a method of dynamic slope stability analysis developed by Newmark (1965) was used. The Newmark method analyzes dynamic slope stability by calculating the cumulative down-slope displacement for a given earthquake strong-motion time history. As implemented for the preparation of earthquake-induced landslide zones, the Newmark method necessitates the selection of a design earthquake strong-motion record to provide the “ground shaking opportunity.” For the Venice Quadrangle, selection of a strong motion record was based on an estimation of probabilistic ground motion parameters for modal magnitude, modal distance, and peak ground acceleration (PGA). The parameters were estimated from maps prepared by DMG for a 10% probability of being exceeded in 50 years (Petersen and others, 1996). The parameters used in the record selection are:

Modal Magnitude:	6.9 to 7.1
Modal Distance:	2.5 to 7.4 km
PGA:	0.40 to 0.49 g

The strong-motion record selected for the slope stability analysis in the Venice Quadrangle was the Channel 3 (north horizontal component) University of Southern California Station #14 recording from the magnitude 6.7 Northridge earthquake (Trifunac and others, 1994). This record had a source to recording site distance of 8.5 km and a peak ground acceleration (PGA) of 0.69 g. The selected strong-motion record was not scaled or otherwise modified prior to its use in the 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 DMG pilot study for earthquake-induced landslides (McCrink and Real, 1996). Applied to the curve in Figure 2.1, these displacements correspond to yield accelerations of 0.076, 0.129 and 0.232 g. 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 Venice Quadrangle.

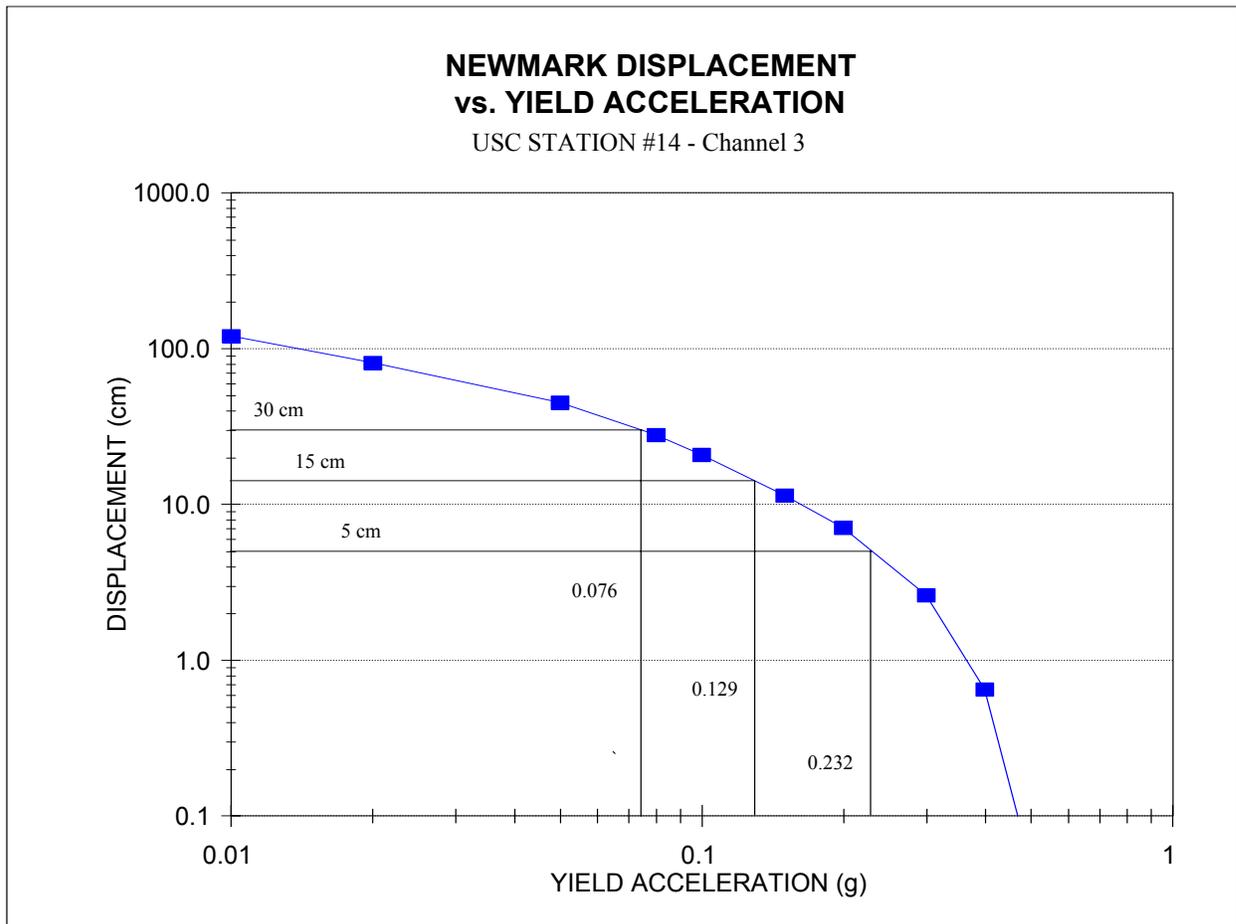


Figure 2.1. Yield Acceleration vs. Newmark Displacement for the USC Station # 14 Strong- Motion Record From the 17 January 1994 Northridge, California Earthquake.

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 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 0.076g, 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 0.076g and 0.129g, 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 0.129g and 0.232g, 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 0.232g, 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.

VENICE QUADRANGLE HAZARD POTENTIAL MATRIX											
SLOPE CATEGORY (% SLOPE)											
Geologic Material Group	MEAN PHI	I	II	III	IV	V	VI	VII	VIII	IX	percent
		0-14	14-19	19-27	27-34	34-36	36-42	42-45	45-50	>50	
1	30	VL	VL	VL	VL	L	L	L	M	H	
2	26	VL	VL	VL	L	L	M	H	H	H	
3	15	L	M	H	H	H	H	H	H	H	

Table 2.3. Hazard Potential Matrix for Earthquake-Induced Landslides in the Venice Quadrangle. Shaded area indicates hazard potential levels included within the hazard zone. H = High, M = Moderate, L = Low, VL = Very Low.

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 DMG (McCrink and Real, 1996), 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 3 is included for all slope gradient categories. (Note: Geologic Strength Group 3 includes all mappable landslides with a definite or probable confidence rating).
2. Geologic Strength Group 2 is included for all slopes steeper than 27 percent.
3. Geologic Strength Group 1 is included for all slopes steeper than 34 percent.

This results in roughly one percent of the quadrangle lying within the earthquake-induced landslide hazard zone for the Venice 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. Geologic material strength data were collected at the City of Los Angeles with the assistance of Nicki Girmay. Technical review of the methodology was provided by Bruce Clark, Randy Jibson, Robert Larson, Scott Lindvall, and J. David Rogers, who are members of the State Mining and Geology Board's Seismic Hazards Mapping Act Advisory Committee Landslides Working Group. At DMG, special thanks to Bob Moskovitz, Teri McGuire, Scott Shepherd and Barbara Wanish for their GIS operations support, and to Barbara Wanish for designing and plotting the graphic displays associated with the hazard zone map and this report.

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APPENDIX A SOURCE OF ROCK STRENGTH DATA

SOURCE	NUMBER OF TESTS SELECTED
City of Los Angeles, Department of Building and Safety	105
CDMG Special Report 152	19
CDMG Hospital Site Reviews	3
Total Number of Shear Tests	127

SECTION 3

GROUND SHAKING EVALUATION REPORT

Potential Ground Shaking in the Venice 7.5-Minute Quadrangle, Los Angeles County, California

By

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Charles R. Real, and Michael S. Reichle**

**California Department of Conservation
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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) 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; also available 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 (California Department of Conservation, 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 DMG’s Internet homepage:

<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, 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.

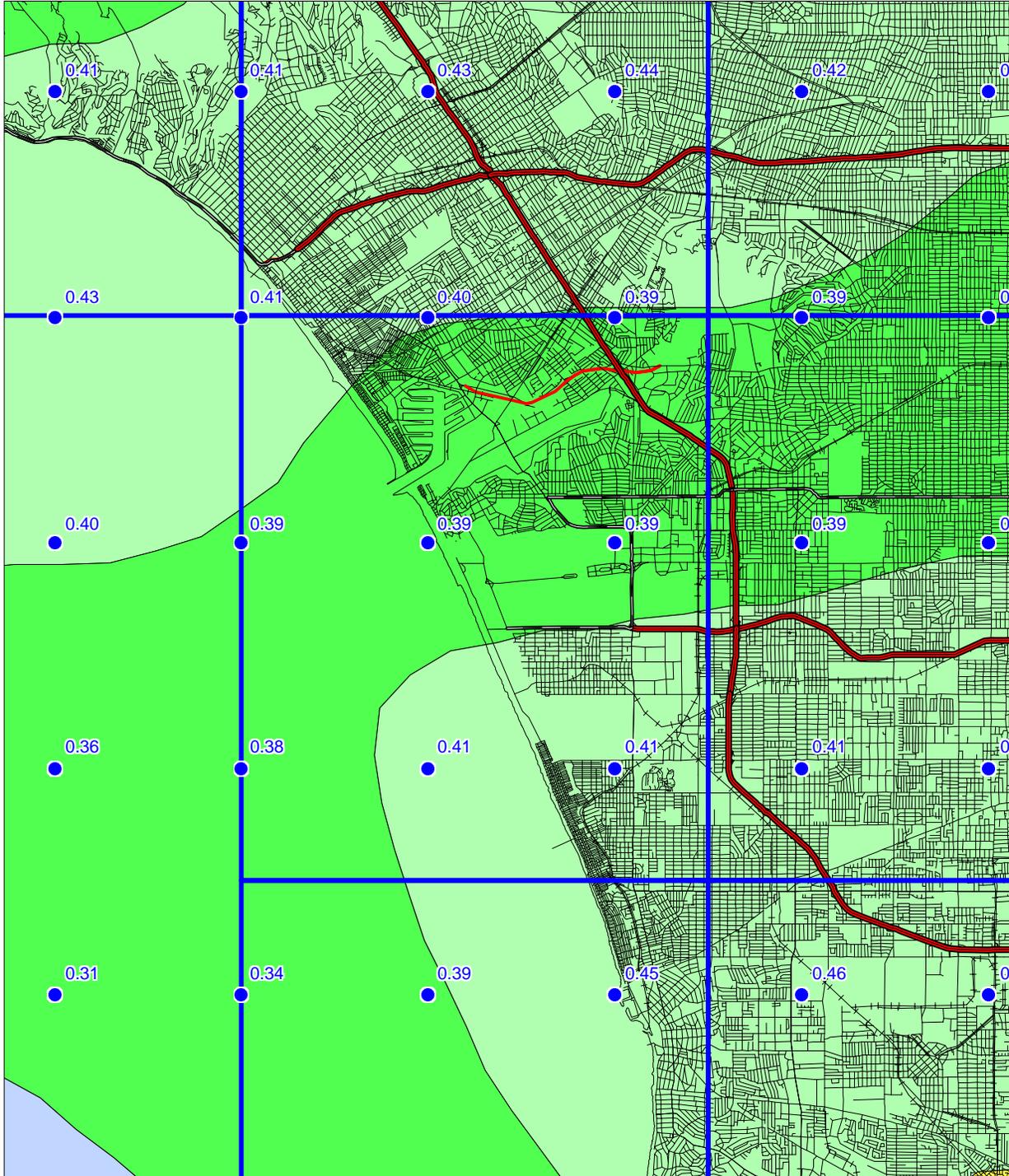
The ground shaking levels are estimated for each of the sources included in the seismic source model using attenuation relations that relate earthquake shaking with magnitude, distance from the earthquake, and type of fault rupture (strike-slip, reverse, normal, or subduction). The published hazard evaluation 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% 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% 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 adjacent

VENICE 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

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

FIRM ROCK CONDITIONS



Base map modified from MapInfo StreetWorks ©1998 MapInfo Corporation



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Division of Mines and Geology



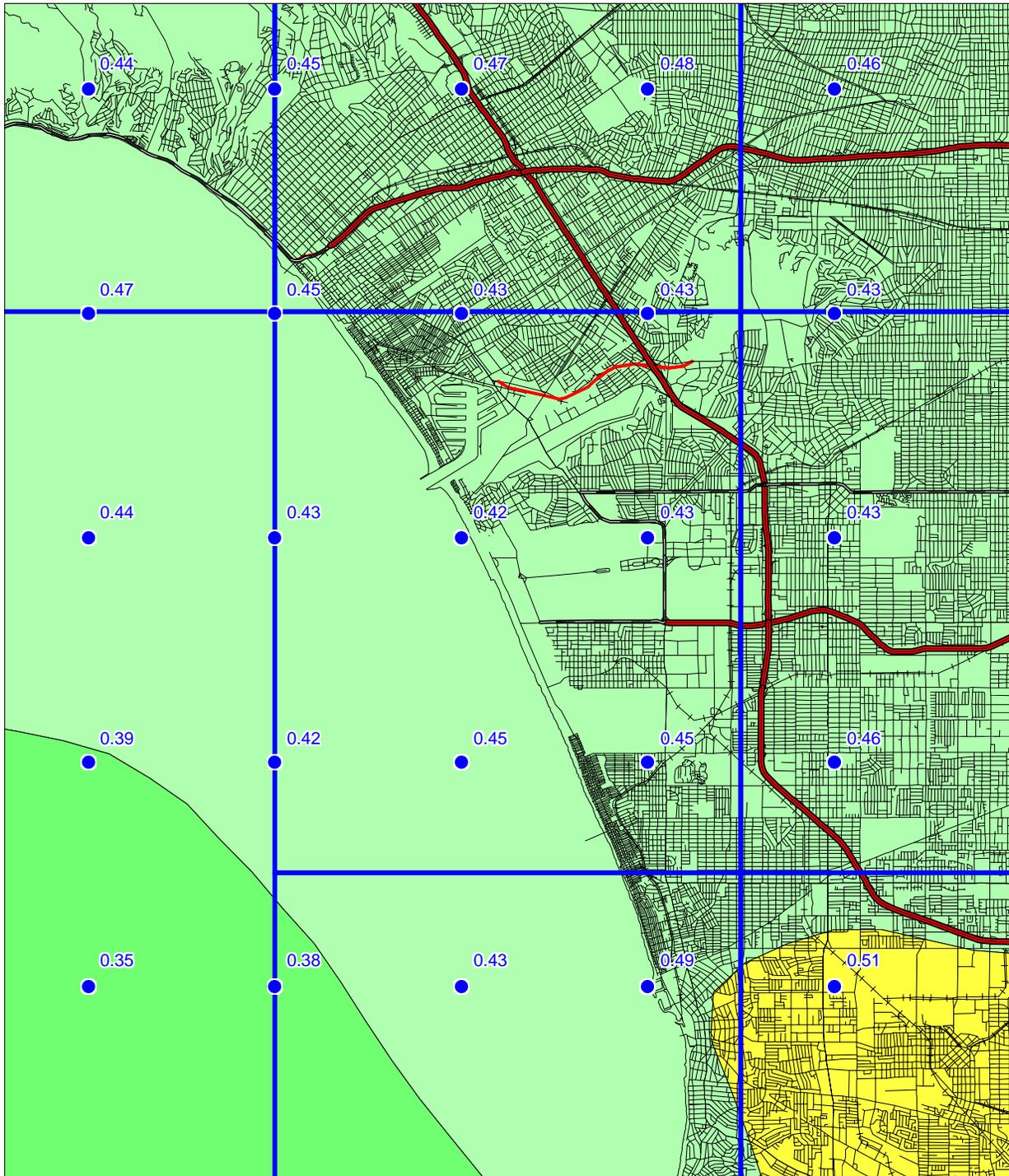
Figure 3.1

VENICE 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

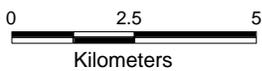
10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

SOFT ROCK CONDITIONS



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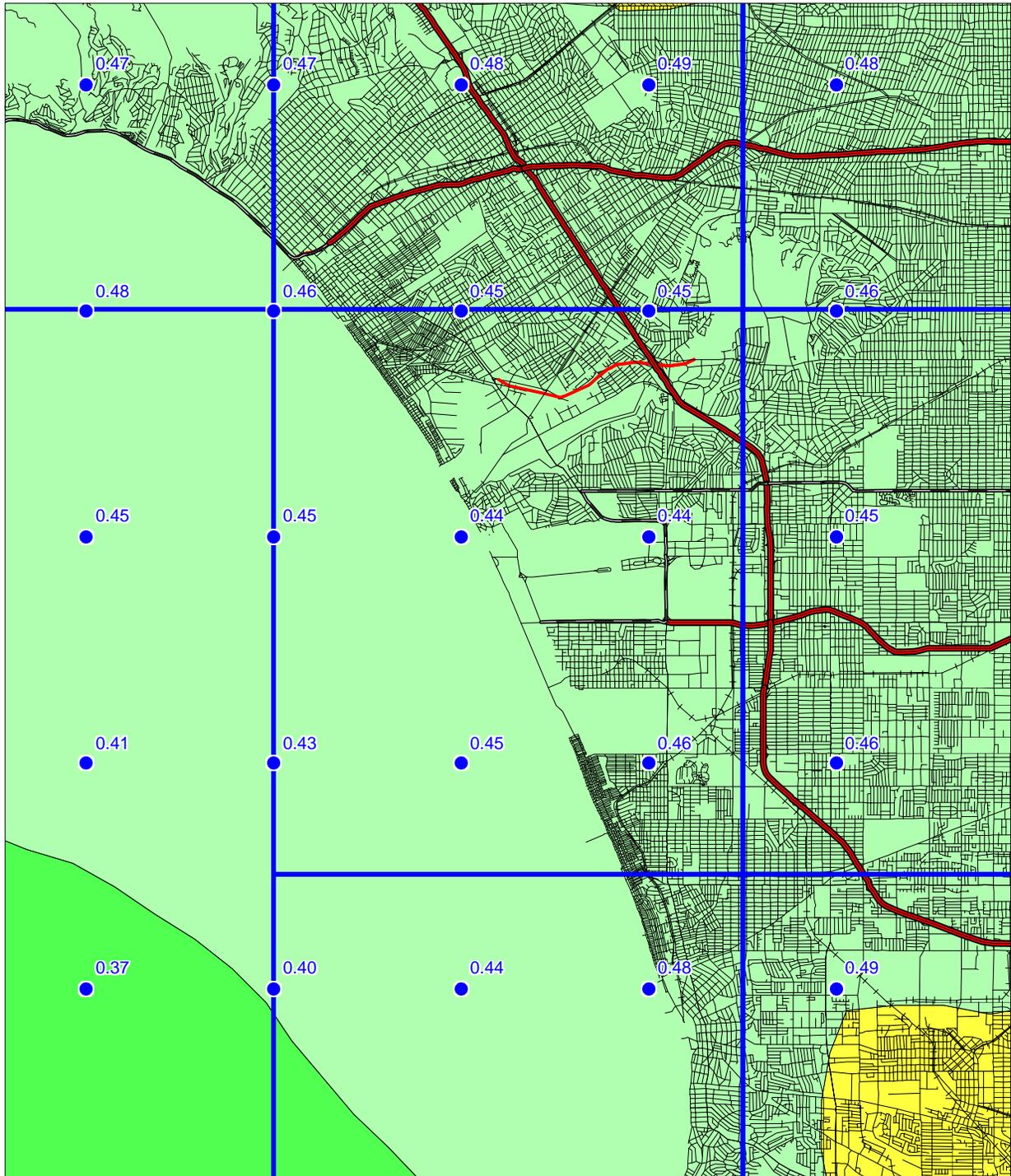
Figure 3.2

VENICE 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

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

1998

ALLUVIUM CONDITIONS



Base map modified from MapInfo Street Works ©1998 MapInfo Corporation



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Figure 3.3



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% 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.

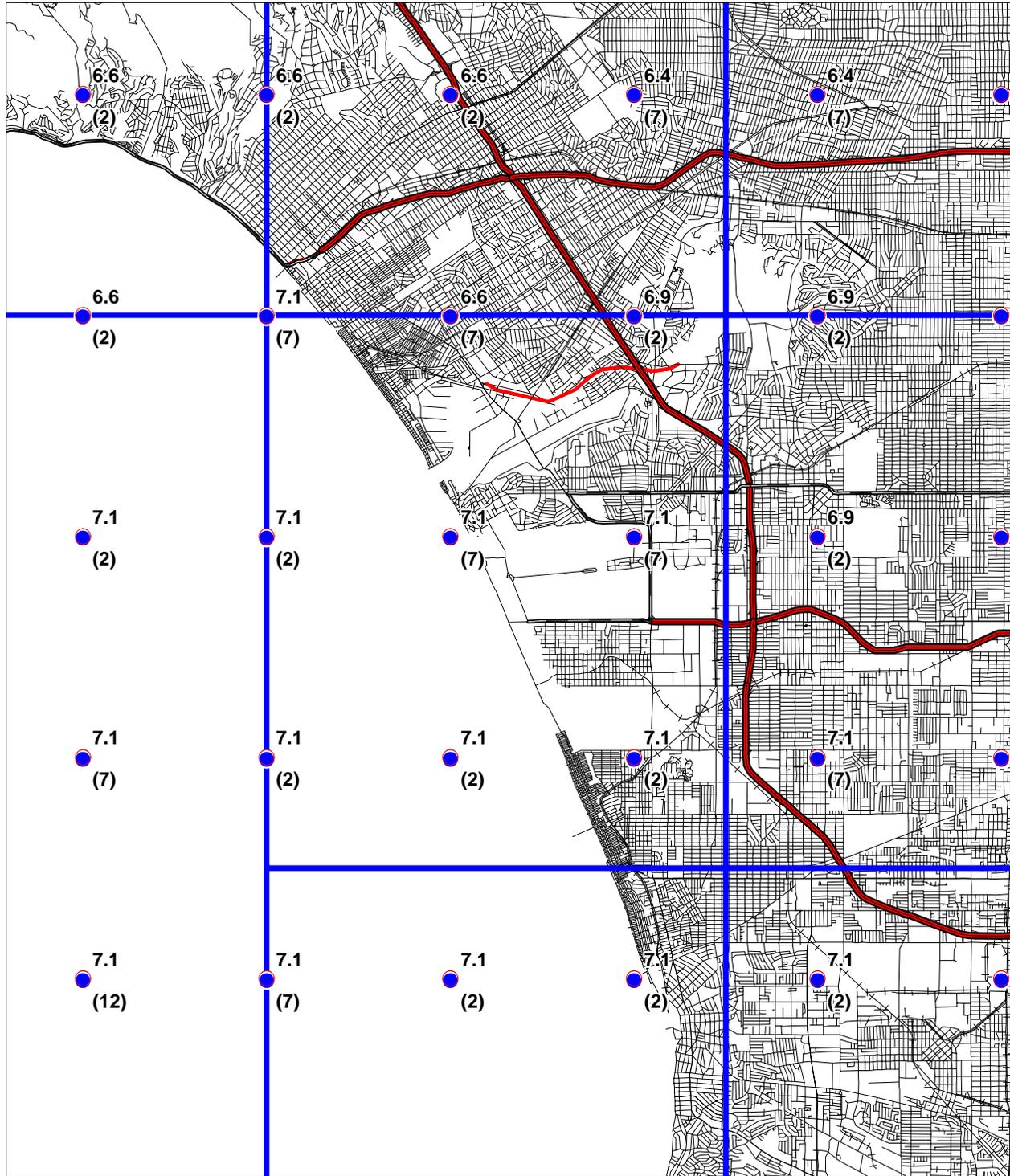
A preferred method of using the probabilistic seismic hazard model and the “simplified Seed-Idriss method” of assessing liquefaction hazard is to apply magnitude scaling probabilistically while calculating peak ground acceleration for alluvium. The result is a “magnitude-weighted” ground motion (liquefaction 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.

SEISMIC HAZARD EVALUATION OF THE VENICE QUADRANGLE
VENICE 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 modified from MapInfo StreetWorks ©1998 MapInfo Corporation

Department of Conservation
Division of Mines and Geology

Figure 3.4

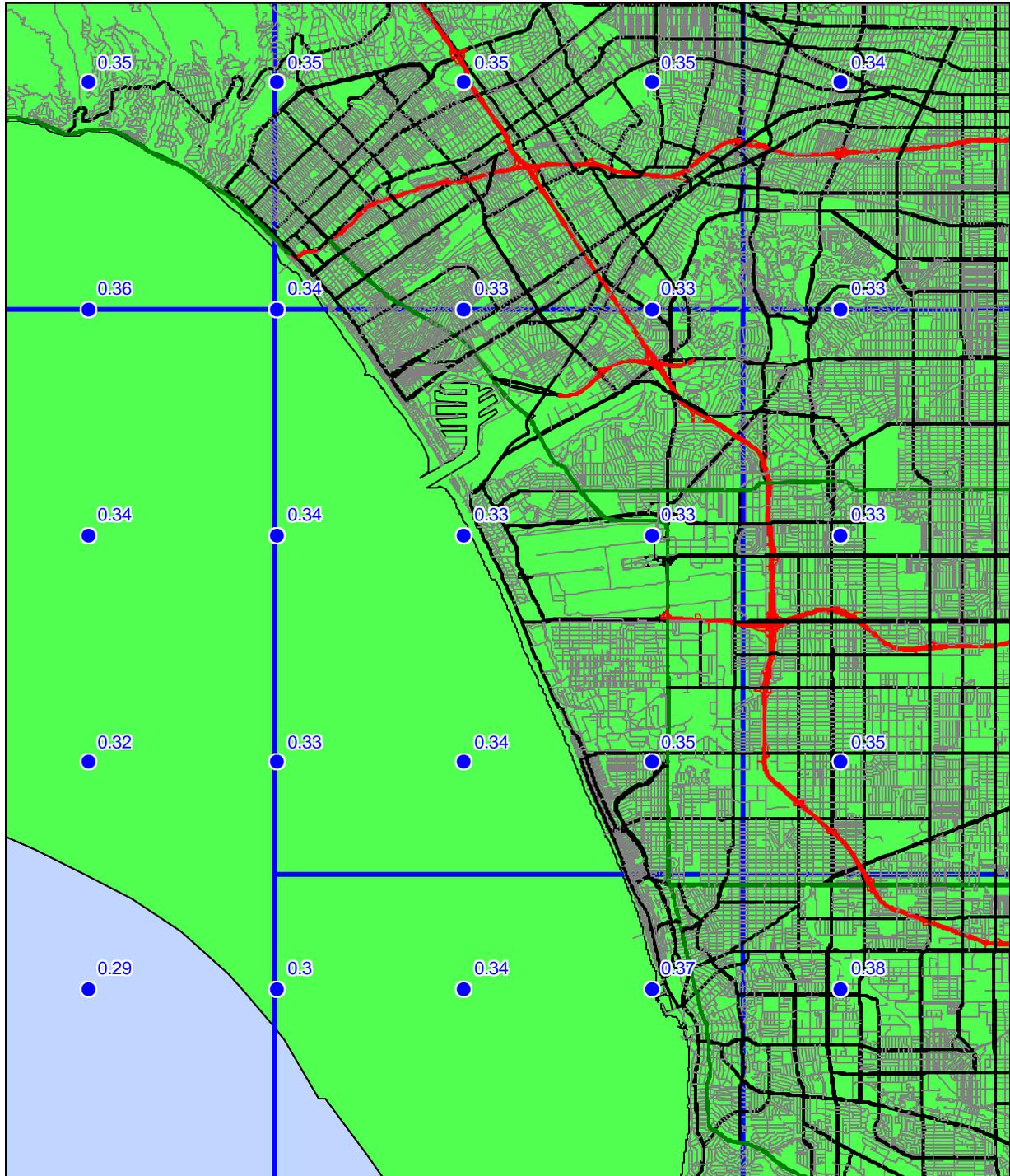


**SEISMIC HAZARD EVALUATION OF THE VENICE QUADRANGLE
VENICE 7.5-MINUTE QUADRANGLE AND PORTIONS OF
ADJACENT QUADRANGLES**

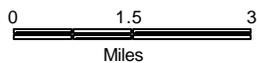
*10% EXCEEDANCE IN 50 YEARS MAGNITUDE-WEIGHTED PSEUDO-PEAK ACCELERATION (g)
FOR ALLUVIUM*

1998

LIQUEFACTION OPPORTUNITY



Base map from GDT



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% 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.

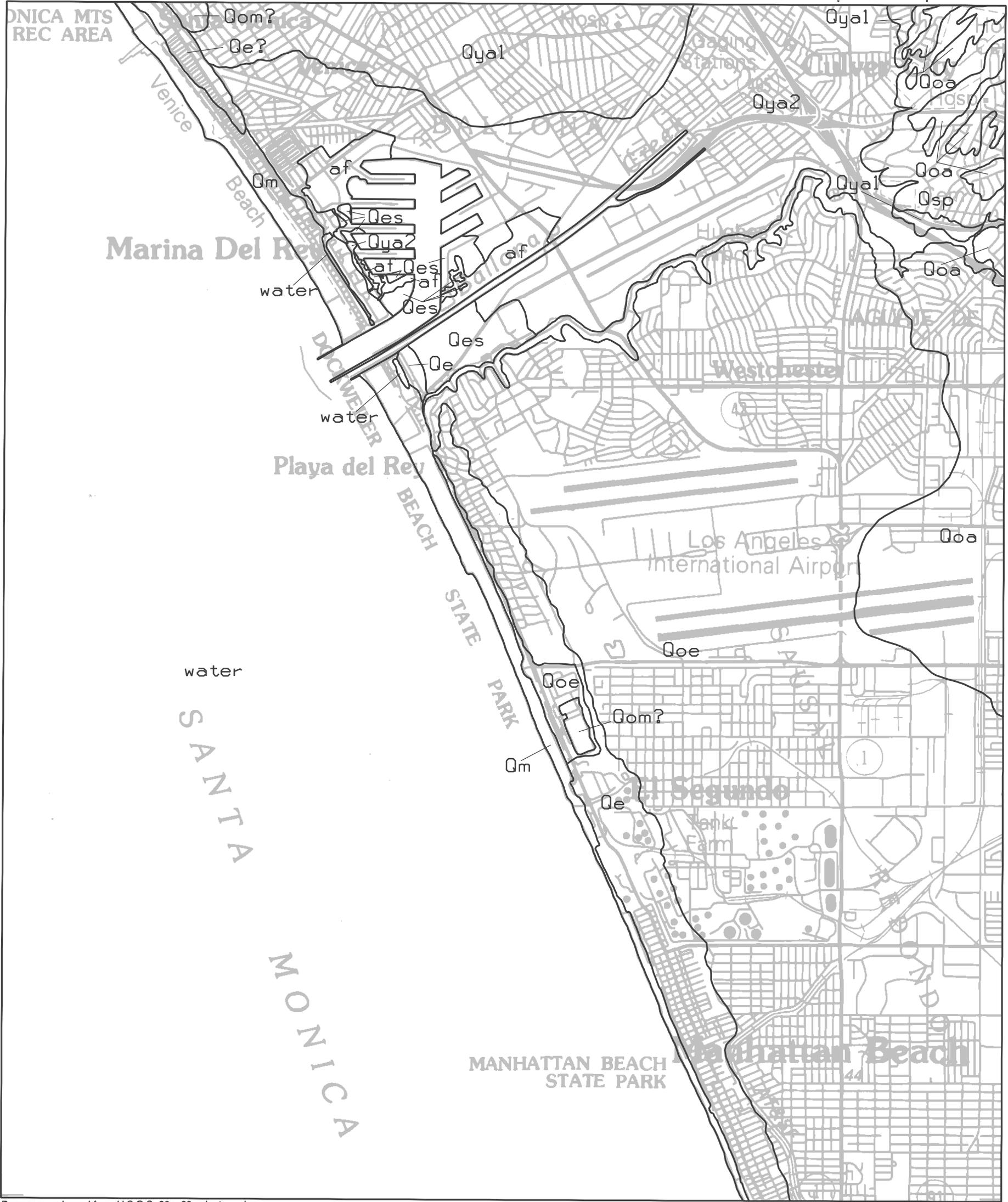
Because of its simplicity, it is likely that the SPPV method (DOC, 1997) will be widely used to estimate earthquake shaking loading conditions for the evaluation of ground failure hazards. It should be kept in mind that ground motions at a given distance from an earthquake will vary depending on site-specific 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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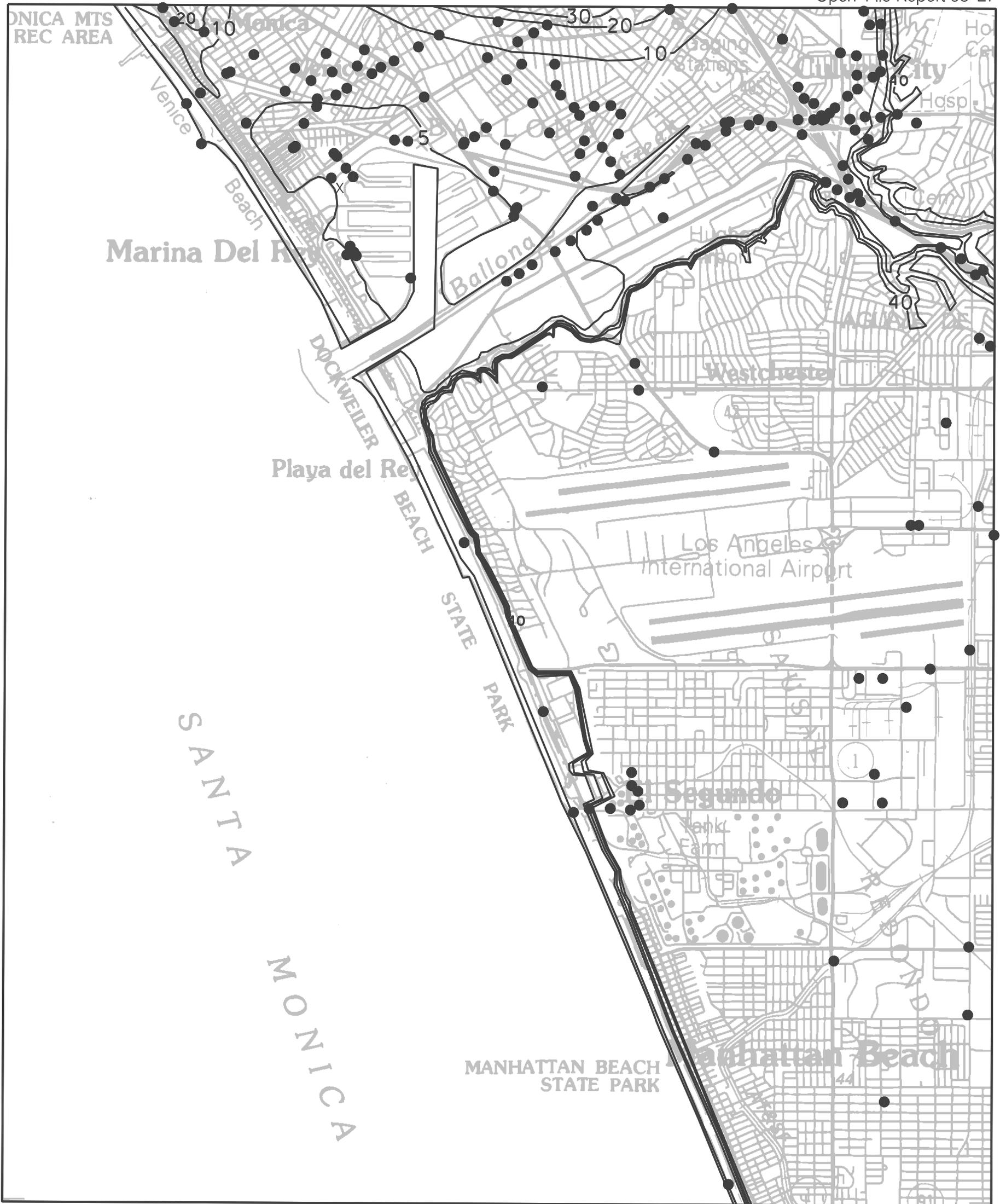


Base map enlarged from U.S.G.S. 30 x 60-minute series

Plate 1.1 Quaternary Geologic Map of the Venice Quadrangle.

See Geologic Conditions section in report for descriptions of the units.

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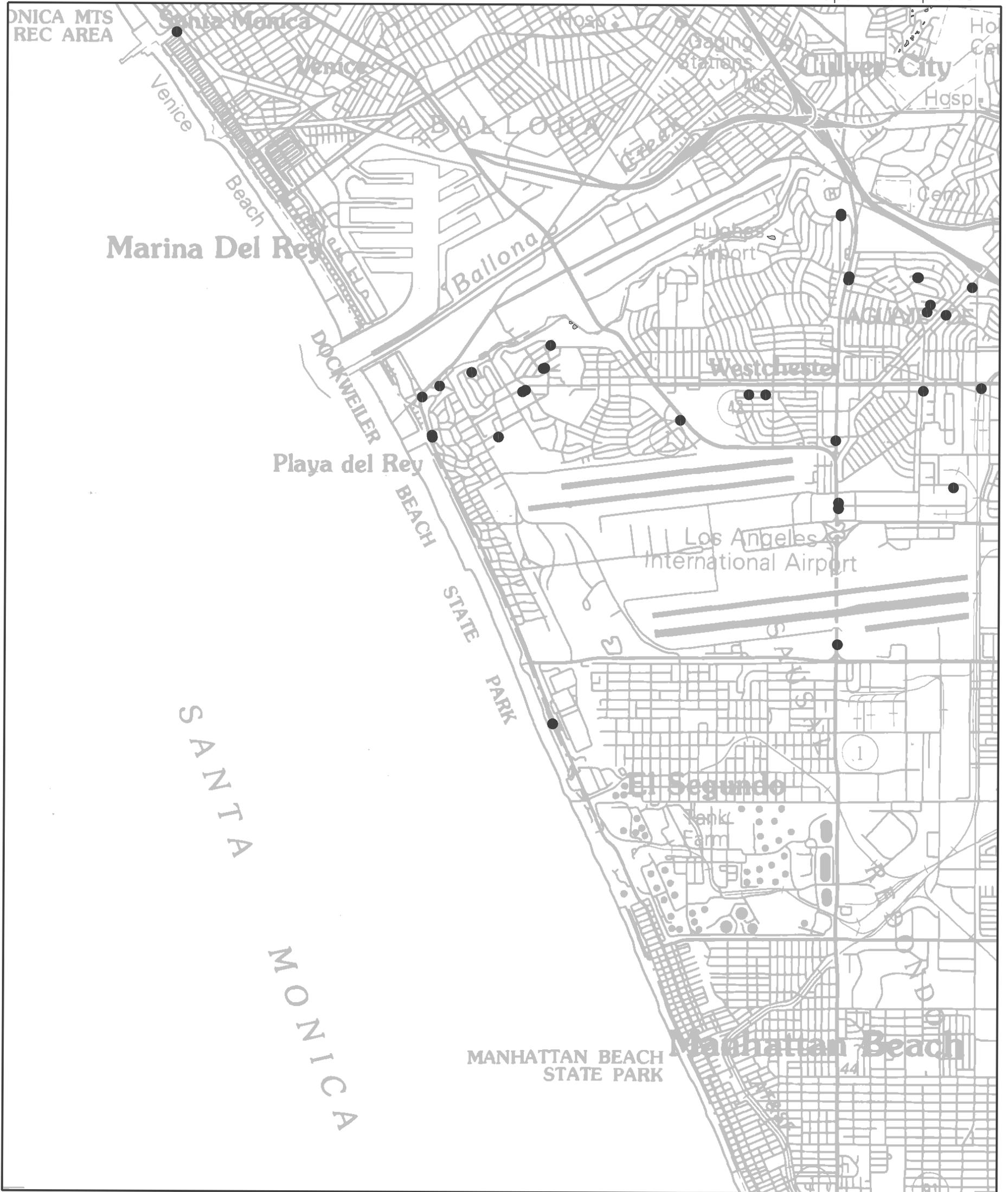
Base map enlarged from U.S.G.S. 30 x 60-minute series

Plate 1.2 Historically Highest Ground Water Contours and Borehole Log Data Locations, Venice Quadrangle.

● Borehole Site — 30 — Depth to ground water in feet

X Site of historical earthquake-generated liquefaction. See "Areas of Past Liquefaction" discussion in text.

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

Plate 2.1 Landslide inventory, Shear Test Sample Locations, Venice Quadrangle.

● shear test sample location landslide

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