SEISMIC HAZARD ZONE REPORT 019

SEISMIC HAZARD ZONE REPORT FOR THE LOS ALAMITOS 7.5-MINUTE QUADRANGLE, LOS ANGELES AND ORANGE COUNTIES, CALIFORNIA

1998

DEPARTMENT OF CONSERVATION
Division of Mines and Geology

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6/8/05	BPS address correction, web link updates
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ILLUSTRATIONS

EXECUTIVE SUMMARY

This report summarizes the methods and sources of information used to prepare the Seismic Hazard Zone Map for the Los Alamitos 7.5-minute Quadrangle, Los Angeles and Orange counties, California. The map displays the boundaries of Zones of Required Investigation for liquefaction over an area of approximately 62 square miles at a scale of 1 inch = 2,000 feet.

The Los Alamitos Quadrangle lies near the coast in southern Los Angeles and northwestern Orange counties. The map area includes all or parts of the cities of Anaheim, Artesia, Bellflower, Buena Park, Cerritos, Cypress, Garden Grove, Hawaiian Gardens, Huntington Beach, Lakewood, La Mirada, La Palma, Long Beach, Los Alamitos, Seal Beach, Stanton, and Westminister. Also included within the map area is unincorporated Los Angeles County and Orange County land and part of the U.S. Naval Weapons Station. Intensive urban development covers most of the quadrangle. Access is by means of Interstate Highway 405 (San Diego Freeway), Interstate Highway 605 (San Gabriel River Freeway), Pacific Coast Highway (State Highway 1), Interstate Highway 5 (Santa Ana Freeway) and State Highway 91 (Artesia Freeway) and a grid of major avenues.

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, 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.

The liquefaction zone covers almost the entire Los Alamitos Quadrangle because of the shallow ground-water table and nearly universal distribution of young sandy alluvial deposits. Only the hilly terrain of Reservoir Hill and Landing Hill are outside the liquefaction zone. No earthquake-induced landslide zone has been designated in the Los Alamitos 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://gmw.consrv.ca.gov/shmp/webdocs/sp117.pdf

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://www.consrv.ca.gov/dmg/pubs/sp/117/).

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 Los Alamitos 7.5-minute Quadrangle.

SECTION 1
LIQUEFACTION EVALUATION REPORT

Liquefaction Zones in the Los Alamitos 7.5-Minute Quadrangle, Los Angeles and Orange Counties, California

By
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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 Los Alamitos 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, as well as in the Los Alamitos 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 Los Alamitos Quadrangle consist mainly of floodplains and low-lying shoreline regions. 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

The Los Alamitos Quadrangle covers an area of about 62 square miles in southern Los Angeles County and northwestern Orange County. The map area includes all or parts of the cities of Anaheim, Artesia, Bellflower, Buena Park, Cerritos, Cypress, Garden Grove, Hawaiian Gardens, Huntington Beach, Lakewood, La Mirada, La Palma, Long Beach, Los Alamitos, Seal Beach, Stanton, and Westminister. Also included within the map area is unincorporated Los Angeles County and Orange County land and part of the U.S. Naval Weapons Station.

The Orange County coastal plain is bound on the north by the inferred trace of the Norwalk Fault Zone and the late Pleistocene fan deposits associated with the adjacent anticlinal hills of the Coyote Hills Uplift (Greenwood and Morton, 1990). The main body of this coastal plain is underlain by the broad, northwest-plunging synclinal Los

Angeles Basin, which includes up to 4200 feet of relatively unconsolidated Pleistocene marine and non-marine sediments (Greenwood, 1980b) and up to 170 feet of unconsolidated non-marine sediments (Fuller, 1980a).

The Los Alamitos Quadrangle includes the broad southern margin of the Los Angeles Basin, which culminates abruptly with coastal hills and mesas associated with the Newport-Inglewood Uplift. This uplift of broadly warped coastal mesas, represented by Landing Hill and Alamitos Heights in the Los Alamitos Quadrangle, are composed of late Pleistocene marine terrace deposits which are covered with a veneer of older alluvium. To the southeast in the Newport Beach Quadrangle coastal mesas expose marine-terrace deposits, which are underlain by late Miocene to early Pleistocene marine sediments. The coastal mesas in the Los Alamitos Quadrangle are separated by Alamitos Gap, a deeply incised by antecedent drainage of the latest Pleistocene to earliest Holocene ancestral Rio Hondo and San Gabriel River.

Access to various parts of the quadrangle is by means of Interstate Highway 405 (San Diego Freeway) and Interstate Highway 605 (San Gabriel River Freeway). The Pacific Coast Highway (State Highway 1) cuts across the southwestern corner of the map and both Interstate Highway 5 (Santa Ana Freeway) and State Highway 91 (Artesia Freeway) cut across the northeastern corner of the map. The quadrangle is also covered by a grid of major avenues.

GEOLOGY

Surficial Geology

Geologic units that generally are susceptible to liquefaction include late Quaternary alluvial and fluvial sedimentary deposits and artificial fill. Geologic mapping of late Quaternary alluvial deposits, digitally compiled by the Southern California Areal Mapping Project (SCAMP, 1995), was used to evaluate the distribution and character of young, unconsolidated sediments exposed in the Los Alamitos Quadrangle. This geologic map relied extensively on early soil surveys (Echmann and others, 1916; Nelson and others, 1919), to which geologic nomenclature was applied. Additional detail was added from the Long Beach 1:100,000-scale digital geologic map, prepared by the California Division of Mines and Geology (Bezore and others, unpublished).

Quaternary geologic contacts received minor modifications in accordance with early edition 1:62,500-scale topographic maps (Downey, 1902) and the old regional soils maps (Echmann and others, 1916 and Nelson and others, 1919). 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 mapped units fall into five basic sediment types: 1) late Pleistocene marine terrace deposits and overlying veneer of older alluvium (Qvoa/s), dense silty sands that cover Alamitos Heights and Landing Hill (Seal Beach); 2) Holocene alluvial soft sand, silt, silty sand, and clay of distal fan deposits (Qyf/a, Qyfa/s, Qyfa/c), associated with the active

Rio Hondo, San Gabriel River, and Santa Ana River alluvial systems; 3) an occurrence of modern eolian deposits (Qyes); and 4) large areas of artificial fill (af), which cover extensive modern beach sands and lagoonal deposits.

Prior to the development of Alamitos Bay, extensive estuarine deposits were present at the mouth of the abandoned drainages of Rio Hondo, the Santa Ana River, and the present San Gabriel River. The organic tidal muds therein were extensively dredged and covered in many places with artificial fill (af).

ENGINEERING GEOLOGY

Information on subsurface geology and engineering characteristics of flatland deposits was obtained from more than 465 borehole logs in the study area. Subsurface data used for this study include the database compiled for previous liquefaction studies in Los Angeles County (Tinsley and Fumal, 1985; Tinsley and others, 1985) and for previous seismic ground response studies in the Orange County area (Sprotte and others, 1980). Additional data were collected for this study from the files of the Orange County Public Health Department, Environmental Health Division, Orange County Public Works Department, Construction and Design Divisions, Municipal Water District of Orange County, Caltrans, Southern California District of the California Department of Water Resources, California Water Quality Control Board, and the California State Architect's Office. Data from previous databases and additional borehole logs were entered into the DMG GIS database. Locations of all exploratory boreholes considered in this investigation are shown on Plate 1.2. 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).

Geologic Map Unit	Material Type	Consistency	Liquefaction Susceptibility
Af, artificial fill	Sand, silty sand	Soft to dense	High
Qyf/a, Younger alluvium	Silty sand, and sand	Soft	High
Qyes, Modern Eolian Deposits	Sand	Soft	Low to moderate
Qvom/s, Marine Terrace Deposits	Silty sand, minor gravel	Dense-very dense	Low

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

Older alluvium (Qvom/a, Qvom/c, Qvom/s) covering marine terrace deposits

Older alluvium overlies, but is not differentiated from, late Pleistocene terrace deposits on Alamitos Heights and Landing Hill. Ground water is deep throughout these areas, so no extensive effort was made to collect subsurface data. They are generally described as dense to very dense sand and silty sand deposits.

Modern eolian deposits (Qyes)

Modern eolian deposits are composed of very well sorted, fine- to medium-grained sand.

Younger alluvium (Qyf/a)

Younger alluvium associated with the lowlands of the San Gabriel River and Santa Ana River were not subdivided into “alluvium” and “floodplain” deposits. These deposits consist of soft sand (Qyf/a), silt (Qyf/s), and clay (Qyf/c).

Artificial fill (af)

Artificial fill in the Los Alamitos Quadrangle consists of undifferentiated young and old fills associated with development of the greater Alamitos Bay complex and the City of Seal Beach.

Subsurface Stratigraphic Analysis

An analysis of the local subsurface geology reveals a dynamic interaction between the Rio Hondo, San Gabriel River, and Santa Ana River fans and the coastal mesas, whose elevation is related to deformation along the Newport-Inglewood Fault Zone. The reference time-frame of the depositional regime is controlled by the last “low stand” of sea level—approximately 20,000 years ago (McNeilan and others, 1996). During that time, local drainages became incised because of lower base levels (for example, sea level was 100’s of feet below the modern level).

Although the immediate scope of the present study focuses on geologic conditions within 50 feet of the ground surface, an appreciation of the underlying aquifers assists in establishing a temporally constrained (Holocene) stratgraphic framework for determining the nature and distribution of overlying, potentially liquefiable sediments.

The temporally constrained stratigraphic framework of the subsurface sediments defines which of these underground, potentially liquefiable sediments are of Holocene age—and, accordingly, meet the “latest Pleistocene to present” age restrictions, which are imposed by the official criteria developed by the State Mining and Geology Board (DOC, 2000).

Latest Pleistocene to Earliest Holocene (?) Aquifers

The stratigraphic base of the Holocene is related to the most recent Pleistocene rise in sea level, which raised stream-base levels, that led to the deposition of fan sediments. This latest Pleistocene to earliest Holocene (?) fluvial backfilling of incised drainages controlled the initial distribution of coarse-grained sediments, locally named the Gaspur aquifer in Los Angeles County and the Bolsa and Talbert aquifers in Orange County (Mendenhall, 1905). These depositional processes have been well documented in Poland and others (1956) and Poland (1959). The depth to base, thickness, and lateral distribution of the Bolsa and Talbert aquifers were mapped by Fuller (1980b), who showed the tops to be generally less than 70 feet deep in the coastal gap areas.

Earliest-Holocene to Modern Sediments

The distribution of Holocene sediments, as recorded in early editions of regional soil survey maps (Eckmann and others, 1916; Nelson and others, 1919), suggests that the Rio Hondo, San Gabriel River, and Santa Ana River have, during the recent past, moved back and forth across the Los Angeles County and Orange County coastal plains from Los Angeles Harbor to Alamitos Bay and from Alamitos Bay to Newport Bay, respectively. Historical accounts further support the conclusion that widespread sheet flooding has been the dominant depositional process associated with the Rio Hondo, the San Gabriel River, and the Santa Ana River. This went on until the construction of Prado Dam and Whittier Narrows Dam (California Department of Water Resources, 1959).

Regional cross sections were constructed using Caltrans and underground tank borehole data, which allowed the definition of at least four and as many as six regional, repetitive, upward-fining sequences of fluvial sediments, with recognizable lateral continuity in the Orange County Coastal Plain (Greenwood, 1998). The cross-sectional models became better defined as local cases of crosscutting relationships and longitudinal facies changes also became apparent. Stratigraphic units were first identified via correlations of lithology and standard penetration tests (SPT) of deep geotechnical boreholes (generally 60 to 80 feet) along U.S. Interstate Highway 5 (I-5) and 405 (I-405). These detailed geotechnical borehole logs were placed in cross sections having a horizontal scale of 1 inch=1000 feet and a vertical scale of 1inch=10 feet.

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 $(N_1)_{60}$.

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 Los Alamitos 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 geotechnical borehole logs acquired from compiled geotechnical boreholes, environmental monitoring wells, and water-well logs. The depths to first-encountered unconfined ground water were plotted onto a map of the project area to constrain the estimate of historically shallowest ground water. Water depths from boreholes known to penetrate confined aquifers were not utilized.

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. DMG's qualitative relations are outlined below and summarized in Table 1.1.

Older alluvium (Qvom/s) covering marine terrace deposits

Older alluvium overlies, but is not differentiated from, late Pleistocene terrace deposits. Ground water is deep throughout the areas of older alluvium, so no extensive effort was made to collect subsurface data. Older alluvium is generally described as dense to very dense sand and silty sand. Liquefaction susceptibility of the unit is low.

Younger alluvium (Qyf/a)

Younger alluvium associated with the lowlands of the San Gabriel and Santa Ana Rivers were not subdivided into "alluvium" and "floodplain" deposits. These deposits consist of soft sand (Qyf/a), silt (Qyf/s), and clay (Qyf/c). Where this unit is saturated, liquefaction susceptibility is high.

Artificial fill (af)

Artificial fills commonly overlie young alluvial or estuarine deposits. Because the artificial fills are usually too thin to affect the liquefaction hazard, and the underlying estuarine and alluvial 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 Los Alamitos Quadrangle, peak accelerations of 0.40 g to 0.51 g resulting from an earthquake of magnitude 6.7 to 6.8 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 portion (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 465 geotechnical borehole logs reviewed in this study (Plate 1.2), 271 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 Los Alamitos Quadrangle is summarized below.

Areas of Past Liquefaction

In the Los Alamitos Quadrangle, numerous effects attributed to liquefaction were noted in the coastal areas of the City of Long Beach and in the soft sediments along the San Gabriel River near Alamitos Bay following the 1933 Long Beach earthquake. Observed damage and effects include including buckled and displaced pavement, fill settlement, surficial cracks, and “mud volcanoes” formed near the north end of Seal Beach (Barrows, 1974).

Areas with Sufficient Existing Geotechnical Data

Borehole logs that include penetration test data and sufficiently detailed lithologic descriptions were used to evaluate liquefaction potential. These areas with sufficient geotechnical data were evaluated for zoning based on the liquefaction potential determined by the Seed-Idriss Simplified Procedure. The marine terrace deposits and/or Older alluvial covering, as exposed in the Los Alamitos Quadrangle (Qova/s) generally have a dense consistency, high fines content, or deep ground water and accordingly have not been included in liquefaction hazard zones. Younger alluvial deposits (Qyf/a) commonly have layers of loose silty sand or sand. Where these deposits are saturated, they are included in a liquefaction hazard zone. Younger eolian deposits (Qyes) are typically very thin and permeable and located on a slope, and therefore, unsaturated. They are not included in liquefaction hazard zones.

Artificial Fills

In the Los Alamitos Quadrangle artificial fill consists of artificial fill around Alamitos Bay, and the City of Seal Beach. Residential-related engineered fills are generally too thin to have an impact on liquefaction, but fills which overlie estuarine deposits are more likely to be susceptible to liquefaction. Extensive low-lying areas of artificial fill have been included in liquefaction hazard zones.

ACKNOWLEDGMENTS

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SECTION 2
EARTHQUAKE-INDUCED LANDSLIDE EVALUATION REPORT

NO LANDSLIDE HAZARDS ZONED

Within the Los Alamitos Quadrangle, no areas have been designated as "zones of required investigation for earthquake-induced landslides." However, the potential for landslides may exist locally, particularly along streambanks, margins of drainage channels, and similar settings where steep banks or slopes occur. Within the liquefaction zones, some of these 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 Los Alamitos 7.5-Minute Quadrangle, Los Angeles and Orange Counties, California

By

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

California Department of Conservation
Division of Mines and Geology
***Formerly with DMG, 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) 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.

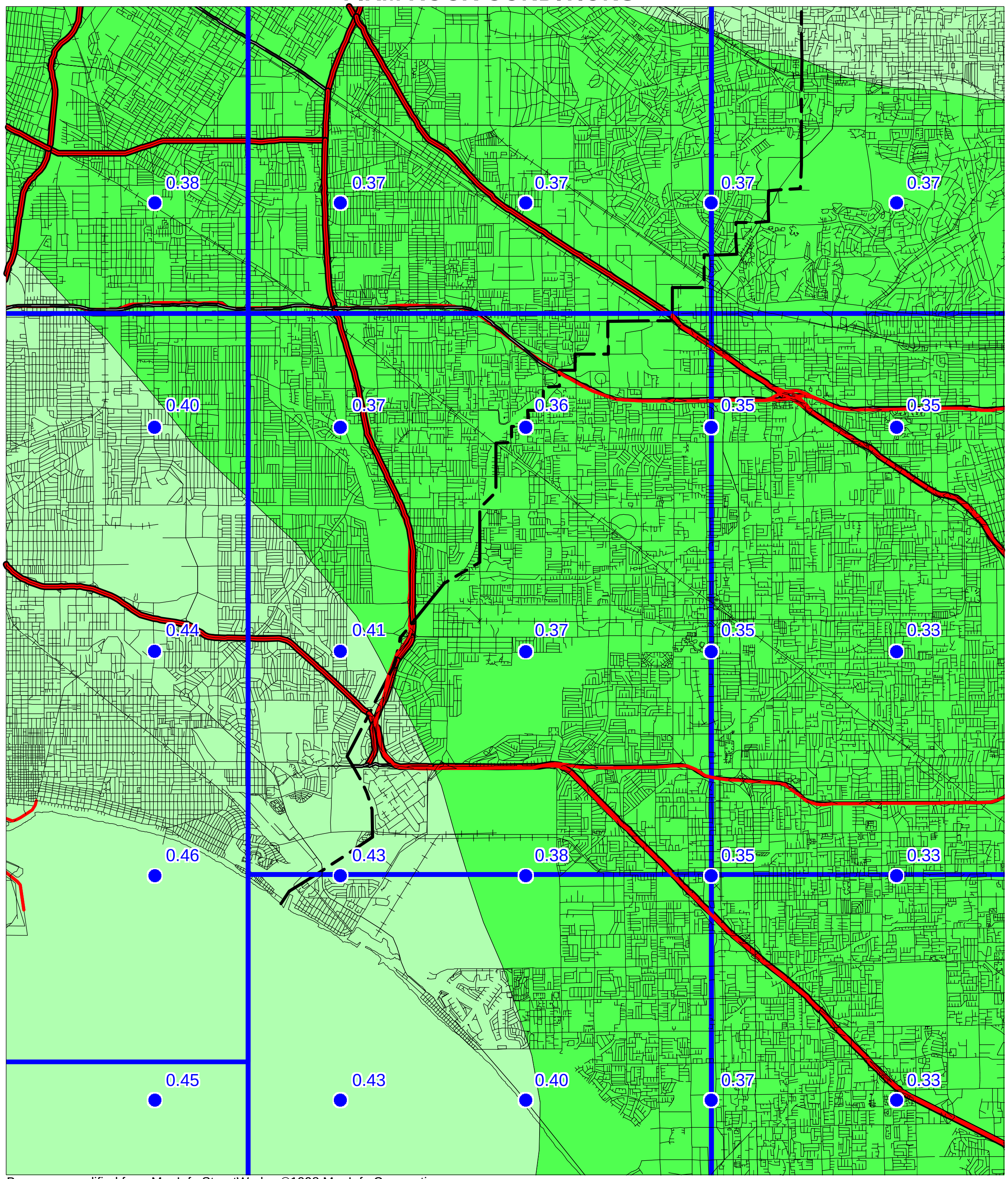
The seismic hazard maps for ground shaking are produced by calculating the hazard at sites separated by about 5 km. Figures 3.1 through 3.3 show the hazard for PGA at 10% probability of exceedance in 50 years assuming the entire map area is firm rock, soft rock, or alluvial site conditions respectively.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

LOS ALAMITOS 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

0 2.5 5
Kilometers

Department of Conservation
Division of Mines and Geology

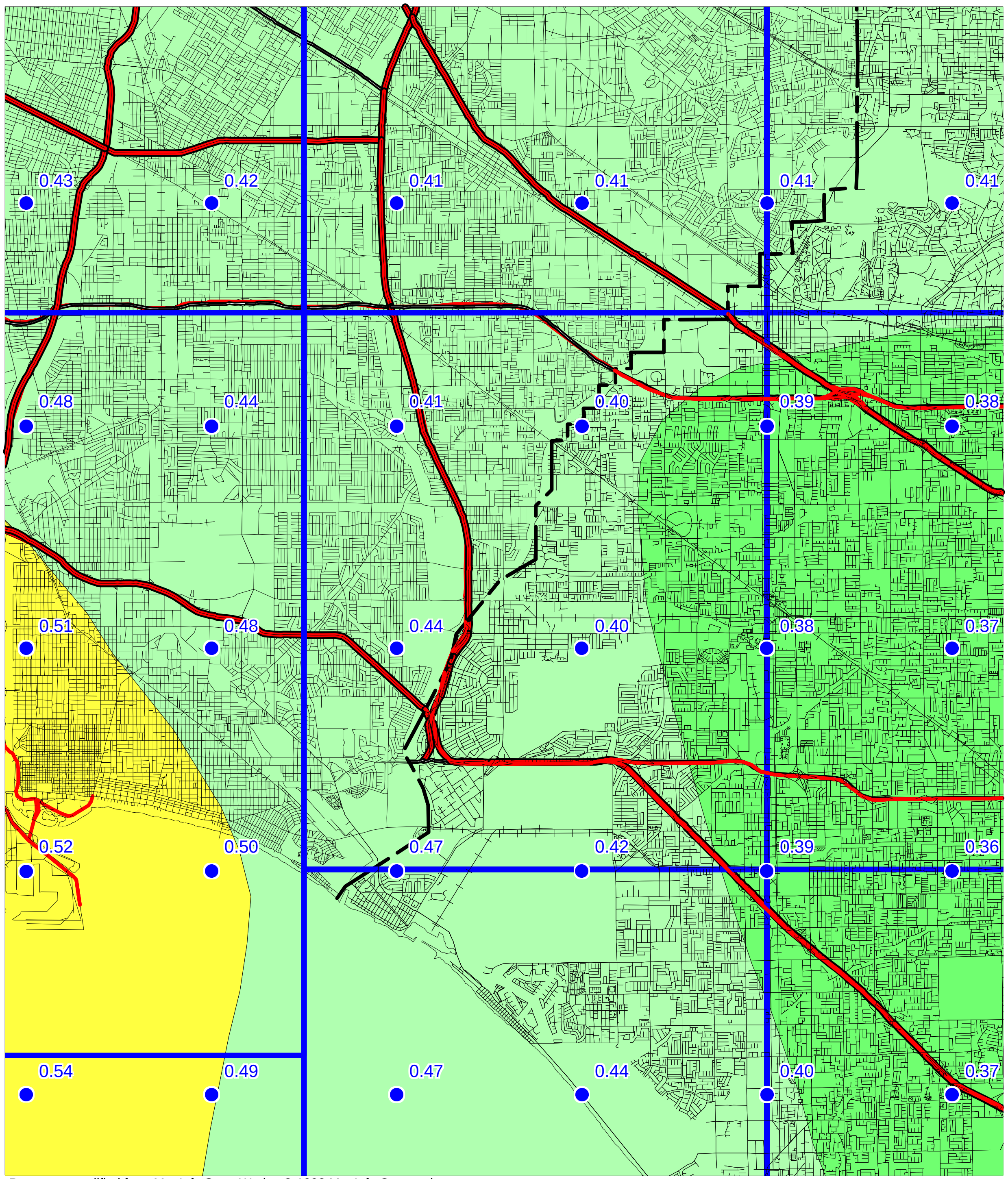
Figure 3.1

LOS ALAMITOS 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

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

1998

SOFT ROCK CONDITIONS



Base map modified from MapInfo StreetWorks © 1998 MapInfo Corporation

0 2.5 5
Kilometers

Department of Conservation
Division of Mines and Geology

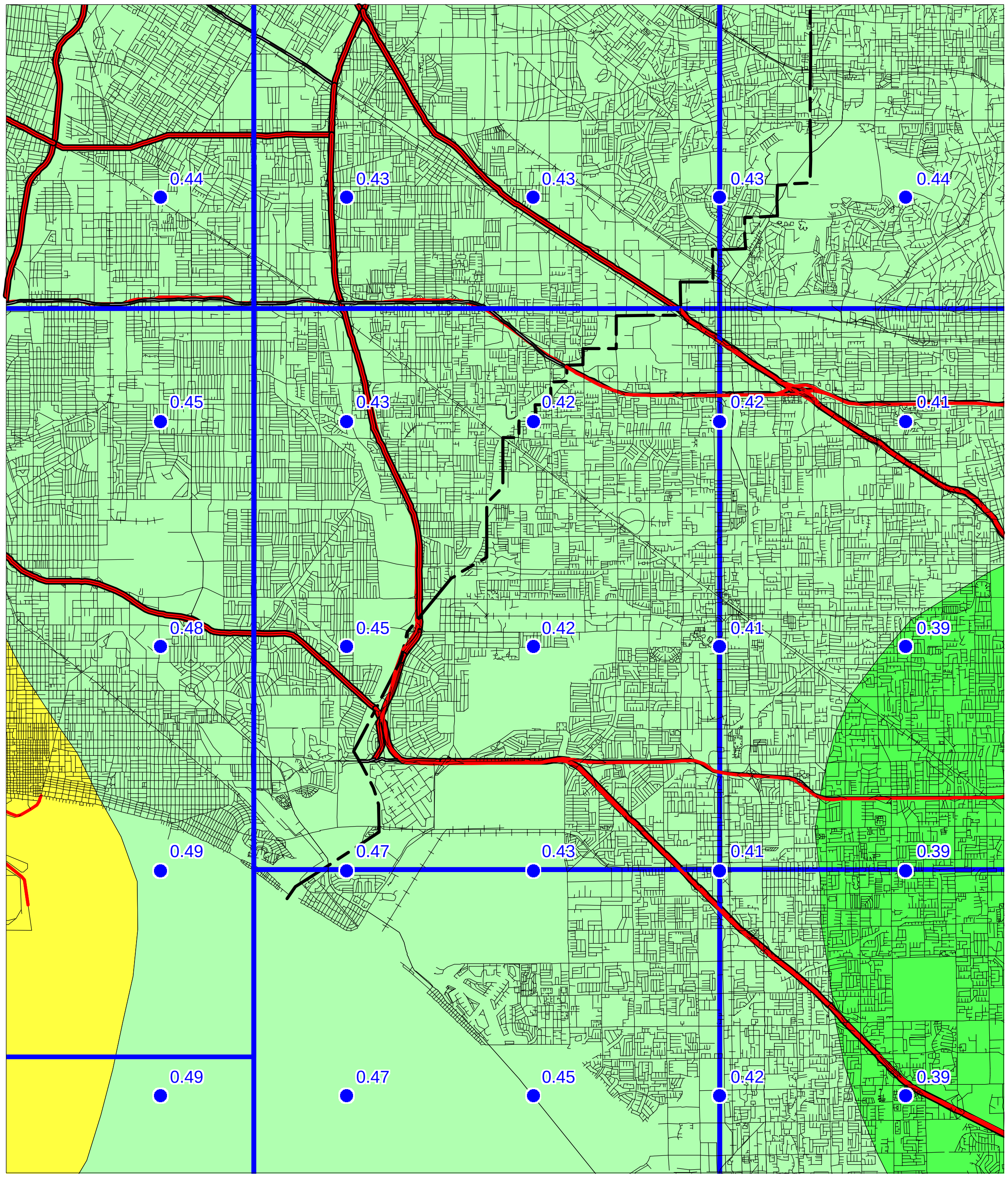
Figure 3.2

LOS ALAMITOS 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

0 2.5 5
Kilometers

Department of Conservation
Division of Mines and Geology

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.

LOS ALAMITOS 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

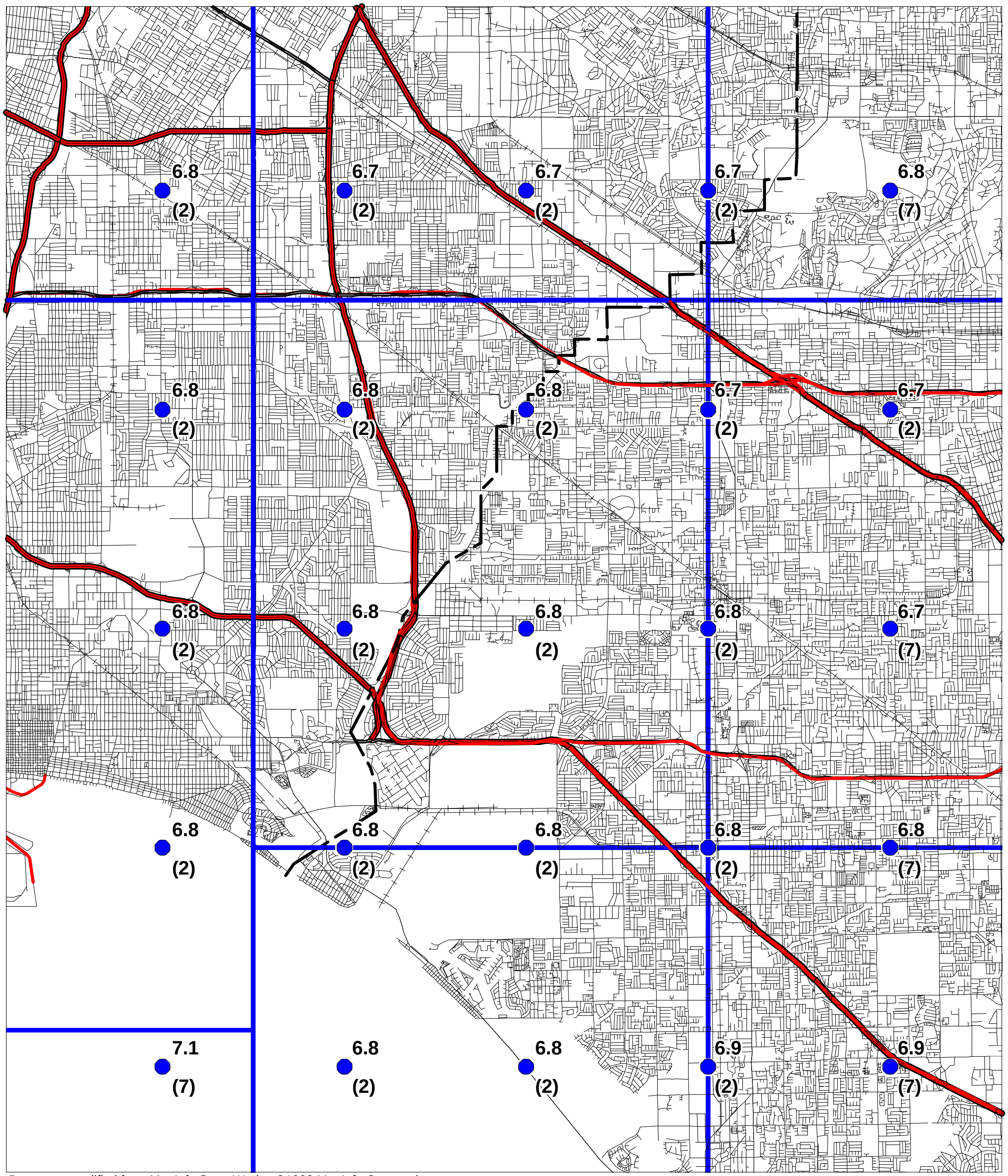
10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION

1998

PREDOMINANT EARTHQUAKE

Magnitude (Mw)

(Distance (km))



0 2.5 5

Kilometers

Department of Conservation

Division of Mines and Geology

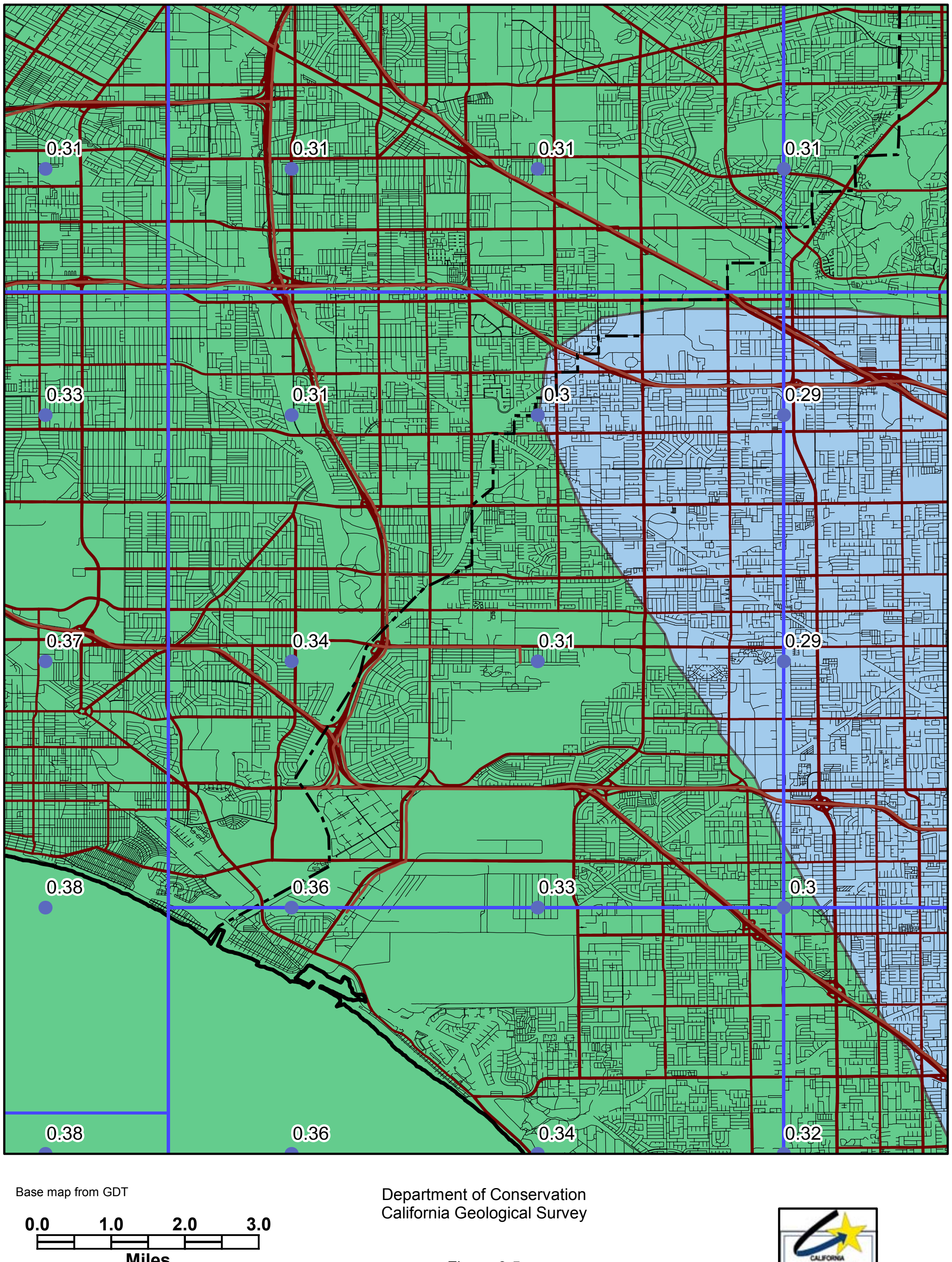
Figure 3.4

LOS ALAMITOS 7.5-MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDENCE IN 50 YEARS MAGNITUDE WEIGHTED PSEUDO-PEAK ACCELERATION (g)

1998

LIQUEFACTION OPPORTUNITY



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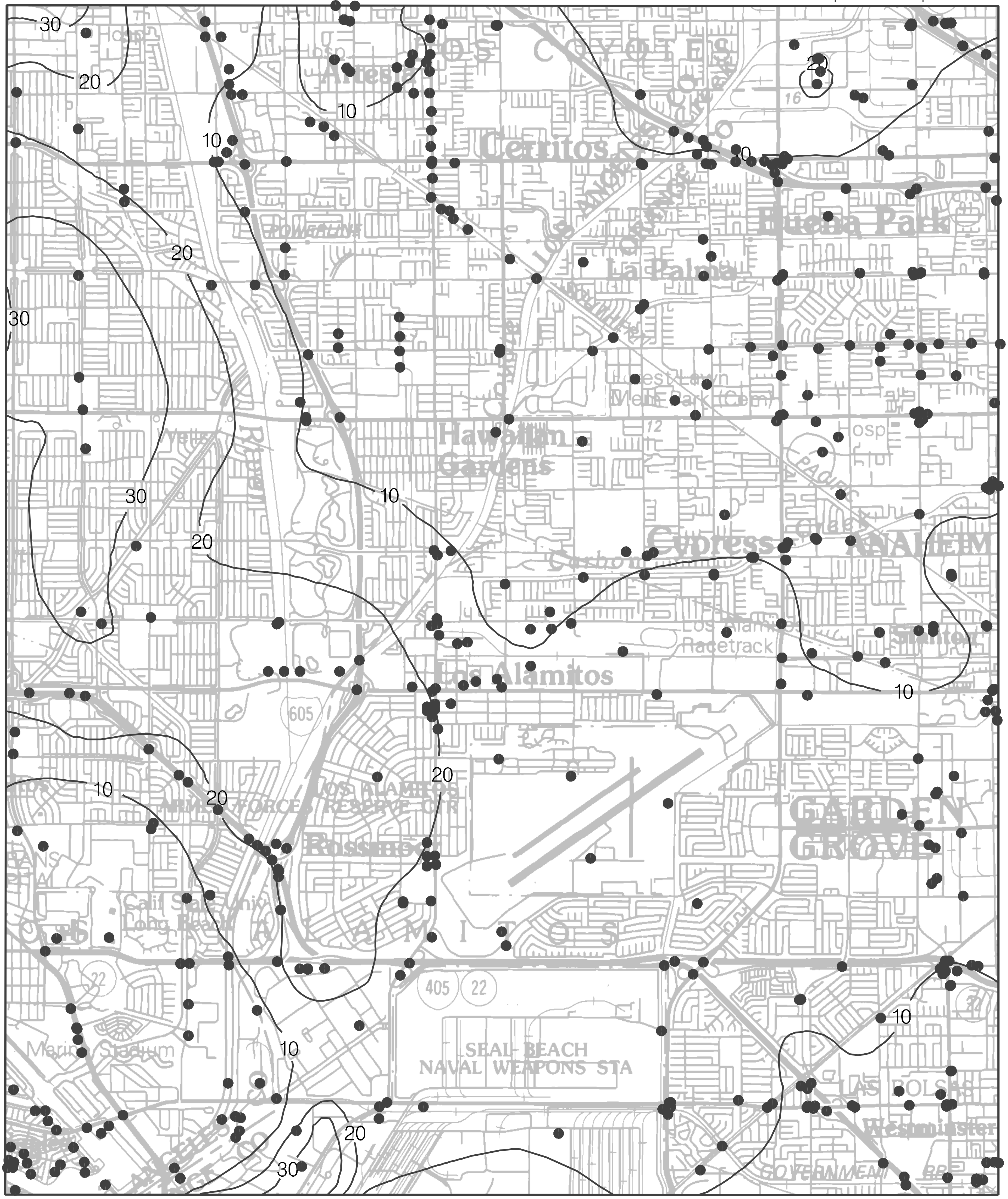
Base map enlarged from U.S.G.S. 30 x 60–minute series

Plate 1.1 Quaternary Geologic Map of the Los Alamitos Quadrangle.

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

ONE MILE

SCALE



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, Los Alamitos Quadrangle.

● Borehole Site

30 Depth to ground water in feet

ONE MILE

SCALE