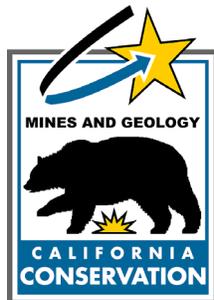


**SEISMIC HAZARD ZONE REPORT FOR THE  
SAN DIMAS 7.5-MINUTE QUADRANGLE,  
LOS ANGELES COUNTY, CALIFORNIA**

**1998**



**DEPARTMENT OF CONSERVATION**  
*Division of Mines and Geology*

**THE RESOURCES AGENCY**  
MARY D. NICHOLS  
*SECRETARY FOR RESOURCES*

**STATE OF CALIFORNIA**  
GRAY DAVIS  
*GOVERNOR*

**DEPARTMENT OF CONSERVATION**  
DARRYL YOUNG  
*DIRECTOR*



DIVISION OF MINES AND GEOLOGY  
JAMES F. DAVIS, *STATE GEOLOGIST*

Copyright © 2001 by the California Department of Conservation. All rights reserved. No part of this publication may be reproduced without written consent of the Department of Conservation.

"The Department of Conservation makes no warranties as to the suitability of this product for any particular purpose."

SEISMIC HAZARD ZONE REPORT 032

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

**CALIFORNIA GEOLOGICAL SURVEY'S PUBLICATION SALES OFFICES:**

Southern California Regional Office  
888 South Figueroa Street, Suite 475  
Los Angeles, CA 90017  
(213) 239-0878

Publications and Information Office  
801 K Street, MS 14-31  
Sacramento, CA 95814-3531  
(916) 445-5716

Bay Area Regional Office  
345 Middlefield Road, MS 520  
Menlo Park, CA 94025  
(650) 688-6327





# CONTENTS

EXECUTIVE SUMMARY .....	viii
INTRODUCTION .....	1
SECTION 1 LIQUEFACTION EVALUATION REPORT Liquefaction Zones in the San Dimas 7.5-Minute Quadrangle, Los Angeles County, California .....	3
PURPOSE .....	3
BACKGROUND .....	4
METHODS SUMMARY .....	4
SCOPE AND LIMITATIONS .....	5
PART I .....	5
PHYSIOGRAPHY .....	5
GEOLOGY .....	6
ENGINEERING GEOLOGY .....	6
GROUND-WATER CONDITIONS .....	7
PART II .....	8
LIQUEFACTION POTENTIAL .....	8
LIQUEFACTION SUSCEPTIBILITY .....	9
LIQUEFACTION OPPORTUNITY .....	10
LIQUEFACTION ZONES .....	12
ACKNOWLEDGMENTS .....	13
REFERENCES .....	14

SECTION 2 EARTHQUAKE-INDUCED LANDSLIDE EVALUATION REPORT Earthquake-Induced Landslide Zones in the San Dimas 7.5-Minute Quadrangle, Los Angeles County, California .....	17
PURPOSE.....	17
BACKGROUND .....	18
METHODS SUMMARY.....	18
SCOPE AND LIMITATIONS.....	19
PART I.....	19
PHYSIOGRAPHY.....	19
GEOLOGY .....	20
ENGINEERING GEOLOGY .....	23
PART II.....	27
EARTHQUAKE-INDUCED LANDSLIDE HAZARD POTENTIAL.....	27
EARTHQUAKE-INDUCED LANDSLIDE HAZARD ZONE .....	30
ACKNOWLEDGMENTS .....	31
REFERENCES .....	32
AIR PHOTOS.....	34
APPENDIX A Source of Rock Strength Data.....	35
SECTION 3 GROUND SHAKING EVALUATION REPORT Potential Ground Shaking in the San Dimas 7.5-Minute Quadrangle, Los Angeles County, California.....	37
PURPOSE.....	37
EARTHQUAKE HAZARD MODEL .....	38
APPLICATIONS FOR LIQUEFACTION AND LANDSLIDE HAZARD ASSESSMENTS	42
USE AND LIMITATIONS.....	45
REFERENCES .....	46

# ILLUSTRATIONS

Figure 3.1. San Dimas 7.5-Minute Quadrangle and portions of adjacent quadrangles, 10% exceedance in 50 years peak ground acceleration (g)—Firm rock conditions. ....	39
Figure 3.2. San Dimas 7.5-Minute Quadrangle and portions of adjacent quadrangles, 10% exceedance in 50 years peak ground acceleration (g)—Soft rock conditions. ....	40
Figure 3.3. San Dimas 7.5-Minute Quadrangle and portions of adjacent quadrangles, 10% exceedance in 50 years peak ground acceleration (g)—Alluvium conditions.....	41
Figure 3.4. San Dimas 7.5-Minute Quadrangle and portions of adjacent quadrangles, 10% exceedance in 50 years peak ground acceleration—Predominant earthquake. ....	43
Figure 3.5. San Dimas 7.5-Minute Quadrangle and portions of adjacent quadrangles, 10% exceedance in 50 years magnitude-weighted pseudo-peak acceleration for alluvium - Liquefaction opportunity .....	44
Table 1.1. General Geotechnical Characteristics and Liquefaction Susceptibility of Quaternary Sedimentary Deposits in the San Dimas Quadrangle. ....	9
Table 2.1. Summary of the Shear Strength Statistics for the San Dimas Quadrangle. ....	25
Table 2.2. Summary of the Shear Strength Groups for the San Dimas Quadrangle.....	26
Table 2.3. Hazard Potential Matrix for Earthquake-Induced Landslides in the San Dimas Quadrangle.....	30
Plate 1.1. Quaternary Geologic Map of the San Dimas Quadrangle. ....	48
Plate 1.2. Historically Highest Ground Water Contours and Borehole Log Data Locations, San Dimas Quadrangle. ....	49
Plate 2.1. Landslide inventory, Shear Test Sample Locations, and Areas of Significant Grading, San Dimas Quadrangle. ....	50



## **EXECUTIVE SUMMARY**

This report summarizes the methods and sources of information used to prepare the Seismic Hazard Zone Map for the San Dimas 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 60 square miles at a scale of 1 inch = 2,000 feet. About two squares miles of San Bernardino County land in the southeastern corner of the map was not zoned.

Half of the San Dimas Quadrangle consists of heavily urbanized lowland areas in the eastern San Gabriel Valley and western Pomona Valley and the other half consists of the highland areas of the San Jose Hills and Puente Hills, which are separated by a narrow stream valley in which San Jose Creek flows toward the southwest. The quadrangle includes all or parts of the cities of Covina, Diamond Bar, Glendora, Industry, La Verne, Pomona, San Dimas, Walnut, and West Covina, as well as unincorporated areas of Los Angeles County. Major transportation routes include the San Bernardino Freeway (I-10), the Pomona Freeway (State Highway 60), the Foothill Freeway (I-210), the Orange Freeway (State Highway 57), State Highway 71 and State Highway 30.

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 San Dimas Quadrangle the liquefaction zone coincides with major drainage course floodplains, canyon bottoms, an area in San Dimas at the junction of the Foothill Freeway and State Route 30, and areas where the ground water is shallow at the eastern base of the San Jose Hills near the Los Angeles County Fairgrounds. The combination of dissected hills and weak rocks has produced widely distributed areas of landslides. These conditions contribute to an earthquake-induced landslide zone that covers about 11 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 San Dimas 7.5-minute Quadrangle.

# **SECTION 1**

## **LIQUEFACTION EVALUATION REPORT**

### **Liquefaction Zones in the San Dimas 7.5-Minute Quadrangle, Los Angeles County, California**

**By**  
**Ralph C. Loyd**

**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 San Dimas 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 San Dimas 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 San Dimas Quadrangle consist mainly of alluviated valleys, floodplains, and canyons. 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 San Dimas Quadrangle covers an area of about 62 square miles in eastern Los Angeles County. In addition, a one and one-half square-mile parcel of San Bernardino County, which in this study was not zoned for seismic hazards, occupies the southeast corner of the quadrangle. About half of the study area consists of densely populated lowland areas in eastern San Gabriel Valley and western Pomona Valley and about half consists of the highland areas of the San Jose Hills and Puente Hills, which are separated by a narrow stream valley in which San Jose Creek flows toward the southwest.

The quadrangle includes all or parts of the cities of Covina, Diamond Bar, Glendora, Industry, La Verne, Pomona, San Dimas, Walnut, and West Covina, as well as unincorporated areas of Los Angeles County. Major transportation routes traversing the San Dimas Quadrangle include the San Bernardino Freeway (I-10), the Pomona Freeway

(State Highway 60), the Foothill Freeway (I-210), the Orange Freeway (State Highway 57), State Highway 71 and State Highway 30.

The San Gabriel and Pomona valleys are sediment-filled, east-trending alluviated basins situated along the southern flank of the San Gabriel Mountains. The San Gabriel Mountains are a major component of the Transverse Ranges geomorphic province of California and are comprised largely of plutonic and metamorphic rocks. In the San Dimas Quadrangle, the southeaster boundary of San Gabriel Valley is defined by the San Jose Hills, which are comprised of Tertiary sedimentary and volcanic rocks.

## **GEOLOGY**

### **Surficial Geology**

Geologic units that generally are susceptible to liquefaction include late Quaternary alluvial and fluvial sedimentary deposits and artificial fill. Quaternary geologic units exposed in San Dimas Quadrangle were differentiated and mapped in detail by McCalpin (unpublished) and Tan (1997; 2000). Their map products, which were released in digital form, are based on stratigraphic, geomorphic, and pedologic criteria, namely relative stratigraphic position, environment of deposition, relative degree of erosion, soil type and development, as well as texture grain size). Map unit nomenclature applied in these geologic maps follow the format developed by the Southern California Areal Mapping Project (SCAMP: Morton and Kennedy, 1989) as presented on the explanation of Plate 1.1. Both maps were utilized in evaluating liquefaction susceptibility of Quaternary sedimentary deposits of the San Dimas Quadrangle.

The geologic map of the San Dimas Quadrangle (Plate 1.1) shows that northern and eastern margins of the study area are covered by valley alluvial sediments of Quaternary age. In the northern part of the quadrangle, these deposits consist of varying amounts of sand, gravel, and silt in layers that are incorporated within large, composite alluvial fans associated with Big Dalton, San Dimas, Live Oak, and Thompson washes. Along the eastern margin, similar sediments were deposited as part of the large San Antonio Wash alluvial fan. Floodplain sediments dominate the alluvial deposits exposed in the San Jose Creek valley. The general mineralogical composition of the Quaternary sediments deposited north and east of the San Jose and Puente hills reflects the Pre-Tertiary igneous and metamorphic bedrock units exposed in the San Gabriel Mountains to the north, whereas the alluvial sediments deposited within the San Jose Creek valley largely reflect Tertiary sedimentary and volcanic rocks exposed in the adjacent highland areas.

## **ENGINEERING GEOLOGY**

Information on subsurface geology and engineering characteristics of flatland deposits was obtained from borehole logs collected from reports on geotechnical and environmental projects. For this investigation, 67 borehole logs were collected from the files of the California Department of Transportation (CalTrans), the California Department of Water Resources, the Regional Water Quality Control Board, Los Angeles

County Flood Control files by U.S. Geological Survey staff, DMG files of seismic reports for hospital and school sites, and a database of shear wave velocity measurements originally compiled by Walter Silva (Wills and Silva, 1998). Locations and geotechnical data from 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 using data reported on the borehole logs enabled staff to relate soil-engineering properties to various depositional units, to correlate soil types from one borehole to another, and to extrapolate geotechnical data into outlying areas containing similar soils.

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 San Dimas 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 technical publications, geotechnical boreholes, and water-well logs dating back to the turn of the century, namely 1904 ground-water contour maps (Mendenhall, 1908), 1944 ground-water contour maps (California Department of Water Resources, 1966), and ground-water level measurements reported in compiled 1960-1997 geotechnical borehole 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.

Water-table elevations reported in Mendenhall (1908) show that shallow ground-water conditions once existed along the northeast margin of the San Jose Hills, (Los Angeles County Fairgrounds), along the eastern margin of the Puente Hills (southwestern Pomona), and within the San Jose Creek valley (Plate 1.2). Near-surface water conditions reported in the vicinity of the county fairgrounds appear to be, in part, caused by the San Jose Fault acting as a ground-water barrier (Plate 1.1). In addition, shallow water conditions that historically existed at the county fairgrounds and southwestern Pomona sites occur where the alluvial fans developed by the Live Oak, Thompson, and San Antonio washes locally reach their lowest elevations before lapping onto the San Jose Hills and Puente Hills. Shallow ground-water conditions along San Jose Creek are largely due to the fact that the creek flows in a shallow, alluviated stream valley.

Where records were examined, measured ground water is also shallow in restricted drainages within the Puente Hills and San Jose Hills. In general, it appears that relatively shallow and impermeable bedrock underlying the stream canyon sediments results in a shallow water table. These sediments can also remain saturated for long periods of time during wet seasons.

## **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 susceptible soil inventory is summarized on Table 1.1.

Map Unit	Age	Environment of Deposition	Primary Textures	General Consistency	Susceptible to Liquefaction?*
Qw	latest Holocene	active stream channels	sand, gravel, cobbles	Very loose to loose	yes
Qf	latest Holocene	active alluvial fan deposits	sand, silt gravel	Very loose to loose	yes
Qa	latest Holocene	active alluvial basin deposits	sand, silt, clay	Very loose to loose	yes
Qyf1-4	Holocene to latest Pleistocene	younger alluvial fan deposits	gravel, sand, silt	Loose to Moderately dense	yes
Qya1-4	Holocene to latest Pleistocene	younger alluvial basin deposits	sand, silt, clay	Loose to Moderately dense	yes
Qof	late Pleistocene	older alluvial fan deposits	sand, gravel, silt, clay	Dense to Very dense	not likely
Qoa	late Pleistocene	older alluvial basin deposits	sand, silt, clay	Dense to Very dense	not likely
Qvoa	Pleistocene	very old alluvial basin deposits	gravel, sand, silt, clay	Dense to Very dense	not likely

**Table 1.1. General Geotechnical Characteristics and Liquefaction Susceptibility of Quaternary Sedimentary Deposits in the San Dimas Quadrangle.**

### 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 San Dimas Quadrangle, PGAs of 0.47 g to 0.56 g, resulting from earthquakes ranging in magnitude from 6.8 to 7.0, 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 67 geotechnical borehole logs reviewed in this study (Plate 1.2), 50 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.

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

susceptibility. To identify potentially liquefiable units where the N values appear to have been affected by gravel content, correlations were made with boreholes in the same unit where the N values do not appear to have been affected by gravel content.

## LIQUEFACTION ZONES

### Criteria for Zoning

Areas underlain by materials susceptible to liquefaction during an earthquake were included in liquefaction zones using criteria developed by the Seismic Hazards Mapping Act Advisory Committee and adopted by the 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 San Dimas Quadrangle is summarized below.

### **Areas of Past Liquefaction**

No areas of documented historic liquefaction in the San Dimas Quadrangle are known. Areas showing evidence of paleoseismic liquefaction have not been reported.

### **Artificial Fills**

Artificial fill sites in the San Dimas Quadrangle include flood-control basin dams and river levees. Although these fills were certainly properly engineered, seismic hazard zoning for liquefaction at these localities is governed by the liquefaction susceptibility of natural soils underlying the fill sites.

### **Areas with Sufficient Existing Geotechnical Data**

Sufficient geologic and geotechnical data exist for DMG to adequately evaluate liquefaction potential of alluvial sediments throughout most the San Dimas Quadrangle. DMG's liquefaction susceptible soil inventory and quantitative analyses of geotechnical data in the San Dimas Quadrangle indicate that all Holocene and modern soils saturated within 40 feet of the ground surface are potentially liquefiable. These conditions are present within the San Jose Creek stream valley, continuing around to the northeast end of the San Jose Hills. Accordingly, DMG delineates this area as a zone of required investigation.

### **Areas with Insufficient Existing Geotechnical Data**

Some stream drainage and alluviated low land areas within the San Jose Hills are zoned on the basis of SMGB criteria for areas where geotechnical data are lacking or insufficient. Most of these areas were placed within zones of required investigations because such soils generally reflect conditions named in criteria item 4a.

## **ACKNOWLEDGMENTS**

The author would like to thank the staff at the California Department of Transportation (Caltrans), the Southern District office of the California Department of Water Resources, and the Los Angeles Regional Water Quality Control Board for their assistance in the collection of subsurface borehole data. We thank James P. McCalpin for sharing his modern Quaternary mapping of the quadrangle and John Tinsley, U. S. Geological Survey, for facilitating access to digital copies of McCalpin's maps. Special thanks to Bob Moskovitz, Teri McGuire, and Scott Shepherd of DMG for their GIS operations support and to Barbara Wanish for graphic layout and reproduction of seismic hazard zone maps.

## REFERENCES

- American Society for Testing and Materials, 1999, Standard test method for penetration test and split-barrel sampling of soils, Test Method D1586-99, *in* Annual Book of ASTM Standards, v. 4.08.
- Budiman, J.S. and Mohammadi, Jamshid, 1995, Effect of large inclusions on liquefaction of sands, *in* Evans, M.D. and Fragaszy, R.J., *editors*, Static and Dynamic properties of Gravelly Soils: American Society of Civil Engineers Geotechnical Special Publication no. 56, p. 48-63.
- California Department of Conservation, Division of Mines and Geology, 1997, Guidelines for evaluating and mitigating seismic hazards in California, Special Publication 117, 74 p.
- California Department of Conservation, Division of Mines and Geology, 2000, Recommended criteria for delineating seismic hazard zones in California, Special Publication 118, 12 p.
- California Department of Water Resources, 1966, Planned utilization of ground water basins, San Gabriel Valley, Appendix A: Geohydrology: Bulletin No. 104-2, 229 p., map scale 1:125,000.
- Cramer, C.H. and Petersen, M.D., 1996, Predominant seismic source distance and magnitude maps for Los Angeles, Orange, and Ventura counties, California: Bulletin of Seismological Society of America, v. 86, no. 5, p. 1,645-1,649.
- Evans, M.D. and Zhou, Shengping, 1995, Liquefaction behaviour of sand-gravel composites: American Society of Civil Engineers, Journal of Geotechnical Engineering, v. 121, no. 3, p. 287-298.
- Harder, L.F. and Seed, H.B., 1986, Determination of penetration resistance for coarse-grained soils using the Becker hammer drill: University of California at Berkeley, College of Engineering, Earthquake Engineering Research Center, report no. UCB/EERC-86/06, 126 p.
- Ishihara, Kenji, 1985, Stability of natural deposits during earthquakes, *in* Proceedings of the Eleventh International Conference on Soil Mechanics and Foundation Engineering, San Francisco, v. 1, p. 321-376.
- McCalpin, J.P., unpublished, Digital geologic map of the San Dimas 7.5-minute Quadrangle, Los Angeles County, California: contracted for the Southern California Areal Mapping Project (SCAMP), resolution 1:24000.
- Mendenhall, W.C., 1908, Ground waters and irrigation enterprises in the foothill belt, southern California: United States Geological Survey Water-Supply Paper 219, 180 p., 9 plates, map scale 1: 62500.

- Morton, D.M. and Kennedy, M.P., 1989, A southern California digital 1:100,000-scale geologic map series: The Santa Ana Quadrangle, The first release: Geological Society of America Abstracts with Programs v. 21, no. 6, p. A107-A108.
- National Research Council, 1985, Liquefaction of soils during earthquakes: National Research Council Special Publication, Committee on Earthquake Engineering, National Academy Press, Washington, D.C., 240 p.
- Petersen, M.D., Bryant, W.A., Cramer, C.H., Cao, Tianqing, Reichle, M.S., Frankel, A.D., Lienkaemper, J.J., McCrory, P.A. and Schwartz, D.P., 1996, Probabilistic seismic hazard assessment for the State of California: California Department of Conservation, Division of Mines and Geology, Open File Report 96-08; U.S. Geological Survey Open File Report 96-706, 33 p.
- Seed, H.B. and Idriss, I.M., 1971, Simplified procedure for evaluating soil liquefaction potential: Journal of the Soil Mechanics and Foundations Division of ASCE, v. 97: SM9, p. 1,249-1,273.
- Seed, H.B. and Idriss, I.M., 1982, Ground motions and soil liquefaction during earthquakes: Monograph Series, Earthquake Engineering Research Institute, Berkeley, California, 134 p.
- Seed, H.B., Idriss, I.M. and Arango, Ignacio, 1983, Evaluation of liquefaction potential using field performance data: Journal of Geotechnical Engineering, v. 109, no. 3, p. 458-482.
- Seed, H.B., Tokimatsu, Kohji, Harder, L.F., and Chung, R.M., 1985, Influence of SPT procedures in soil liquefaction resistance evaluations: Journal of Geotechnical Engineering, ASCE, v. 111, no. 12, p. 1,425-1,445.
- Seed, R.B. and Harder, L.F., 1990, SPT-based analysis of cyclic pore pressure generation and undrained residual strength: Proceedings of the H. Bolton Seed Memorial Symposium, v. 2, p. 351-376.
- Smith, T.C., 1996, Preliminary maps of seismic hazard zones and draft guidelines for evaluating and mitigating seismic hazards: California Geology, v. 49, no. 6, p. 147-150.
- Sy, Alex, Campanella, R.G. and Stewart, R.A., 1995, BPT-SPT correlations for evaluations of liquefaction resistance in gravelly soils, *in* Evans, M.D. and Frigaszy, R.J., *editors*, Static and Dynamic Properties of Gravelly Soils: American Society of Civil Engineers Geotechnical Special Publication no. 56, p. 1-19.
- Tan, S.S., 1997 *in preparation*, Geologic map of the San Dimas 7.5-minute Quadrangle, Los Angeles County, California: Division of Mines and Geology Southern California Areal Mapping Project, digital map, scale 1:24,000.

- Tan, S.S., 2000, Digital geologic map of the San Dimas 7.5' Quadrangle, Los Angeles County, California: Division of Mines and Geology Open-File Report 98-31, scale 1:24,000.
- Tinsley, J.C. and Fumal, T.E., 1985, Mapping Quaternary sedimentary deposits for areal variations in shaking response, *in* Ziony, J.I., *editor*, Evaluating earthquake hazards in the Los Angeles Region -- An earth-science perspective: U.S. Geological Survey Professional Paper 1360, p. 101 -125.
- Tinsley, J.C., Youd, T.L., Perkins, D.M. and Chen, A.T.F., 1985, Evaluating liquefaction potential, *in* Ziony, J.I., *editor*, Evaluating earthquake hazards in the Los Angeles region — An earth science perspective: U.S. Geological Survey Professional Paper 1360, p. 263-316.
- Wills, C.J. and Silva, Walter, 1998, Shear wave velocity characteristics of geologic units in California: Earthquake Spectra, v. 14, p. 533-556.
- Youd, T.L., 1973, Liquefaction, flow and associated ground failure: U.S. Geological Survey Circular 688, 12 p.
- Youd, T.L., 1991, Mapping of earthquake-induced liquefaction for seismic zonation: Earthquake Engineering Research Institute, Proceedings, Fourth International Conference on Seismic Zonation, v. 1, p. 111-138.
- Youd, T.L. and Idriss, I.M., 1997, *editors*, Proceedings of the NCEER workshop on evaluation of liquefaction resistance of soils: National Center for Earthquake Engineering Research Technical Report NCEER-97-0022, 276 p.
- Youd, T.L. and Perkins, D.M., 1978, Mapping liquefaction-induced ground failure potential: Journal of Geotechnical Engineering, v. 104, p. 433-446.

## **SECTION 2 EARTHQUAKE-INDUCED LANDSLIDE EVALUATION REPORT**

### **Earthquake-Induced Landslide Zones in the San Dimas 7.5-Minute Quadrangle, Los Angeles County, California**

**By  
Florante G. Perez, Timothy P. McCrink, Siang S. Tan, and Rick I.  
Wilson**

**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 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 San Dimas 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 San Dimas 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 San Dimas 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 San Dimas Quadrangle. The information is presented in two parts. Part I covers physiographic, geologic and engineering geologic conditions in the study area. Part II covers the preparation of landslide hazard potential and landslide zone maps.

## **PART I**

### **PHYSIOGRAPHY**

#### **Study Area Location and Physiography**

The San Dimas Quadrangle covers an area of about 62 square miles in eastern Los Angeles County. In addition, a one and one-half square-mile parcel of San Bernardino County, which in this study is not zoned for seismic hazards, occupies the southeast corner of the quadrangle. About half of the study area consists of densely populated lowland areas in eastern San Gabriel Valley and western Pomona Valley and about half

consists of the highland areas of the San Jose Hills and Puente Hills, which are separated by a narrow stream valley in which San Jose Creek flows toward the southwest.

The quadrangle includes all or parts of the cities of Covina, Diamond Bar, Glendora, Industry, La Verne, Pomona, San Dimas, Walnut, and West Covina, as well as unincorporated areas of Los Angeles County. Major transportation routes traversing the San Dimas Quadrangle include the San Bernardino Freeway (I-10), the Pomona Freeway (State Highway 60), the Foothill Freeway (I-210), the Orange Freeway (State Highway 57), State Highway 71 and State Highway 30.

The San Gabriel and Pomona valleys are sediment-filled, east-trending alluviated basins situated along the southern flank of the San Gabriel Mountains. The San Gabriel Mountains are a major component of the Transverse Ranges geomorphic province of California and are comprised largely of plutonic and metamorphic rocks. In the San Dimas Quadrangle, the southeastern boundary of San Gabriel Valley is defined by the San Jose Hills, which are comprised of Tertiary sedimentary and volcanic rocks.

### **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 San Dimas 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 1964 aerial photography, has a 10-meter horizontal resolution and a 7.5-meter vertical accuracy.

To update the topographic base map, areas that have undergone large-scale grading as a part of residential development in the hilly portions of the San Dimas Quadrangle were identified (see Plate 2.1). Using 1:40,000-scale NAPP photography taken in May 1994, and October 1995, photogrammetric DEMs covering the graded areas were prepared by the U.S. Bureau of Reclamation with ground control obtained by DMG (USGS 1994; 1995 a; 1994 b). The photogrammetric DEMs were then merged into the USGS DEM, replacing the areas of out-dated elevation data.

A slope map was made from the combined DEMs 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**

For the San Dimas Quadrangle, a geologic map was compiled and digitized by the Southern California Mapping Project (SCAMP: Morton and Kennedy, 1989) from original mapping by Tan (1997; 2000). The digital geologic map obtained from SCAMP

was modified to reflect the most recent mapping in the area. 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.

Basement rocks of Mesozoic age are exposed in only three locations within the San Dimas Quadrangle and are collectively mapped as granitic batholith rock (Kqd). Southwest of Pomona, these rocks are composed of coarse-grained biotite granodiorite and biotite-quartz diorite with associated pegmatites and aplite dikes. The prevailing rock northwest of Pomona is pinkish gneissoid granite and granodiorite with associated dikes and basic inclusions (Shelton, 1955). The exposure on the northeast corner of the quadrangle near La Verne is chiefly biotite quartz diorite and granodiorite.

The basement rocks are intruded and overlain by biotite dacite porphyry, known locally as Mountain Meadows Dacite (Tmd) of probable early Cretaceous to pre-middle Miocene age. It crops out at Mountain Meadows Country Club near the eastern end of San Jose Hills and consists of phenocrysts of biotite and oligoclase and quartz grains in a fine-grained groundmass (Olmsted, 1950).

A series of flows, breccias, tuffs, and related intrusives known as the Glendora Volcanics crops out from north to south in the Glendora South Hills, in the northeastern end of San Jose Hills, and in the northeasternmost end of the Puente Hills. The middle Miocene Glendora Volcanics (Tg) are subdivided according to dominant rock type: dacite and rhyolite (Tgr), dacite and rhyolite breccia (Tgrb), andesitic flows (Tga), tuff breccia/Johnstone Peak (Tgj), basaltic flows (Tgb), palagonitic tuff and pillow lava (Tgbt), and volcanic conglomerate (Tgc). These volcanic rocks are overlain by and interbedded with the oldest sedimentary rocks in the area, the middle Miocene Topanga Formation (Tt). It consists of interbedded marine conglomerate, sandstone, and foraminiferal siltstone. Exposed in the central part of San Jose Hills is a poorly sorted conglomerate and conglomeratic sandstone, which is locally called "Buzzard Peak conglomerate" (Ttc)(Woodford, 1946), that forms an asymmetrical anticline. North of this area and in Glendora South Hills, the Topanga Formation rocks consist predominantly of massive to bedded sandstone with lenses of conglomerate.

Extensively exposed in the southern and central portions of the quadrangle is the middle-upper Miocene Puente Formation consisting of a very thick sequence of marine sandstone, siltstone, shale, and pebble conglomerate. The Puente Formation unconformably overlies the Topanga Formation and is subdivided into four members. The lowest member, the La Vida Member (Tpl), consists of laminated to platy siltstone with interbedded pebbly sandstone (Tplc) and local limestone and tuff beds. The La Vida Member grades upwards into the Soquel Member (Tpsq), which consists of massive to, locally, thick-bedded sandstone with interbedded clayey siltstone and pebble-cobble conglomerate (Tpsqc). The Yorba Member (Tpy) has a gradational contact with the Soquel Member and is made up of interbedded sandy and diatomaceous siltstone containing thin beds of limestone and thin-bedded to massive sandstone. The uppermost member, the Sycamore Canyon Member (Tpsc), consists of interlayered micaceous siltstone and coarse-grained sandstone with interbedded conglomerate (Tpssc).

Quaternary deposits cover the floor and margins of the San Gabriel and Pomona valleys, including stream channels and alluvial fans and flood plains. They are composed of active channel wash (Qwa), lacustrine deposits (Ql), younger alluvial fan deposits (Qyfc, Qyfa, Qyfs, Qyfag, Qyfcs, Qyfsg), and older alluvial fan deposits (Qofc, Qofs). Landslides (Qls, Qls?) are widespread in the southern portion of the quadrangle. A more detailed discussion of the Quaternary deposits in the San Dimas Quadrangle can be found in Section 1.

### **Structural Geology**

Folds are the dominant structural features of the San Jose Hills, two anticlines and an intervening syncline that all trend generally eastward. The eastern part of the San Jose anticline is strongly asymmetrical. The south limb is steeper and cut abruptly by a steep fault where the south block has dropped (Olmsted, 1950). The Amar syncline is also asymmetrical with a steep north limb and a gentler south limb. The Little Puente Hills anticline is characterized by a broad nose that plunges eastward. It is symmetrical throughout most of its extent but is overturned southward at the eastern end of the Little Puente Hills.

The San Jose Fault transects the central portion of the quadrangle and is manifested by the abrupt drop in the south limb of the San Jose anticline and by the steepening of dips and local overturning near the fault zone. The fault generally strikes to the north-northeast and probably has a vertical dip with the south block being dropped down (Olmsted, 1950).

### **Landslide Inventory**

The evaluation of earthquake-induced landsliding requires an up-to-date and complete analysis of previously mapped landslides. DMG geologists compiled the existing landslides in the San Dimas Quadrangle from published landslide hazard maps by Tan (1988; 1997; 2000). Then by combining analysis of aerial photos and interpretation of landforms with field observations, all landslides compiled on the map were verified, re-mapped, or deleted during the preparation of the landslide inventory map. 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.

The most landslide-prone bedrock units in the quadrangle are the Yorba and La Vida members of the Puente Formation. The most stable are the Glendora Volcanics and the Soquel Member of the Puente Formation. Most of the landslides inventoried are debris slides, block slides, and slumps.

## 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 San Dimas Quadrangle geologic map were obtained from geotechnical reports prepared by consultants. The reports were obtained from the files of the local government permitting departments, from the Corporate Library of Leighton and Associates, Inc., the City of Walnut, and the Los Angeles County Department of Public Works (see Appendix A). The locations of rock and soil samples taken for shear testing are shown on Plate 2.1.

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. Geologic formations that had little or no shear test information were added to existing groups on the basis of lithologic and stratigraphic similarities. No data are available for the granitic batholith rocks (Kqd), although outcrops of this unit are moderately weathered, highly jointed, and disintegrate easily, it is included in Group 1 by virtue of the shear tests gathered from similar rocks in adjacent quadrangles. 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.

### Adverse Bedding Conditions

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

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

The formations, which contain interbedded sandstone and shale, were subdivided based on shear strength differences between coarse-grained (crse in Table 2.1; higher strength) and fine-grained (fine in Table 2.1; lower strength) lithologies. Shear strength values for the fine- and coarse-grained lithologies were then applied to areas of favorable and adverse bedding orientation, which were determined from structural and terrain data as discussed above. It was assumed that coarse-grained material (higher strength) dominates where bedding dips into a slope (favorable bedding) while fine-grained (lower strength) material dominates where bedding dips out of a slope (adverse bedding). The geologic material strength map was modified by assigning the lower, fine-grained shear strength values to areas where potential adverse bedding conditions were identified. The favorable and adverse bedding shear strength parameters for the formations are included in Table 2.1.

The results of the grouping of geologic materials in the San Dimas Quadrangle are in Tables 2.1 and 2.2.

**SAN DIMAS QUADRANGLE  
SHEAR STRENGTH GROUPS STATISTICS**

	Formation Name	Number of Tests	Mean Phi Value	Group Phi Mean/Median (degrees)	Group C Mean/Median (psf)	No Data Similar Lithology	Phi Values in
<b>Group 1</b>	Tpsq Tps(crse)	26	36.6	36.6/35.5	354/312	Tpsq, Tpsc, Tpscc Ttc, Tg, Tgr, Kqd Tgrb, Tga, Tgj Tgbt, Tgc, Tmd	36
<b>Group 2</b>	Tpy (crse) Qof/Qyf	7 50	33.7 32.3	32.5/32.5	259/200	Tpsc, Tt, Tgb Qwa, Qyfc, Qyfa Qyfs, Qyfag, Qyfc Qyfs, Qyfc, Qofs	32
<b>Group 3</b>	Tps-Tp(fine) Tpl (crse)	9 3	30.9 29.3	30.5/30.2	507/400		30
<b>Group 4</b>	Tpl (fine) Tpy (fine)	16 10	27.4 26.0	26.8/27.7	758/750		26
<b>Group 5</b>	Qls					QlsD, QlsP	14

**Table 2.1. Summary of the Shear Strength Statistics for the San Dimas Quadrangle.**

<b>SAN DIMAS QUADRANGLE SHEAR STRENGTH GROUPS</b>				
<b>Group 1</b>	<b>Group 2</b>	<b>Group 3</b>	<b>Group 4</b>	<b>Group 5</b>
Tpsq-Tps (crse)	Tpy (crse)	Tpsq-Tps (fine)	Tpl (fine)	Qls <i>D</i>
Tpsqc- Tpsc	Tpsc	Tpl (crse)	Tpy (fine)	Qls <i>P</i>
Tpscc	Tt			
Ttc	Tgb			
Tgr	Qwa			
Tgrb	Qyfc			
Tga	Qyfa			
Tgj	Qyfs			
Tgbt	Qyfag			
Tgc	Qyfcs			
Tmd	Qyfsg			
Tg	Qofc			
Kqd	Qofs			

**Table 2.2. Summary of the Shear Strength Groups for the San Dimas Quadrangle.**

### **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.

## 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 San Dimas 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:	6.8 to 7.0
Modal Distance:	2.5 to 17.4 km
PGA:	0.49 to 0.74 g

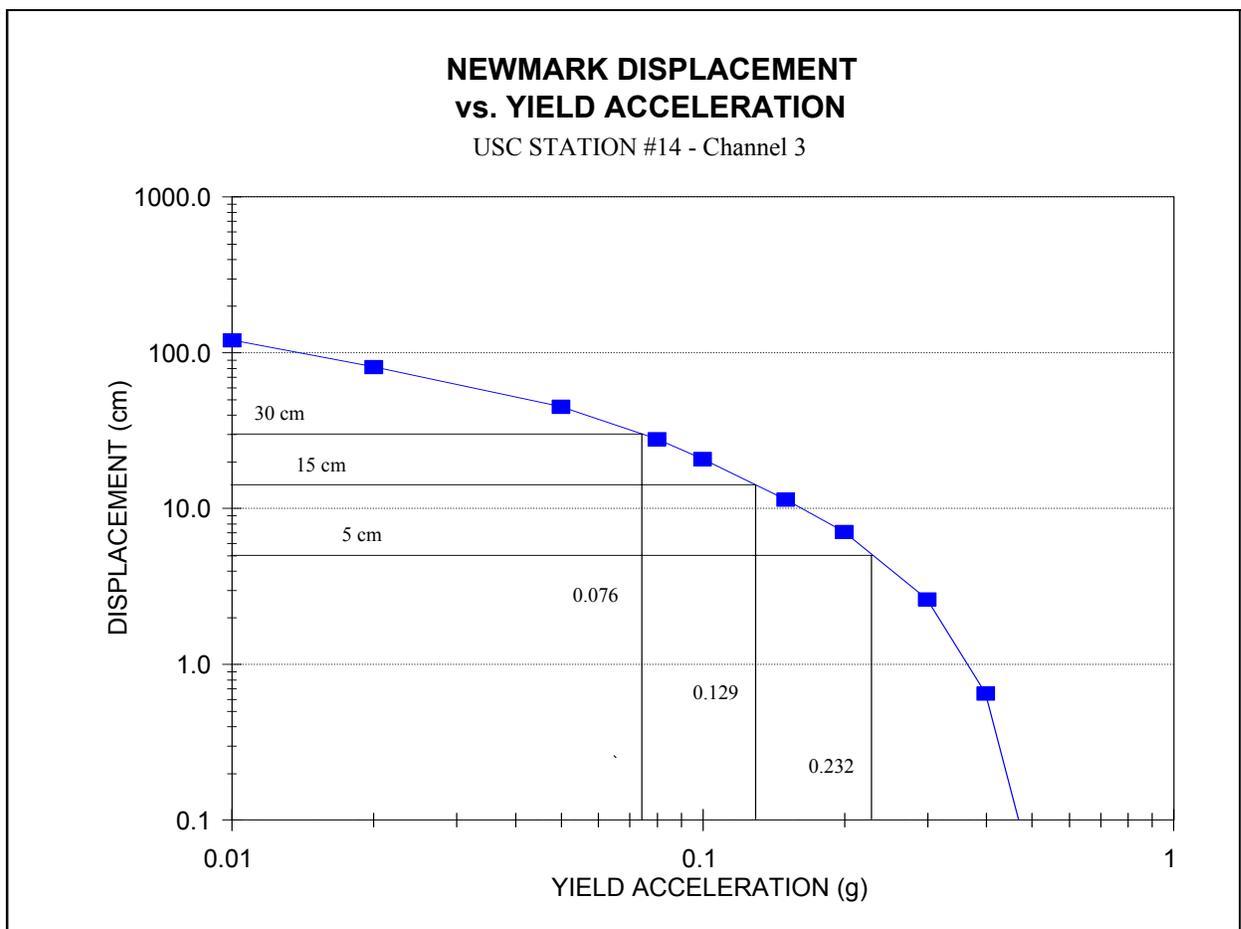
The strong-motion record selected for the slope stability analysis in the San Dimas Quadrangle was the Channel 3 (north 35 degrees east horizontal component) University of Southern California Station #14 recording from the magnitude 6.7 Northridge earthquake (Trifunac and others, 1994). This record had a source to recording site distance of 8.5 km and a peak ground acceleration (PGA) of 0.59 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 San Dimas 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  $\alpha$  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  $\alpha$  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.

San Dimas Quadrangle Hazard Potential Matrix									
Slope Category									
Geologic	I	II	III	IV	V	VI	VII	VIII	
Material	0 to 11	12 to 24	25 to 33	34 to 38	39 to 48	49 to 59	60 to 64	>65	Percent
Group	0 to 6	7 to 13	14 to 18	19 to 21	22 to 26	27 to 30	31 to 33	>34	Degrees
Group 1	VL	VL	VL	VL	VL	L	M	H	
Group 2	VL	VL	VL	VL	L	H	H	H	
Group 3	VL	VL	VL	L	M	H	H	H	
Group 4	VL	VL	L	M	H	H	H	H	
Group 5	L	H	H	H	H	H	H	H	

**Table 2.3. Hazard Potential Matrix for Earthquake-Induced Landslides in the San Dimas 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 5 is included for all slope gradient categories. (Note: Geologic Strength Group 5 includes all mappable landslides with a definite or probable confidence rating).
2. Geologic Strength Group 4 is included for all slopes steeper than 24 percent.
3. Geologic Strength Group 3 is included for all slopes steeper than 33 percent.
4. Geologic Strength Group 2 is included for all slopes steeper than 38 percent.
5. Geologic Strength Group 1 is included for all slopes greater than 48 percent.

This results in approximately 11 percent of the quadrangle lying within the earthquake-induced landslide hazard zone for the San Dimas Quadrangle.

## **ACKNOWLEDGMENTS**

The authors thank Kathryn Davanaugh of Leighton and Associates, Inc. Corporate Library, Robert Larson and Mario Ramirez of the Los Angeles County Department of Public Works Material Engineering Division, and Carleen Price of the City of Walnut for

their assistance in obtaining geologic material strength data used in the preparation of this report. Patricia V. Kennedy assisted in the collection of geotechnical data. Digital terrain data were provided by Randy Jibson of the U.S. Geological Survey, and Monte Lorenz and George Knight of the U.S. Bureau of Reclamation. 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 Scott Shepherd, Teri McGuire, and Bob Moskovitz for their Geographic Information System operations support, Barbara Wanish for designing and plotting the graphic displays associated with the hazard zone map and this report, Lisa Chisholm for preparing the landslide attribute tables, and Jacob Summerhayes for the data entry of geotechnical data into the Paradox database.

### REFERENCES

- Brabb, E.E., 1983, Map showing direction and amount of bedding dip of sedimentary rocks in San Mateo County, California: U.S. Geological Survey Miscellaneous Investigations Series Map I-1257C, 1 sheet, scale 1:62,500.
- California Department of Conservation, Division of Mines and Geology, 1997, Guidelines for evaluating and mitigating seismic hazards in California: California Department of Conservation, Division of Mines and Geology, Special Publication 117, 74 p.
- California Department of Conservation, Division of Mines and Geology, 2000, Recommended criteria for delineating seismic hazard zones: California Department of Conservation, Division of Mines and Geology, Special Publication 118, 12 p.
- Horn, B.K.P., 1981, Hill shading and the reflectance map: Proceedings of the IEEE, v. 69, no. 1, p. 14-47.
- Jibson, R.W., 1993, Predicting earthquake-induced landslide displacements using Newmark's sliding block analysis: Transportation Research Board, National Research Council, Transportation Research Record 1411, 17 p.
- Keefer, D.K., 1984, Landslides caused by earthquakes: Geological Society of America Bulletin, v. 95, no. 4, p. 406-421.
- McCrink, T.P. and Real, C.R., 1996, Evaluation of the Newmark method for mapping earthquake-induced landslide hazards in the Laurel 7-1/2 minute Quadrangle, Santa Cruz County, California: California Division of Mines and Geology Final Technical Report for U.S. Geological Survey Contract 143-93-G-2334, U.S. Geological Survey, Reston, Virginia, 31 p.

- Morton, D.M. and Kennedy, M.P., 1989, A southern California digital 1:100,000-scale geologic map series: The Santa Ana Quadrangle, The first release: Geological Society of America Abstracts with Programs v. 21, no. 6, p. A107-A108.
- Newmark, N.M., 1965, Effects of earthquakes on dams and embankments: *Geotechnique*, v. 15, no. 2, p. 139-160.
- Olmsted, F. H., 1950, Geology and oil prospects of western San Jose Hills, Los Angeles county, California: California Division of Mines, *California Journal of Mines and Geology*, v. 46, no. 2, p. 191-212, plate 23, 1:24,000.
- Petersen, M.D., Bryant, W.A., Cramer, C.H., Cao. T., Reichle, M.S., Frankel, A.D., Lienkaemper, J.J., McCrory, P.A. and Schwartz, D.P., 1996, Probabilistic seismic hazard assessment for the State of California: California Department of Conservation, Division of Mines and Geology, Open File Report 96-08; U.S. Geological Survey Open File Report 96-706, 33 p.
- Shelton, J. S., 1955, Glendora volcanic rocks, Los Angeles basin, California: *Geological Society of America Bulletin*, v. 66, no. 1, p. 45-90, plate 1, 1:24,000.
- Smith, T.C., 1996, Preliminary maps of seismic hazard zones and draft guidelines for evaluating and mitigating seismic hazards: *California Geology*, v. 49, no. 6, p. 147-150.
- Tan, S.S., 1988, Landslide hazards in the Puente and San Jose hills, southern California: California Department of Conservation, Division of Mines and Geology, Open-File Report 88-21, 6 plates, 1:24,000.
- Tan, S.S., 1997 *in preparation*, Geologic map of the San Dimas 7.5- minute Quadrangle, Los Angeles County, California: California Department of Conservation, Division of Mines and Geology Southern California Areal Mapping Project, digital map, 1:24,000.
- Tan, S.S., 2000, Digital geologic map of the San Dimas 7.5' Quadrangle, Los Angeles County, California: Division of Mines and Geology Open-File Report 98-31, scale 1:24,000.
- Trifunac, M.D., Todorovska, M.I. and Ivanovic, S.S., 1994, A note on distribution of uncorrected peak ground accelerations during the Northridge, California earthquake of 17 January 1994: *Soil Dynamic and Earthquake Engineering*, v. 13, no. 3, p. 187-196.
- U.S. Geological Survey, 1993, Digital Elevation Models: National Mapping Program, Technical Instructions, Data Users Guide 5, 48 p.
- Varnes, D. J., 1978, Slope movement types and processes: *Landslide Analysis and Control*, Transportation Research Board, National Research Council, Special Report 176, p. 11-33.

- Wilson, R.C. and Keefer, D.K., 1983, Dynamic analysis of a slope failure from the 1979 Coyote Lake, California, earthquake: Bulletin of the Seismological Society of America, v. 73, p. 863-877.
- Woodford, A.O., 1946, Miocene conglomerates of Puente and San Jose hills, California: American Association of Petroleum Geologists Bulletin, v. 30, p. 514-560.
- Yerkes, R.F., 1955, Preliminary geologic map of southern part of the San Dimas 7.5-minute quadrangle, Los Angeles: U. S. Geological Surveys, unpublished field map, 1:24,000.
- Yerkes, R.F., McCulloh, T.H., Schoellhamer, J.E. and Vedder, J.G., 1965, Geology of the Los Angeles basin, California - An introduction: Geological Survey Professional Paper 420-A, 57 p.
- Youd, T.L., 1980, Ground failure displacement and earthquake damage to buildings: American Society of Civil Engineers Conference on Civil Engineering and Nuclear Power, 2d, Knoxville, Tennessee, 1980, v. 2, p. 7-6-2 to 7-6-26.

#### **AIR PHOTOS**

- USGS Project GS-VEZS, I.K. Curtis Services, Inc. 1980 Aerial Photographs, flight 1, frames 58-64, 108-114, and 229-235, flight 2, frames 22-29, black & white, vertical, approximate scale 1:24,000.
- USGS (U.S. Geological Survey), 1994, NAPP Aerial Photography, Flight 6862, June 1, 1994, Frames 17 to 21, black and white, vertical; scale 1:40,000.
- USGS (U.S. Geological Survey), 1995a, NAPP Aerial Photography, Flight 6875, October 3, 1995, Frames 72 to 75, black and white, vertical; scale 1:40,000.
- USGS (U.S. Geological Survey), 1995b, NAPP Aerial Photography, Flight 6877, October 7, 1995, Frames 57, black and white, vertical; scale 1:40,000.

**APPENDIX A  
SOURCE OF ROCK STRENGTH DATA**

<b>SOURCE</b>	<b>NUMBER OF TESTS SELECTED</b>
<b>Leighton and Associates, Corporate Library</b>	<b>109</b>
<b>City of Walnut</b>	<b>59</b>
<b>Los Angeles County Department of Public Works, Materials Engineering Division</b>	<b>55</b>
<b>Total Number of Shear Tests</b>	<b>223</b>



## **SECTION 3**

# **GROUND SHAKING EVALUATION REPORT**

### **Potential Ground Shaking in the San Dimas 7.5-Minute Quadrangle, Los Angeles County, 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.

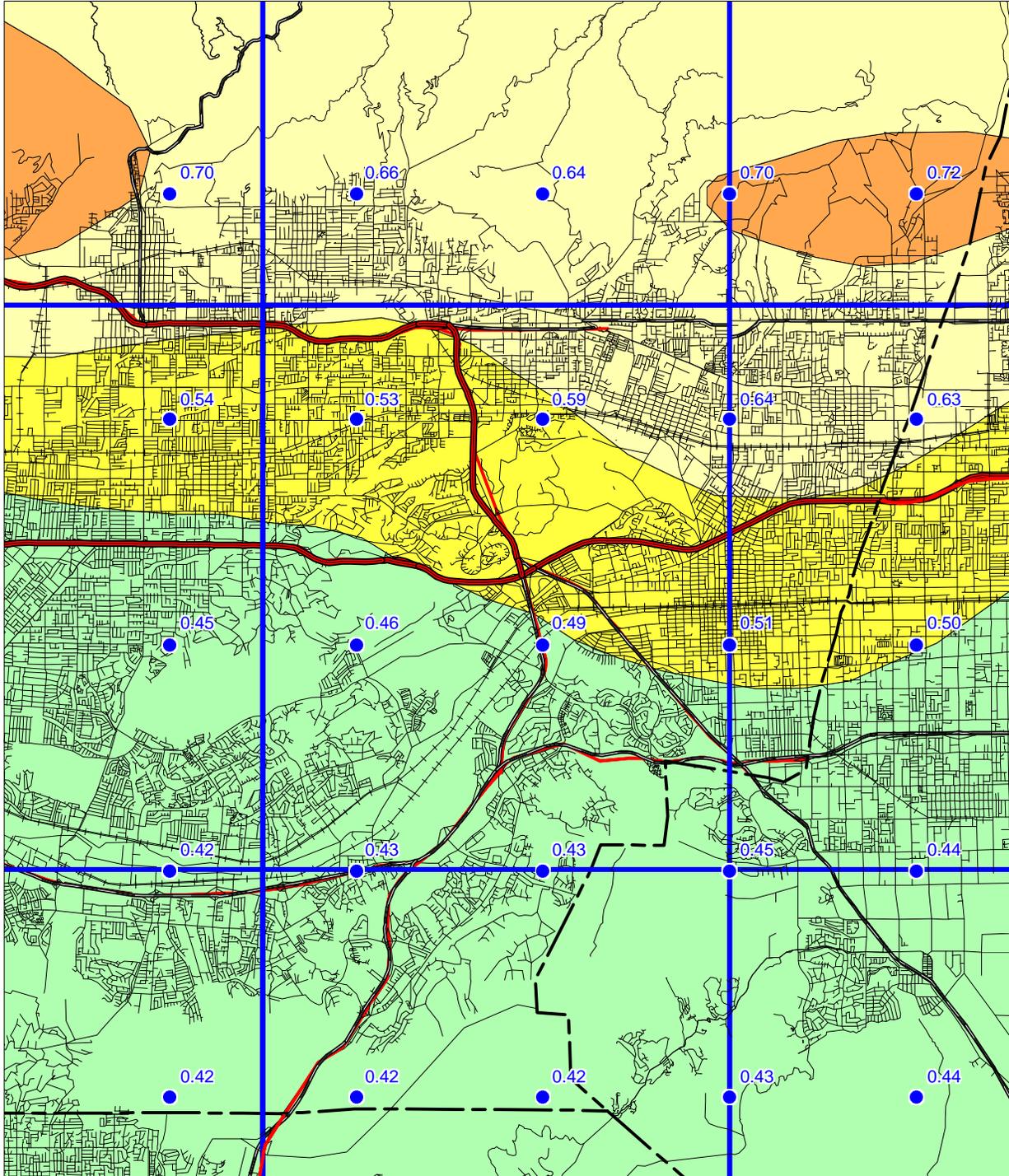
The seismic hazard maps for ground shaking are produced by calculating the hazard at sites separated by about 5 km. Figures 3.1 through 3.3 show the hazard for PGA at 10% probability of exceedance in 50 years assuming the entire map area is firm rock, soft rock, or alluvial site conditions respectively.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

# SAN DIMAS 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

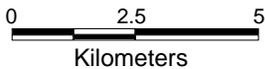
10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

FIRM ROCK CONDITIONS



Base map modified from MapInfo StreetWorks ©1998 MapInfo Corporation



Department of Conservation  
Division of Mines and Geology



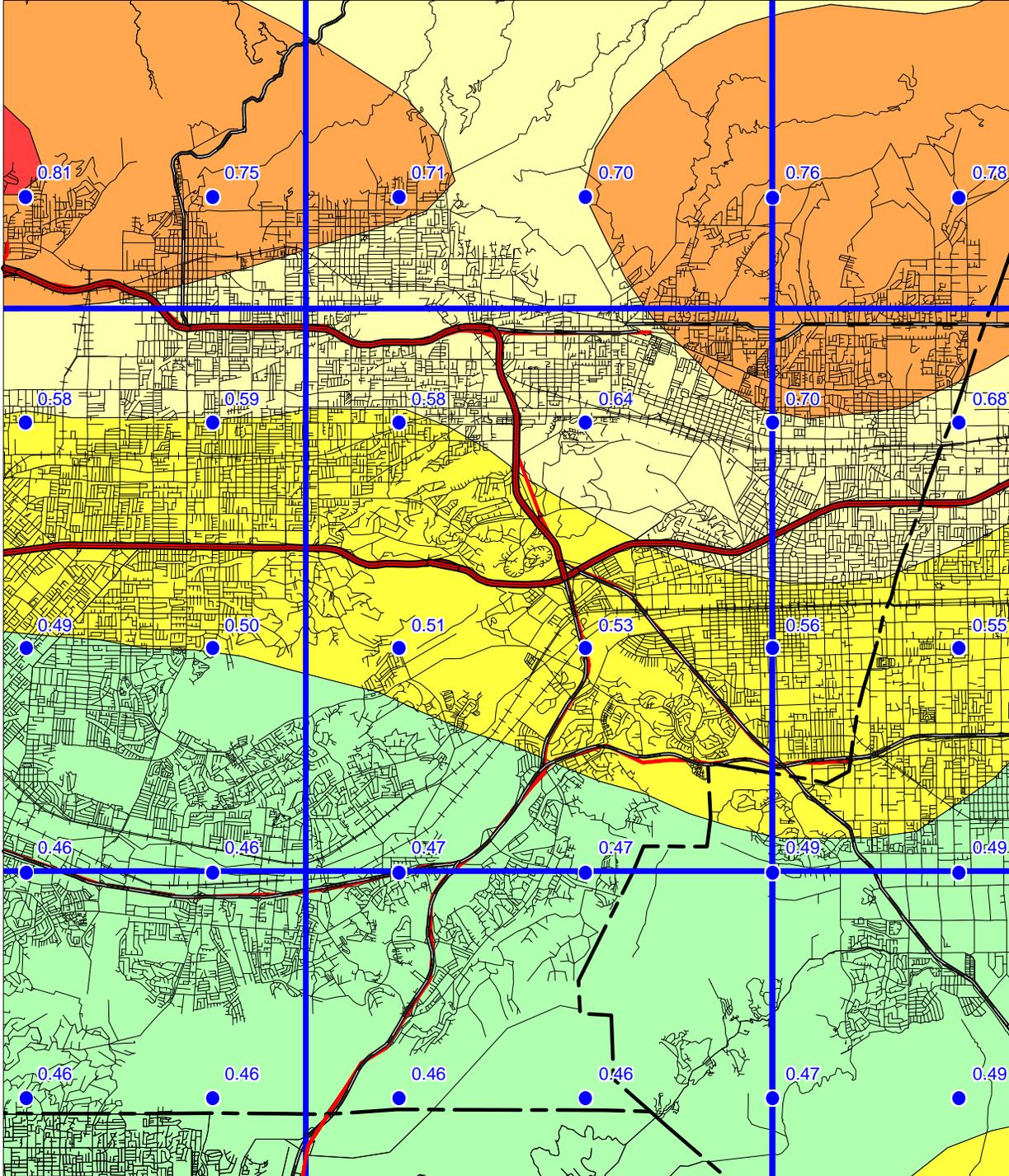
Figure 3.1

# SAN DIMAS 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

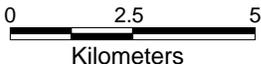
10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

SOFT ROCK CONDITIONS



Base map modified from MapInfo StreetWorks © 1998 MapInfo Corporation



Department of Conservation  
Division of Mines and Geology



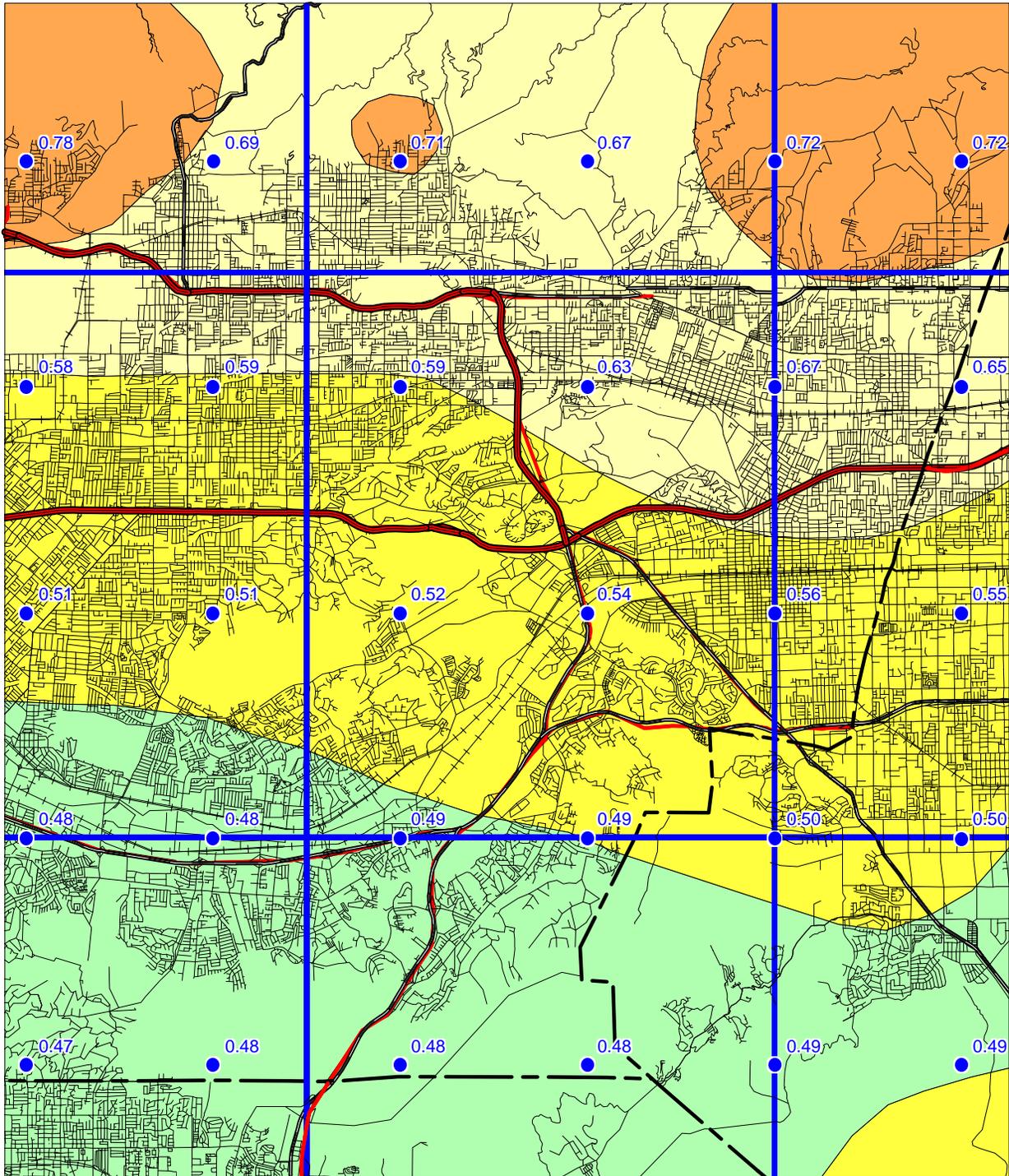
Figure 3.2

### SAN DIMAS 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

Department of Conservation  
Division of Mines and Geology



0 2.5 5  
Kilometers

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.

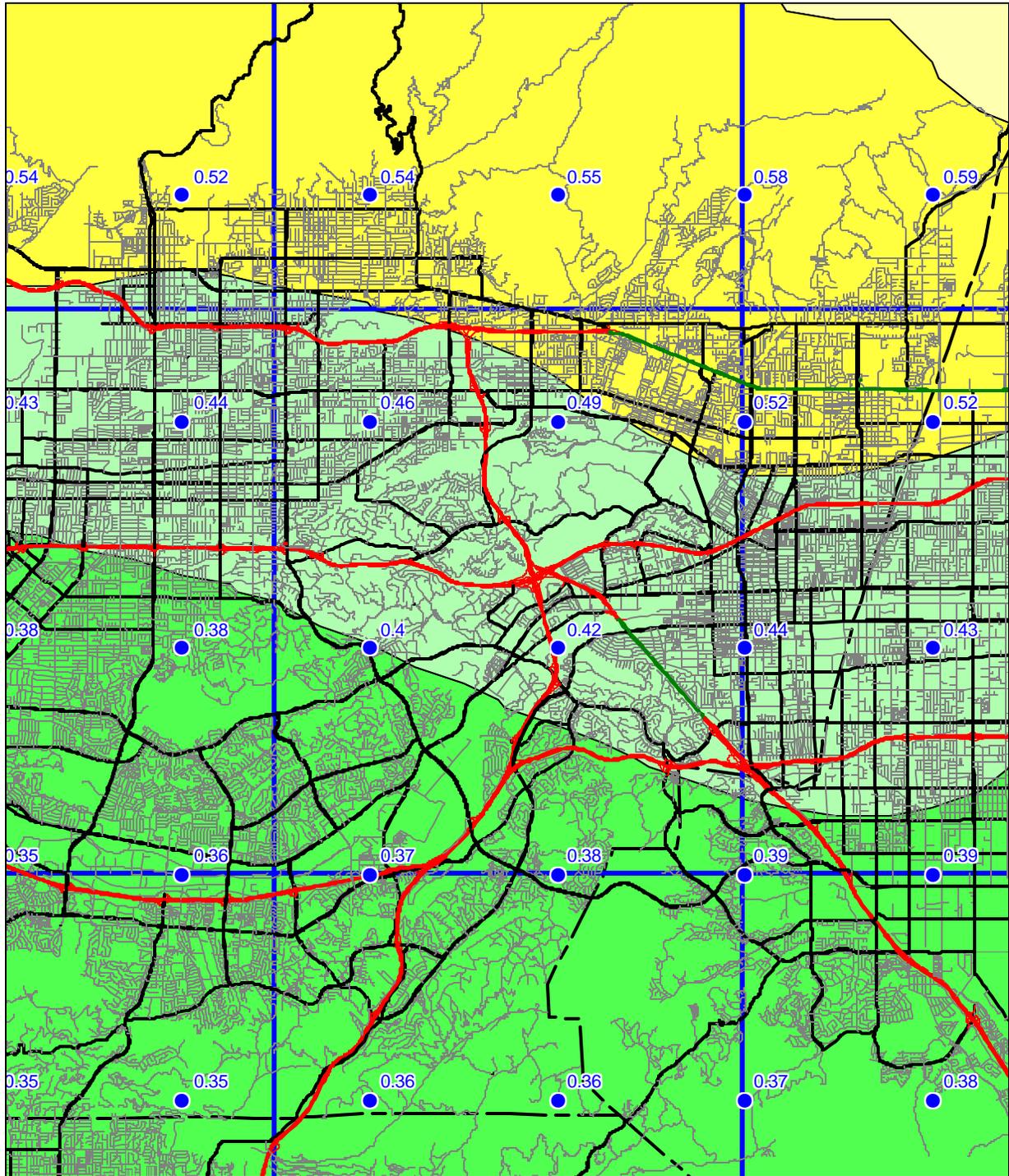


SEISMIC HAZARD EVALUATION OF THE SAN DIMAS QUADRANGLE  
SAN DIMAS 7.5-MINUTE QUADRANGLE AND PORTIONS OF  
ADJACENT QUADRANGLES

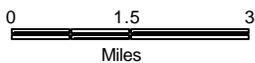
10% EXCEEDANCE IN 50 YEARS MAGNITUDE-WEIGHTED PSEUDO-PEAK ACCELERATION (g)  
FOR ALLUVIUM

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

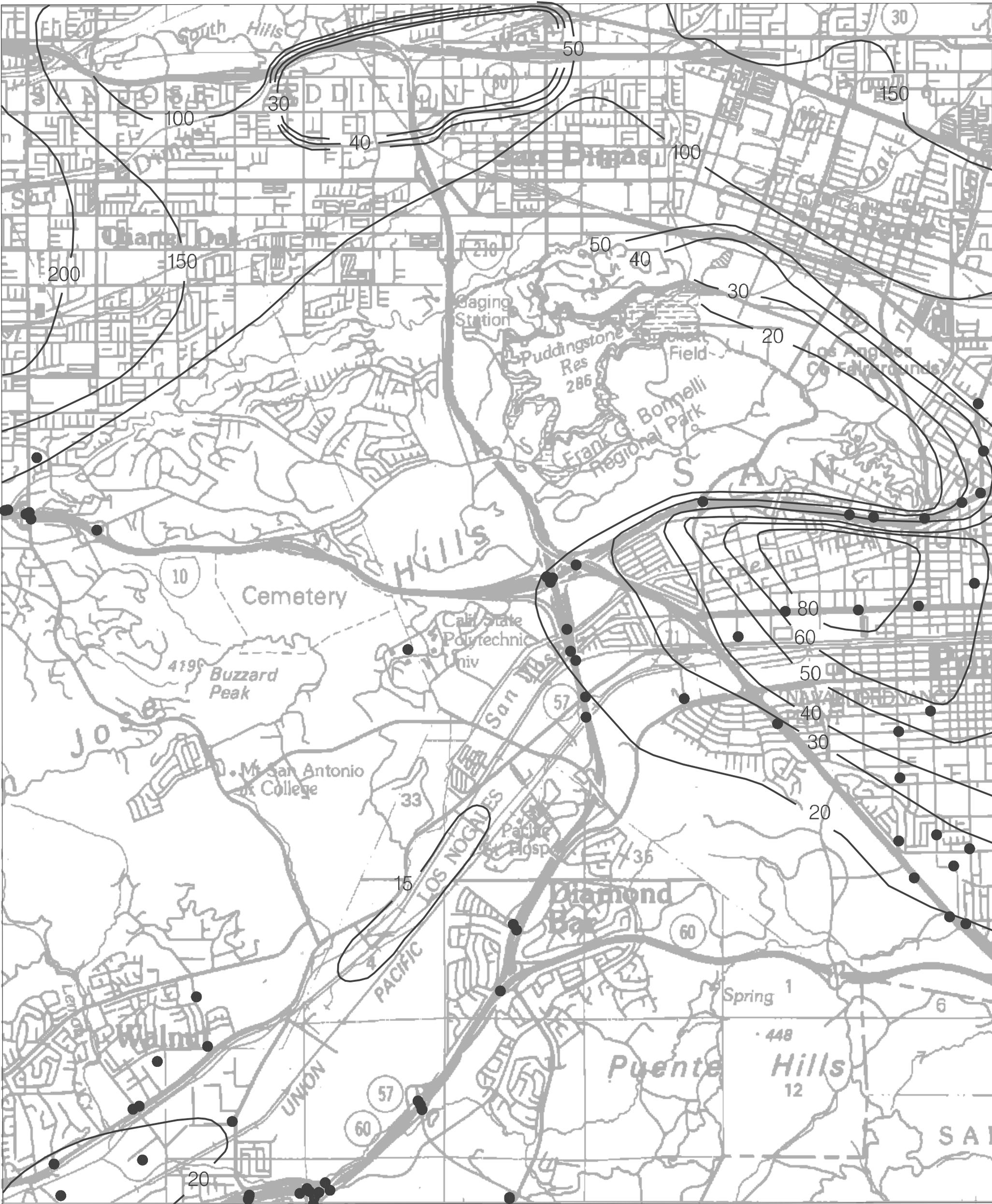
recorded ground motions that form the basis of the hazard model used to produce Figures 3.1, 3.2, and 3.3, extreme deviations can occur. More sophisticated methods that take into account other factors that may be present at the site (site amplification, basin effects, near source effects, etc.) should 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.

## REFERENCES

- Boore, D.M., Joyner, W.B. and Fumal, T.E., 1997, Empirical near-source attenuation relationships for horizontal and vertical components of peak ground acceleration, peak ground velocity, and pseudo-absolute acceleration response spectra: *Seismological Research Letters*, v. 68, p. 154-179.
- California Department of Conservation, Division of Mines and Geology, 1997, *Guidelines for evaluating and mitigating seismic hazards in California: Special Publication 117*, 74 p.
- Campbell, K.W., 1997, Attenuation relationships for shallow crustal earthquakes based on California strong motion data: *Seismological Research Letters*, v. 68, p. 180-189.
- Cramer, C.H. and Petersen, M.D., 1996, Predominant seismic source distance and magnitude maps for Los Angeles, Orange and Ventura counties, California: *Bulletin of the Seismological Society of America*, v. 85, no. 5, p. 1645-1649.
- Cramer, C.H., Petersen, M.D. and Reichle, M.S., 1996, A Monte Carlo approach in estimating uncertainty for a seismic hazard assessment of Los Angeles, Ventura, and Orange counties, California: *Bulletin of the Seismological Society of America*, v. 86, p. 1681-1691.
- International Conference of Building Officials (ICBO), 1997, *Uniform Building Code: v. 2, Structural engineering and installation standards*, 492 p.
- Jennings, C.W., *compiler*, 1994, *Fault activity map of California and adjacent areas: California Department of Conservation, Division of Mines and Geology, California Geologic Data Map Series, map no. 8.*
- Petersen, M.D., Bryant, W.A., Cramer, C.H., Cao, T., Reichle, M.S., Frankel, A.D., Lienkaemper, J.J., McCrory, P.A. and Schwartz, D.P., 1996, Probabilistic seismic hazard assessment for the State of California: California Department of Conservation, Division of Mines and Geology Open-File Report 96-08; also U.S. Geological Survey Open-File Report 96-706, 33 p.

- Real, C.R., Petersen, M.D., McCrink, T.P. and Cramer, C.H., 2000, Seismic Hazard Deaggregation in zoning earthquake-induced ground failures in southern California: Proceedings of the Sixth International Conference on Seismic Zonation, November 12-15, Palm Springs, California, EERI, Oakland, CA.
- Sadigh, K., Chang, C.-Y., Egan, J.A., Makdisi, F. and Youngs, R.R., 1997, SEA96- A new predictive relation for earthquake ground motions in extensional tectonic regimes: *Seismological Research Letters*, v. 68, p. 190-198.
- Wilson, R.C. and Keefer, D.K., 1983, Dynamic analysis of a slope failure from the 1979 Coyote Lake, California, *Earthquake: Bulletin of the Seismological Society of America*, v. 73, p. 863-877.
- Youd, T.L. and Idriss I.M., 1997, Proceedings of the NCEER workshop on evaluation of liquefaction resistance of soils: Technical Report NCEER-97-0022, 40 p.
- Youngs, R.R., Chiou, S.-J., Silva, W.J. and Humphrey, J.R., 1997, Stochastic point-source modeling of ground motions in the Cascadia Region: *Seismological Research Letters*, v. 68, p. 74-85.





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, San Dimas Quadrangle.

● Borehole Site

— 30 — Depth to ground water in feet

ONE MILE

SCALE



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

Plate 2.1 Landslide inventory, Shear Test Sample Locations, and Areas of Significant Grading, San Dimas Quadrangle.

- shear test sample location
- ☉ landslide
- ▨ areas of significant grading
- ▩ tract report with multiple borings

ONE MILE  
 SCALE