SEISMIC HAZARD ZONE REPORT FOR THE RITTER RIDGE 7.5-MINUTE QUADRANGLE, LOS ANGELES COUNTY, CALIFORNIA

2003

DEPARTMENT OF CONSERVATION
California Geological Survey

STATE OF CALIFORNIA
GRAY DAVIS
GOVERNOR

THE RESOURCES AGENCY
MARY D. NICHOLS
SECRETARY FOR RESOURCES

DEPARTMENT OF CONSERVATION
DARRYL YOUNG
DIRECTOR

CALIFORNIA GEOLOGICAL SURVEY
MICHAEL S. REICHLE, *ACTING STATE GEOLOGIST*

SEISMIC HAZARD ZONE REPORT FOR THE RITTER RIDGE 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

List of Revisions – Ritter Ridge SHZR 083	
5/27/05	BPS address correction, weblink updates
10/10/05	Bay Area Regional Office and Southern California Regional Office addresses updated

CONTENTS

ILLUSTRATIONS

EXECUTIVE SUMMARY

This report summarizes the methods and sources of information used to prepare the Seismic Hazard Zone Map for the Ritter Ridge 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 62 square miles at a scale of 1 inch = 2,000 feet.

The Ritter Ridge Quadrangle lies at the edge of the Antelope Valley in northern Los Angeles County southwest of Palmdale and 35 miles north of the Los Angeles Civic Center. High desert terrain of low local relief characterizes the northeastern third of the quadrangle. The San Andreas Rift Zone cuts across the center of the quadrangle as a series of aligned trough-like valleys, including Anaverde Valley and Leona Valley, bordered by linear ridges, including Ritter Ridge. South of the fault zone the Sierra Pelona rises to 5,217 feet. Alluvial fans slope toward Acton on the south side of the Sierra Pelona. Much of the northern half of the quadrangle lies within the city of Palmdale, including Rancho Vista, Ritter Ranch, City Ranch, most of the land along the California Aqueduct, and the crest of the Sierra Pelona. The rest of the quadrangle is unincorporated Los Angeles County land. Residential tract development and associated commercial facilities have characterized the rapid growth and expansion of the city of Palmdale during recent decades.

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

In the Ritter Ridge Quadrangle Antelope Valley is excluded from the zone, because the historically shallowest ground water is deep, except for the ground water in the Amargosa Creek channel. Amargosa Creek, Leona Valley and Anaverde Valley contain saturated, liquefiable sediments and are included in the zone. Saturated Holocene alluvium in stream channels on the south side of Sierra Pelona is also zoned for liquefaction. The deformed and uplifted metamorphic rocks in the Sierra Pelona contain many large landslides. Much of the landslide zone is related to dip slopes in the foliated metamorphic rocks and strata of the Vasquez Formation. The earthquake-induced landslide zone covers about 13 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 California Geological Survey's Internet page: http://www.conservation.ca.gov/CGS/index.htm

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

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

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

INTRODUCTION

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

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

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

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

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

SECTION 1
LIQUEFACTION EVALUATION REPORT

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

By
M. Elise Mattison and Allan G. Barrows

California Department of Conservation
California Geological Survey

PURPOSE

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

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

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

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

BACKGROUND

Liquefaction-induced ground failure historically has been a major cause of earthquake damage in 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 Ritter Ridge 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

- Ground-water maps constructed to show the historically highest known ground-water levels

- Geotechnical data analyzed to evaluate liquefaction potential of deposits

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

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

SCOPE AND LIMITATIONS

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

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

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

PART I

PHYSIOGRAPHY

Study Area Location and Physiography

The Ritter Ridge 7.5-minute Quadrangle covers approximately 62 square miles at the edge of the Antelope Valley in northern Los Angeles County. The center of the area is southwest of Palmdale and 35 miles north of the Los Angeles Civic Center. Typical high desert terrain of low local relief characterizes the northeastern third of the quadrangle. The northwest-trending San Andreas Rift Zone cuts across the center of the quadrangle as a series of aligned trough-like valleys, including Anaverde Valley and Leona Valley, bordered by linear ridges, including Ritter Ridge. South of the San Andreas Fault Zone mountainous terrain of the Sierra Pelona rises to 5,217 feet. The lowest point in the quadrangle, below 2,600 feet, is in Amargosa Creek at the northern boundary. Alluvial fans slope toward Acton on the south side of the Sierra Pelona in the southwestern corner of the quadrangle. Much of the land in the northern half of the quadrangle is within the city of Palmdale, including Rancho Vista, Ritter Ranch, City Ranch, most of the land along the California Aqueduct, and the crest of the Sierra Pelona. The rest of the quadrangle is unincorporated Los Angeles County land.

In the past two decades residential tract development and associated commercial facilities have characterized the rapid growth and expansion of the city of Palmdale. Access to the region is via State Highway 14 (Antelope Valley Freeway), Sierra Highway and Escondido Canyon Road in the southwestern corner, Avenue S, Rancho Vista Boulevard (formerly Avenue P), Elizabeth Lake-Pine Canyon Road through Leona Valley, and a grid of east-west avenues (lettered) and north-south streets (numbered).

GEOLOGY

Bedrock and Surficial Geology

Geologic units that generally are susceptible to liquefaction include late Quaternary alluvial and fluvial sedimentary deposits and artificial fill. For this evaluation, the Quaternary geologic map of the central Antelope Valley (Ponti and others, 1981; scale 1:62,500) was digitized by the Southern California Areal Mapping Project (SCAMP). The geology for northeastern Ritter Ridge Quadrangle was extracted from this regional map, modified by CGS, and attached to a SCAMP-digitized geologic map of the San Andreas Fault Zone (Barrows and others, 1985; scale 1:12,000). Attached to this is the southwest half of the CGS-digitized geologic map of the Ritter Ridge Quadrangle by Dibblee (1997; scale 1:24,000). The distribution of Quaternary deposits on this composite map was used in combination with other data, discussed below, to evaluate liquefaction susceptibility and develop the Seismic Hazard Zone Map. The map has been simplified for illustration on Plate 1.1, by removal of exposures too small to show at the current scale and, in the San Andreas Fault segment by grouping the units according to age into Qy (younger Quaternary), Qo (older Quaternary), and B (bedrock or pre-Quaternary).

Quaternary deposits cover approximately half of the Ritter Ridge Quadrangle. Older and younger Quaternary deposits each cover approximately equal areas. In Antelope Valley, in the northeastern corner of the quadrangle, Ponti and others (1981) mapped alluvial and colluvial textural facies symbolized by Q, followed by a number or sc, for modern stream channel (Table 1.1). The numbers signify age (3 is mid-Pleistocene, 6 straddles the Holocene/Pleistocene boundary, and 7 is Holocene). The numbers are followed by abbreviations for grain size, m (medium) or c (coarse). The unit labeled Qsc is sediment from Amargosa Creek, which flows northeastward from the foothills. The larger exposures of Q7m and Q7c flank the creek. The larger exposures of Q6 are downslope from Ritter Ridge and parallel to the Q7 deposits along Amargosa Creek. Ponti and others (1981) map the remainder of the Quaternary in the northeastern corner of the quadrangle as Q4c and Q3c.

Map Unit	Description	Age
Qsc	Modern stream channel	latest Holocene
Q7	Floodplains adjacent to ponded washes and channels	late Holocene
Q6	Low terraces, alluvial fans, and colluvial aprons	Holocene to late Pleistocene
Q4	Intermediate terraces, alluvial fans, and colluvial aprons	middle to late Pleistocene
Q3	High terrace deposits and alluvial fans	middle Pleistocene

Table 1.1. Quaternary map units used in northeastern Ritter Ridge Quadrangle as shown on Plate 1.1 (after Ponti and others, 1981).

Most of the Quaternary sediments (Table 1.2) in the San Andreas Fault Zone map (Barrows and others, 1985) are unconsolidated to weakly consolidated, mostly undissected, fluvial gravel, sand, and silt (Qal) in Antelope and Anaverde valleys, or unconsolidated gravel, sand, and silt of stream channel deposits (Qsc) along Amargosa Creek. Other Holocene units are scattered, small exposures of ponded alluvium (Qpa), mostly adjacent to strands of the San Andreas Fault; slope wash (Qsw); terrace deposits (Qt); alluvial fan deposits (Qf); lake deposits (Ql); and landslide rubble (Qls). Moderately to deeply dissected Pleistocene alluvium, especially older alluvium with Pelona Schist clasts (Qopl), and the well-bedded coarse sand and gravel of the Pelona Schist-Clast member of the Harold Formation (Qhp), extend north from the Sierra Pelona into Anaverde Valley. The Pleistocene Nadeau Gravel (Qn), a coarse, poorly sorted, weakly consolidated, fluvial gravel, is more prevalent than the Harold Formation in northwestern Anaverde Valley and in Leona Valley.

Barrows and others (1995) map unit	Plate 1.1 this report map unit	Description	Age
af	Qy	artificial fill	latest Holocene
Qal	Qy	alluvium	Holocene
Qpa	Qy	ponded alluvium	Holocene
Qsc	Qy	stream channel deposits	Holocene
Qsw	Qy	slope wash	Holocene
Qt	Qy	terrace deposits	Holocene
Qf	Qy	alluvial fan deposits	Holocene
Ql	Qy	lake deposits	Holocene
Qoa	Qo	older alluvium	late Pleistocene
Qopl	Qo	older alluvium with Pelona Schist clasts	late Pleistocene
Qopp	Qo	older alluvium with Pelona and Portal Schist clasts	late Pleistocene
Qops	Qo	older alluvium with Pelona Schist and syenite clasts	late Pleistocene
Qos	Qo	older alluvium with syenite clasts	late Pleistocene
Qot	Qo	older terrace deposits	late Pleistocene
Qof	Qo	older fan deposits	late Pleistocene
Qcm	Qo	older colluvium with metamorphic debris	late Pleistocene
Qn	Qo	Nadeau Gravel (fluvial)	middle to late Pleistocene
Qh	Qo	Harold Formation, undiffferentiated (alluvial fan and playa deposits)	early to middle Pleistocene
Qhp	Qo	Harold Formation, Pelona Schist-clast member (fluvial)	early to middle Pleistocene

Table 1.2. Quaternary map units used in the San Andreas Fault Zone portion of the Ritter Ridge Quadrangle (after Barrows and others, 1985).

Dibblee (1997) mapped Pleistocene alluvium consisting of older dissected surficial sediments of granitic gravel and sand (Qoa) and of schistose gravel and sand (Qos) covering about half of the southern quarter of the Ritter Ridge Quadrangle and delineated Holocene alluvium (Qa) in Acton Canyon and other north-to-south drainages in Sierra Pelona (Table 1.3).

Map Unit	Description	Age
Qa	alluvial gravel, sand, and silt	Holocene
Qoa	alluvial gravel and sand of mostly granitic detritus	Pleistocene
Qos	alluvial gravel and sand of mostly schist detritus	Pleistocene

Table 1.3. Quaternary map units used in the southwestern portion of the Ritter Ridge Quadrangle as shown on Plate1.1 (after Dibblee, 1997).

In addition to Precambrian gneiss and syenite, bedrock exposed in the Ritter Ridge Quadrangle consists of Portal Schist, Holcomb Quartz Monzonite, and the arkosic sandstone and clay shale units of the Anaverde Formation, within and north of the San Andreas Fault Zone, and generally, Pelona Schist, fluvial sandstone of the Ritter Formation, Lowe Granodiorite, and volcanic rocks of the Vasquez Formation to the south. See the Earthquake Induced Landslide portion (Section 2) of this report for further details on the bedrock geology.

Structural Geology

The dominant structural feature in the Ritter Ridge quadrangle is the San Andreas Fault Zone, which crosses the entire quadrangle and separates geologic terranes with dissimilar rock assemblages. The tectonic boundaries of the fault zone include the Little Rock Fault on the north and the inferred continuation of the Nadeau Fault, which passes through Anaverde Valley, on the south. The distance between these two bounding faults ranges from nearly a mile at the Antelope Valley freeway (Highway 14) to 200 feet in eastern Leona Valley where the western extension of the Nadeau Fault may be buried beneath the south-dipping Power Line Thrust Fault. Topographically, the San Andreas Fault lies within a linear, trough-like valley called the San Andreas Rift Zone. To the north, Portal Ridge and its eastern extension, Ritter Ridge, parallel the zone. South of the fault are depressed areas, including Lake Palmdale, a sag that was man-modified to contain the reservoir, and Anaverde Valley. The bulk of the area south of the fault zone consists of the eastern portion of Sierra Pelona. Sierra Pelona is a westward-plunging antiform of Pelona Schist. The mylonitic rocks at the contact between the Pelona Schist and the granitic rocks to the south have been interpreted as being associated with a segment of the south-dipping Vincent Thrust Fault (Ehlig, 1968). The thrust has been described as the most important structural feature in the basement rocks of the San Gabriel Mountains (Ehlig, 1981). The Precambrian basement rocks, such as the ferruginous syenite and augen gneiss, and the Triassic Lowe Granodiorite exposed within the southern third of the Ritter Ridge Quadrangle are western extensions of the San Gabriel Mountains basement terrane. The overlying Vasquez Formation volcanic and fluvial sedimentary rocks are manifestations of the eastern part of the Soledad Basin, which widens and deepens to the west of the quadrangle.

ENGINEERING GEOLOGY

Information on subsurface geology and engineering characteristics of Quaternary deposits was obtained from borehole logs collected from reports on geotechnical projects. For this investigation, borehole logs were collected from the files of Earth Systems Consultants and the Los Angeles County Department of Public Works. Data from 98 borehole logs were entered into a CGS geotechnical GIS database.

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

Geotechnical borehole logs provided information on lithologic and engineering characteristics of Quaternary deposits within the study area. Geotechnical characteristics of the Quaternary map units are generalized in Table 1.4 (see Part II Liquefaction Susceptibility).

GROUND WATER

Depth to ground water information is fundamental to liquefaction hazard studies. Liquefaction of subsurface sediments can result in structure-damaging ground failure at the surface through differential settlement or lateral spreading. Liquefaction hazard may exist in areas where depth to ground water is 40 feet or less, where saturation reduces the effective normal stress (Youd, 1973). Natural processes and human activities cause large fluctuations in ground-water levels over time, so it is impossible to specify what exact conditions will exist when ground shaking occurs. To address this uncertainty, CGS develops ground-water maps that show depths to historically shallowest levels recorded from water wells and boreholes. The resultant maps differ considerably from conventional ground-water maps that are based on measurements collected during a single season or year.

For purposes of seismic hazard zoning in the Ritter Ridge study area, depth to shallow ground water in alluviated canyon environments is the difference in elevation between the measured or estimated high water surface and the upper limit of adjacent liquefiable Quaternary deposits. Plate 1.2 shows a range of depths to historically shallowest ground water within the stream channels because the map scale disallows detailed contour lines. First-encountered water measured in Anaverde and Leona valleys was 5 to 38 feet below the surface. Of the four boreholes drilled 40 feet deep or deeper in the northeast corner of the quadrangle, none encountered water, even in winter months. Johnson (1911) tabulated well data for Antelope Valley, but none for the Ritter Ridge Quadrangle. Wells drilled in adjoining Palmdale Quadrangle around the turn of the 20th century produced non-artesian water at 190 feet or deeper (Johnson, 1911).

PART II

LIQUEFACTION POTENTIAL

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

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

LIQUEFACTION SUSCEPTIBILITY

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

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

CGS's map inventory of areas containing soils susceptible to liquefaction begins with evaluation of geologic maps and historical occurrences, cross-sections, geotechnical test data, geomorphology, and ground-water hydrology. Soil properties and soil conditions such as type, age, texture, color, and consistency, along with historical depths to ground water are used to identify, characterize, and correlate susceptible soils. Because Quaternary geologic mapping is based on similar soil observations, liquefaction susceptibility maps typically are similar to Quaternary geologic maps. CGS's qualitative relations between susceptibility and geologic map unit are summarized in Table 1.4.

Geologic Map Unit	Description	Material Type	Consistency	Age	Susceptible to Liquefacton ?*
af	artificial fill	man-made deposits of earth materials derived from local sources	loose to dense	latest Holocene	yes
Q7m	floodplains adjacent to ponded washes and channels	fine to medium sand with silt and clay matrix or interbeds	loose	late Holocene	yes
Q7c	floodplains adjacent to ponded washes and channels	pebble gravel with sand and silt matrix; or very coarse to coarse sand with gravel	loose	late Holocene	yes
Qa	alluvial gravel, sand, and silt	alluvial gravel, sand and silt	loose	Holocene	yes
Qal	alluvium	fluvial gravel, sand and silt	loose	Holocene	yes
Qf	alluvial fan deposits	rubble, gravel, sand, and silt	loose	Holocene	yes
Ql	lake deposits	dissected surficial sediments	loose to dense	Holocene	yes
Qpa	ponded alluvium	gravel, sand, silt and clay	loose to dense	Holocene	yes
Qsc	stream channel deposits	gravel, sand and silt	loose	Holocene	yes
Qsw	slope wash	sand and rubble	loose	Holocene	not likely (thin deposits)
Qt	terrace deposits	fluvial gravel, sand and silt	loose	Holocene	yes
Q6m	low terraces, alluvial fans, and colluvial aprons	fine to medium sand with silt and clay matrix or interbeds	loose to medium dense	late Pleistocene to Holocene	yes
Q6c	low terraces, alluvial fans, and colluvial aprons	pebble gravel with sand and silt matrix; or very coarse to coarse sand with gravel	loose to medium dense	late Pleistocene to Holocene	yes
Qcm	older colluvium with metamorphic debris	cobble to boulder-size blocks of Pelona Schist in silty sand matrix	dense	late Pleistocene	not likely
Qn	Nadeau Gravel	fluvial pebble to boulder gravel with earthy matrix	dense	middle to late Pleistocene	not likely
Qoa**	older alluvium	fluvial gravel, sand, silt and minor muddy debris	dense	late Pleistocene	not likely
Qoa***	older dissected surficial sediments	alluvial gravel and sand of mostly granitic detritus	dense	Pleistocene	no
Qof	older fan deposits	coarse debris, boulder to pebble gravel, sand and locally, interbedded silt	dense	late Pleistocene	not likely
Qopl	older alluvium with Pelona Schist clasts	fluvial gravel, sand and silt	dense	late Pleistocene	not likely
Qopp	older alluvium with Pelona and Portal Schist clasts	fluvial gravel, sand and silt	dense	late Pleistocene	not likely

Qops	older alluvium with Pelona Schist and syenite clasts	fluvial gravel, sand and silt	dense	late Pleistocene	not likely
Qos**	older alluvium with syenite clasts	fluvial gravel, sand and silt	dense	late Pleistocene	not likely
Qos***	older dissected surficial sediments	alluvial gravel and sand of mostly schist detritus	dense	Pleistocene	no
Qot	older terrace deposits	fluvial boulder, cobble gravel and sand	dense	late Pleistocene	not likely
Q3c	high terrace deposits and alluvial fans	pebble gravel with sand and silt matrix; or very coarse to coarse sand with gravel	medium to very dense	middle Pleistocene	no
Q4c	intermediate terraces, alluvial fans, and colluvial aprons	pebble gravel with sand and silt matrix; or very coarse to coarse sand with gravel	medium to very dense	middle to late Pleistocene	not likely
Qh	Harold Formation, undiffferentiated (alluvial fan and playa deposits)	silt, sand, and gravel	dense	early to middle Pleistocene	not likely
Qhp	Harold Formation, Pelona Schist-clast member	fluvial gravel with interbedded coarse sand	dense	early to middle Pleistocene	not likely

* when saturated ** Barrows and others (1985) *** Dibblee (1997)

Table 1.4. Quaternary map units used in the Ritter Ridge 7.5-Minute Quadrangle and their geotechnical characteristics and liquefaction susceptibility

LIQUEFACTION OPPORTUNITY

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

For the Ritter Ridge Quadrangle, PGAs of 0.55 to 0.77 g, resulting from earthquakes of magnitude 7.8 to 8.8, were used for liquefaction analyses. The PGA and magnitude values were based on de-aggregation of the probabilistic hazard at the 10 percent in 50-year hazard level (Cramer and Petersen, 1996; Petersen and others, 1996). See the ground motion portion (Section 3) of this report for further details.

Quantitative Liquefaction Analysis

CGS performs quantitative analysis of geotechnical data to evaluate liquefaction potential using the Seed-Idriss Simplified Procedure (Seed and Idriss, 1971; Seed and others, 1983;

National Research Council, 1985; Seed and others, 1985; Seed and Harder, 1990; Youd and Idriss, 1997; Youd and others, 2001). Using the Seed-Idriss Simplified Procedure one can calculate soil resistance to liquefaction, expressed in terms of cyclic resistance ratio (CRR), based on SPT results, ground-water level, soil density, moisture content, soil type, and sample depth. CRR values are then compared to calculated earthquake-generated shear stresses expressed in terms of cyclic stress ratio (CSR). The Seed-Idriss Simplified Procedure requires normalizing earthquake loading relative to a M7.5 event for the liquefaction analysis. To accomplish this, CGS's analysis uses the Idriss magnitude-scaling factor (MSF) (Youd and Idriss, 1997). It is convenient to think in terms of a factor of safety (FS) relative to liquefaction, where: FS = (CRR / CSR) * MSF. FS, therefore, is a quantitative measure of liquefaction potential. CGS uses a factor of safety of 1.0 or less, where CSR equals or exceeds CRR, to indicate the presence of potentially liquefiable soil. While an FS of 1.0 is considered the "trigger" for liquefaction, for a site specific analysis an FS of as much as 1.5 may be appropriate depending on the vulnerability of the site and related structures.

The CGS liquefaction analysis program calculates an FS for each geotechnical sample where blow counts were collected. Typically, multiple samples are collected for each borehole. The program then independently calculates an FS for each non-clay layer that includes at least one penetration test using the minimum $(N1)_{60}$ value for that layer. The minimum FS value of the layers penetrated by the borehole is used to determine the liquefaction potential for each borehole location. The reliability of FS values varies according to the quality of the geotechnical data. FS, as well as other considerations such as slope, presence of free faces, and thickness and depth of potentially liquefiable soil, are evaluated in order to construct liquefaction potential maps, which are then used to make a map showing zones of required investigation.

Of the 111 geotechnical borehole logs reviewed in this study (Plate 1.2), 75 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 SMGB (DOC, 2000). Under those guideline criteria, liquefaction zones are areas meeting one or more of the following:

1. Areas known to have experienced liquefaction during historical earthquakes

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

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

4. Areas where existing geotechnical data are insufficient

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

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

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

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

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

Areas of Past Liquefaction

In the Ritter Ridge Quadrangle, areas showing evidence of historic or paleoseismic liquefaction have not been reported.

Artificial Fills

In the Ritter Ridge Quadrangle, artificial fill areas large enough to show at the scale of mapping include engineered fill for the California Aqueduct and freeways. Since these fills are considered to be properly engineered, zoning for liquefaction in such areas depends on soil conditions in underlying deposits. Non-engineered fills, commonly loose and uncompacted, are included in the zone.

Areas with Sufficient Existing Geotechnical Data

Borehole logs that include penetration test data and sufficiently detailed lithologic descriptions were used to evaluate liquefaction potential. These areas with sufficient geotechnical data were evaluated for zoning based on the liquefaction potential determined by the Seed-Idriss Simplified Procedure. In Holocene alluvial deposits that cover much of Antelope Valley, of the borehole logs that were analyzed using the Seed-Idriss Simplified Procedure, most contain sediment layers that may liquefy under the expected earthquake loading, but are not saturated. Because the historically high ground water is deep, Antelope Valley is excluded from the zone, except for the Amargosa Creek channel. Amargosa and Leona valleys contain saturated, liquefiable sediment and are included in the zone.

Areas with Insufficient Existing Geotechnical Data

Saturated Holocene alluvium in stream channels and valleys other than the Anaverde and Leona (Qa, Qal, Qpa, Qsc, Qt, Qf, Ql, Q6c, Q7m, and Q7c, combined as Qy on Plate 1.1) are zoned for liquefaction based on criteria 4a and 4b.

ACKNOWLEDGMENTS

The authors thank for their help Steven Phillips at the U.S. Geological Survey (Water Resources Division); Dan Schneidereit, Bruce Hick and the staff at Earth Systems Consultants; Ted Bruce and the staff at California Department of Water Resources (Division of Engineering); Charles Nestle at Los Angeles County Department of Public Works (Land Development Division); and Gwen Ling at the California Department of Transportation. Additionally, the authors would like to acknowledge CGS staff Terilee McGuire, Bob Moscovitz, Lee Wallinder and Barbara Wanish for providing many levels of GIS support.

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.

Barrows, A.G., Kahle, J.E. and Beeby, D.J., 1985, Earthquake hazards and tectonic history of the San Andreas Fault Zone, Los Angeles County, California: California Department of Conservation, Division of Mines and Geology Open-File Report 85-10; 139 p., scale 1:12,000.

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: 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 in California: Division of Mines and Geology Special Publication 118, 12 p.

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.

Dibblee, T.W., Jr., 1997, Geologic map of the Sleepy Valley and Ritter Ridge quadrangles, Los Angeles County, California: Dibblee Geological Foundation Map DF-66, scale 1:24,000.

Ehlig, P.L., 1968, Causes of distribution of Pelona, Rand, and Orocopia Schist along the San Andreas and Garlock faults, *in* Dickinson, W.R. and Grantz, Arthur, *editors*, Proceedings of the conference on geologic problems of San Andreas Fault System: Stanford Univ. Pub.in Geol. Sci., v.11, p. 294-305.

Ehlig, P.L., 1981, Origin and tectonic history of the basement terrane of the San Gabriel Mountains, Central Transverse Ranges, *in* Ernst, W.G., *editor*, The geotectonic development of California, Rubey Volume 1: Prentice-Hall, Inc., Englewood Cliffs, New Jersey, p. 253-283.

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.

Johnson, H.R., 1911, Water resources of Antelope Valley, California: U.S. Geological Survey Water Supply Paper 278, 92 p., scale 1:125,000.

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; also U.S. Geological Survey Open-File Report 96-706, 33 p.

Ponti, D.J., Burke, D.B., and Hedel, C.W., 1981, Map showing Quaternary geology of the central Antelope Valley and vicinity, California: U.S. Geological Survey Open-File Report 81-737, scale 1:62,500.

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.

Southern California Earthquake Center, 1999, Recommended procedures for implementation of DMG Special Publication 117 guidelines for analyzing and mitigating liquefaction in California: Southern California Earthquake Center, University of Southern California, 63 p.

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 Fragaszy, R.J., *editors*, Static and Dynamic Properties of Gravelly Soils: American Society of Civil Engineers Geotechnical Special Publication no. 56, p. 1-19.

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.

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., Idriss, I.M., Andrus, R.D., Arango, I., Castro, G., Christian, J.T., Dobry, R., Finn, W.D.L., Harder, L.F. Jr., Hynes, M.E., Ishihara, K., Koester, J.P., Liao, S.S.C., Marcusson, W.F., Martin, G.R., Mitchell, J.K., Moriwaki, Y., Power, M.S., Robertson, P.K., Seed, R.B. and Stokoe, K.H., 2001, Liquefaction resistance of soils; Summary report from the 1996 NCEER and 1998 NCEER/NSF workshops on evaluation of liquefaction resistance of soils: Journal of Geotechnical and Geoenvironmental Engineering, October 2001, p. 817-833.

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 Ritter Ridge 7.5-Minute Quadrangle, Los Angeles County, California

By
Rick I. Wilson, Florante G. Perez, and Allan G. Barrows

California Department of Conservation
California Geological Survey

PURPOSE

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

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

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

METHODS SUMMARY

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

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

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

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

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

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

SCOPE AND LIMITATIONS

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

Earthquake-induced landslide zone maps are intended to prompt more detailed, site-specific geotechnical investigations as required by the Act. As such, these zone maps identify areas where the potential for earthquake-induced landslides is relatively high. Due to limitations in methodology, it should be noted that these zone maps do not necessarily capture all potential earthquake-induced landslide hazards. Earthquake-induced ground failures that are not addressed by this map include those associated with ridge-top spreading and shattered ridges. It should also be noted that no attempt has been made to map potential run-out areas of triggered landslides. It is possible that such run-out areas may extend beyond the zone boundaries. The potential for ground failure resulting from liquefaction-induced lateral spreading of alluvial materials, considered by some to be a form of landsliding, is not specifically addressed by the earthquake-induced landslide zone or this report. See Section 1, Liquefaction Evaluation Report for the Ritter Ridge 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 Ritter Ridge 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 Ritter Ridge 7.5-Minute Quadrangle covers approximately 62 square miles at the edge of the Antelope Valley in northern Los Angeles County. The center of the area is southwest of Palmdale and 35 miles north of the Los Angeles Civic Center. Typical high desert terrain of low local relief characterizes the northeastern third of the quadrangle. The northwest-trending San Andreas Rift Zone cuts diagonally across the center of the quadrangle as a series of aligned trough-like valleys, including Anaverde Valley and Leona Valley, bordered by linear ridges, including Ritter Ridge. South of the San Andreas Fault Zone mountainous terrain of the Sierra Pelona rises to 5,217 feet. The lowest point in the quadrangle, below 2,600 feet, is in Amargosa Creek at the northern boundary. Alluvial fans slope toward Acton on the south side of the Sierra Pelona. Much of the land in the northern half of the quadrangle is within City of Palmdale, including Rancho Vista, Ritter Ranch, City Ranch, most of the land along the California Aqueduct, and the crest of the Sierra Pelona. The rest of the quadrangle is unincorporated Los Angeles County land.

In the past two decades residential tract development and associated commercial facilities has characterized the rapid growth and expansion of the City of Palmdale. Access to the region is via State Highway 14 (Antelope Valley Freeway), Sierra Highway and Escondido Canyon Road in the southwestern corner, Avenue S, Rancho Vista Boulevard (formerly Avenue P), Elizabeth Lake-Pine Canyon Road through Leona Valley, and a grid of east-west avenues (lettered) and north-south streets (numbered).

Digital Terrain Data

The calculation of slope gradient is an essential part of the evaluation of slope stability under earthquake conditions. An accurate slope gradient calculation begins with an up-to-date map representation of the earth's surface in the form of a digital topographic map. Within the Ritter Ridge Quadrangle, a Level 2 digital elevation model (DEM) was obtained from the USGS (U.S. Geological Survey, 1993). This DEM, prepared from the 7.5-minute quadrangle topographic contours based on 1956 aerial photography, has a 10-meter horizontal resolution and a 7.5-meter vertical accuracy.

Areas that have undergone large-scale grading since 1956 in the hilly portions of the quadrangle were updated to reflect the new topography. A DEM reflecting this recent grading, specifically along the California Aqueduct and State Highway 14, was obtained from an airborne interferometric radar platform flown in 2001, with an estimated vertical accuracy of approximately 1.5 meters (Intermap Corporation, 2002). An interferometric radar DEM is prone to creating false topography where tall buildings, metal structures, or trees are present. The DEM used for the graded areas within the Ritter Ridge Quadrangle underwent additional processing to remove these types of artifacts (Wang and others, 2001). Nevertheless, the final hazard zone map was checked for potential errors resulting from the use of the radar DEM and corrected if necessary. Graded areas where the radar DEM was applied are shown on Plate 2.1.

A slope map was made from the DEM using a third-order, finite difference, center-weighted algorithm (Horn, 1981). The DEM was also used to make a slope aspect map. The manner in which the slope and aspect maps were used to prepare the zone map will be described in subsequent sections of this report.

GEOLOGY

Bedrock and Surficial Geology

The geologic map used as background geology for the Ritter Ridge Quadrangle was prepared from three sources. Ponti and others (1981) mapped the Quaternary geology of western Antelope Valley and vicinity, including the Ritter Ridge Quadrangle. Detailed geologic maps of the San Andreas Fault Zone, including the segment that traverses the Ritter Ridge Quadrangle, were prepared by Barrows and others (1985, Plates 1D and 1E). Geologic maps from both of these sources were digitized by the Southern California Areal Mapping Project [SCAMP]. The pre-Quaternary sedimentary, volcanic, and crystalline rocks are generalized on the Ponti and others (1981) map. Therefore, part of a geologic map by Dibblee (1997) was digitized by CGS for the portion of the quadrangle south of the detailed strip map along the fault zone. During the search for landslides (Qls on map) in the field, observations were made of exposures, aspects of weathering, and general surface expression of the geologic units.

Rock assemblages are distinct for areas that are north of, within, and south of the San Andreas Fault Zone, which crosses the entire quadrangle.

North of and within the San Andreas Fault Zone

Portal Schist (pos or sch on Barrows and others, 1985; psp on Dibblee, 1997), the oldest rock unit north of the main trace of the San Andreas Fault, is well exposed on Ritter Ridge. Portal Schist predominantly consists of quartzo-feldspathic and dark biotite schist, with common marble and quartzite interlayers and abundant vein quartz (Barrows and others, 1985). To the east of Ritter Ridge, a linear body of Holcomb Quartz Monzonite (hqm on Barrows and others, 1985; qm on Dibblee, 1997) is bound on the south by the Little Rock Fault, about 1,500 to 2,000 feet north of the San Andreas Fault. South of the Little Rock Fault are poor exposures of white, crushed granitic rocks (grc) that range in composition from granite to granodiorite and are, locally, pulverized to a microbreccia (Barrows and others, 1985).

Exposed within the San Andreas Fault Zone are several members of the non-marine Pliocene Anaverde Formation. These include the red arkose, buff arkose, clay shale, gray arkose, and breccia members (Barrows and others, 1985). The red arkose member (Tar) is a pink to red, medium-to thick-bedded, locally massive, coarse pebbly arkose. The buff arkose (Tab) is a buff to gray, medium-bedded to massive, medium- to very coarse-grained pebbly arkose with thin silty interbeds near the top. The gray arkose member (Tag) is a gray to buff, medium- to thick-bedded arkosic sandstone with pods and lenses of pebbly to cobbly arkose and conglomerate. Other coarse-grained subunits of the Anaverde Formation include buff and red arkose members with predominantly volcanic clasts (Tavb and Tavr, respectively). The Tar, Tab, Tag, and portions of the Tavb and Tavr are the equivalent of the "white to tan sandstone" (Tas) of Dibblee (1997). The clay shale member (Tac) is a gray to brown, thin-bedded, sandy, silty, locally very gypsiferous clay shale with interbedded siltstone and sandstone layers. The breccia member (Tabx) is a very distinctive, reddish to dark gray, massive, pervasively sheared sedimentary breccia with angular clasts of hornblende diorite that occurs only within the San Andreas Fault Zone near the western boundary of the quadrangle. The bedding within the Anaverde Formation members mostly parallels the bounding faults and has steep to vertical dips. Highly contorted beds of the clay shale member (Tac) are dramatically exposed within the large roadcut on the Antelope Valley Freeway (Highway 14). Within the fault zone, near the western edge of the quadrangle, are small exposures of Ritter Formation (TQr), which is a light gray to white, moderately well-indurated to poorly indurated, thin- to medium-bedded fluvial sandstone with thin micaceous shale layers. Clasts in the Ritter Formation appear to have been derived from the diorite and gneiss complex west of the Sierra Pelona (Barrows and others, 1985).

A variety of older and younger alluvial deposits cover the pre-Quaternary rocks north of the San Andreas Fault. In the portion of the map complied from Ponti and others (1981) the upper Quaternary alluvial and colluvial units are designated by numbers (higher numbers signify more recent deposits) and letters that signify coarseness of the materials (c being coarse- and m being m-grained). In the Ritter Ridge Quadrangle these units include Q3c, Q4c, Q6m, Q6c, Q7m, and Q7c.

Within the detailed strip map by Barrows and others (1985) numerous Quaternary alluvial deposits are differentiated. The oldest group of deposits includes the following units. Harold Formation, Pelona Schist-Clast Member (Qhp) is a well-bedded fluvial gravel with 80 percent of the pebble- to cobble-size clasts that consist of micaceous Pelona Schist. It is found near the western boundary of the quadrangle within the San Andreas Fault Zone. Nadeau Gravel (Qn), which is a coarse, poorly sorted dark reddish brown, pebble to boulder gravel with abundant Pelona Schist fragments also located near the western boundary. Older alluvium with Portal Schist and Pelona Schist clasts (Qopp), older alluvium with Pelona Schist clasts (Qopl), and older alluvium with Portal Schist clasts (Qopo) are unconsolidated, poorly sorted, moderately dissected fluvial gravel, sand, and silt deposits that are found within the San Andreas Fault Zone near the western boundary of the quadrangle. Older alluvium (Qoa) and older fan deposits (Qof), which are highly variable in texture and composition and occur above modern erosional surfaces, are also scattered in the fault zone. Younger alluvial units include terrace deposits (Qt), fan deposits (Qf), slope wash (Qsw), lake deposits (Ql), ponded alluvium

(Qpa), stream channel deposits (Qsc), and alluvium (Qal). Artificial fill (af), especially that associated with the construction of the California Aqueduct, is also scattered across the quadrangle.

South of the San Andreas Fault

Within the strip map of Barrows and others (1985), fewer units occur south of the main trace of the San Andreas Fault than occur to the north of the fault zone. Ancient basement rocks such as Precambrian gneissoid basement rocks (gn) and distinctive red-weathering ferruginous syenite (fs) are exposed in the southeastern part of the strip map; a diorite and gneiss complex (dgn; qd on Dibblee) is exposed in the southwestern part of the strip map. Much of the bedrock in the strip map area is pre-Tertiary Pelona Schist (pls) that consists of predominantly silver to dark-gray, fine- to medium-grained, well-foliated to massive, quartz-muscovite schist with interlayers of quartzo-feldspathic and greenish chlorite-epidote schist and white quartz veins. Adjacent to the San Andreas Fault, perhaps as slivers dragged along strands of the zone, are exposures of the Pliocene clay shale member (Tac) of the Anaverde Formation. In the Leona Valley area where Pelona Schist comes closest to the San Andreas Fault it is bounded on the north by a south-dipping fault called the Powerline Thrust Fault. Beneath this fault are Ritter Formation (TQr) fluvial sandstone rocks that are distributed between the Pelona Schist and the San Andreas Fault.

South of the San Andreas Fault fewer Quaternary alluvial units have been mapped than to the north. The oldest unit is the Harold Formation (Qh where undifferentiated), Pelona Schist-Clast Member (Qhp), which is a well-bedded fluvial gravel with 80 percent of the pebble- to cobble-size clasts that consist of micaceous Pelona Schist that is widespread in Anaverde Valley and on City Ranch. Deposits of Nadeau Gravel (Qn), a coarse, poorly sorted dark reddish brown, pebble to boulder gravel with abundant Pelona Schist fragments, rest upon the Pelona Schist and are common on City Ranch, west of the California Aqueduct. In the west part of the quadrangle in the Leona Valley is older colluvium with metamorphic debris (Qcm) comprised of exclusively caliche-coated clasts of Pelona Schist. Older terrace deposits (Qot) composed of sand, gravel, and cobbles exist within the northwestern part of the Anaverde Valley. On the slopes south of Anaverde Valley, south of the California Aqueduct, is a dissected apron of older alluvial debris comprised of Pelona Schist clasts (Qopl). To the east, where ferruginous syenite clasts are mixed with Pelona Schist clasts the older alluvial unit is Qops (Barrows and others, 1985). Younger units are present in addition to the older units. These include fan deposits (Qf), slope wash (Qsw), lake deposits (Ql), ponded alluvium (Qpa), stream channel deposits (Qsc), and alluvium (Qal). Artificial fill (af on Barrows and others, 1981, and cf on Dibblee, 1997) associated with the construction of the California Aqueduct, roads, and highways is also scattered across the quadrangle.

For the portion of the Ritter Ridge Quadrangle south of the detailed strip map of Barrows and others (1985) along the fault zone a geologic map by Dibblee (1997) was utilized. Within this portion of the map the oldest rocks are Precambrian gray, banded gneiss (gnb) and dark gray augen gneiss (agn), which are inclusions within intrusive bodies.

Precambrian syenite (sy) is exposed over a large area in the southeastern quarter of the quadrangle. This red-stained unit is the same as the ferruginous syenite (fs) discussed above. Lowe Granodiorite (lgdb) of Triassic age is also present in the southeastern corner of the quadrangle. Other pre-Tertiary intrusive rocks include diorite (di), hornblende diorite (hd), and light-colored granitic (gr) rocks. Along the southern slope of Sierra Pelona a band of gray mylonite (my) separates the granitic rocks (gr) from micaceous Pelona Schist (ps), within which are small lenses of marble (psl) and white quartz (q) veins (Dibblee, 1997). Also within the southeastern corner of the quadrangle are Oligocene nonmarine, predominantly volcanic, rocks of the Vasquez Formation including andesitic volcanic rocks (Tva), tuff-breccia (Tvt), basaltic volcanic rocks (Tvb), andesitic-basaltic rocks (Tvba), and gray to pink basal conglomerate (Tvcgl). The Vasquez Formation also contains younger calcite travertine veins (tr) and andesite dikes (ai). Dibblee (1997) mapped large areas of older dissected surficial sediments that include alluvial gravel and sand of mostly granitic debris (Qoa) and alluvial gravel and sand of mostly schist detritus (Qos). All younger alluvial units were mapped as surficial sediments (Qa).

Structural Geology

The dominant structural feature in the Ritter Ridge Quadrangle is the San Andreas Fault Zone that crosses the entire quadrangle and separates geologic terranes with dissimilar rock assemblages. The tectonic boundaries of the fault zone include the Little Rock Fault on the north and the inferred continuation of the Nadeau Fault, which passes through Anaverde Valley, on the south. The distance between these two bounding faults ranges from nearly a mile at the Antelope Valley freeway (Highway 14) to 200 feet in eastern Leona Valley where the western extension of the Nadeau Fault may be buried beneath the south-dipping Power Line Thrust Fault. Topographically, the San Andreas Fault lies within a linear, trough-like valley called the San Andreas Rift Zone. Portal Ridge on the north and its eastern extension, Ritter Ridge, parallel the rift zone. South of the fault are depressed areas, including Lake Palmdale, a sag that was man-modified to contain the reservoir, and Anaverde Valley. The bulk of the area south of the fault zone consists of the eastern portion of Sierra Pelona. Sierra Pelona is a westward-plunging antiform comprised of Pelona Schist. The mylonitic rocks at the contact between the Pelona Schist and the granitic rocks to the south have been interpreted as being associated with a segment of the south-dipping Vincent Thrust Fault (Ehlig, 1968). The thrust has been described as the most important structural feature in the basement rocks of the San Gabriel Mountains (Ehlig, 1981). The Precambrian basement rocks, such as the ferruginous syenite and augen gneiss, and the Triassic Lowe Granodiorite that are exposed within the southern third of the Ritter Ridge Quadrangle are western extensions of the San Gabriel Mountains basement terrane. The overlying Vasquez Formation volcanic and fluvial sedimentary rocks are manifestations of the eastern part of the Soledad Basin, which widens and deepens to the west of the quadrangle.

Landslide Inventory

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

Most of the landslides in the Ritter Ridge Quadrangle occur in metamorphic rocks, particularly in the Pelona Schist. Identification and delineation of landslides in the metamorphic terrain was made difficult by the complexity of the structures as manifested by the foliation, the intricate folding, and the highly jointed/broken-up nature of the rock exposures. The proximity to the San Andreas Fault Zone, internal thrust faulting, and the presence of quartz veins and bands of marble that tend to form isolated resistant outcrops made photo identification of landslides difficult. This preliminary landslide inventory is subject to revision pending the synthesis of data collected during field checking and the subsequent review of aerial photographs. Any revisions on the extent and classification of some of the landslides will be incorporated in the final report accompanying the official release of the Ritter Ridge Quadrangle hazard zone map.

Debris slides are the most common types of landslides in the area. Their location and distribution are strongly influenced by folding. Several large debris slides are mapped on both limbs of the anticline and syncline bordering Anaverde Creek. The attitude of the foliation in the metamorphic rocks in this location indicates that most of these landslides are on a dip slope. Highly eroded and relatively old rock slides also occur in the western part of the quadrangle. Debris slides are also mapped in the southeastern portion of the quadrangle, which is underlain by the Vasquez Formation wherein the attitude of the bedding indicates that the slides are on dip slopes. A debris slide mapped in the Leona Valley near Elizabeth Lake whose toe is bounded by the Powerline Thrust Fault is made up of angular to very-angular broken-up pieces of Pelona Schist and, to a limited extent, blankets the Ritter Formation which is exposed downslope and north of the thrust fault.

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

ENGINEERING GEOLOGY

Geologic Material Strength

To evaluate the stability of geologic materials under earthquake conditions, the geologic map units described above were ranked and grouped on the basis of their shear strength. Generally, the primary source for shear-strength measurements is geotechnical reports prepared by consultants on file with local government permitting departments. Shear-strength data for the units identified on the Ritter Ridge Quadrangle geologic map were obtained from the Los Angeles County Planning Department and Earth Systems Consultants (see Appendix A). The locations of rock and soil samples taken for shear testing within the Ritter Ridge Quadrangle are shown on Plate 2.1. Shear tests from the adjoining Agua Dulce and Acton quadrangles were referenced for several geologic formations for which little or no shear test information was available within the Ritter Ridge Quadrangle.

Shear strength data gathered from the above sources were compiled for each geologic map unit. Geologic units were grouped on the basis of average angle of internal friction (average phi) and lithologic character. Average (mean or median) phi values for each geologic map unit and corresponding strength group are summarized in Table 2.1. For most of the geologic strength groups (Table 2.2) 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 Table 2.1 and Table 2.2, and this map provides a spatial representation of material strength for use in the slope stability analysis. The different units for the Vasquez Formation were subdivided further, as described below in the "Adverse Bedding Conditions" section; an additional strength group was created to represent the adverse bedding conditions of the Tvb, Tva, Tvba, and Tvt portions of the Vasquez Formation based on strength data from the adjacent quadrangles. In addition, all of the Quaternary map units referenced in the three geologic maps used for the Ritter Ridge Quadrangle were combined into the three Quaternary units (Qoa, Qos, and Qa) designated by Dibblee (1997) due to their similar age and composition.

Adverse Bedding Conditions

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

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

The members of the Vasquez Formation, which contain interbedded resistant sandstone/volcanic rocks and softer shale, were subdivided based on shear strength differences between coarse-grained (higher strength) and fine-grained (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 strength dominates where bedding dips into a slope (favorable bedding) while fine-grained material strength 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 members of the Vasquez Formation are included in Table 2.1.

Existing Landslides

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

The strength characteristics of existing landslides (Qls) must be based on tests of the materials along the landslide slip surface. Ideally, shear tests of slip surfaces formed in each mapped geologic unit would be used. However, this amount of information is rarely available, and for the preparation of the earthquake-induced landslide zone map it has been assumed that all landslides within the quadrangle have the same slip surface strength parameters. We collect and use primarily “residual” strength parameters from laboratory tests of slip surface materials tested in direct shear or ring shear test equipment. Back-calculated strength parameters, if the calculations appear to have been performed appropriately, have also been used.

No material strength tests of landslide slip surface were available within the Ritter Ridge Quadrangle. The value presented in Table 2.1 reflects a phi found for slip surface materials in nearby quadrangles.

RITTER RIDGE QUADRANGLE
SHEAR STRENGTH GROUPS

	Formation Name	Number Tests	Mean/Median Phi (deg)	Mean/Median Group Phi (deg)	Mean/Median Group C (psf)	No Data: Similar Lithology	Phi Values Used in Stability Analyses
GROUP 1	my	4	39/39	38/38	371/210	agn	38
	sy	11	39/40			hd	
	lgdb	6	38/37			fs	
	di	37	38/36			dgn	
	qd	1	38/38				
GROUP 2	ps	6	35/37	34/34	279/220	q, psl, pls	34
	psp	10	32/35			pos, sch	
	gnb	7	32/33			hqm, qm	
	gr	41	34/35			gn, grc	
	Qoa*	87	33/32			Tvcgl(fbc)	
	Qos*	20	34/36				
	Qa*	66	35/35			Tvb(fbc)	
	cf/af	25	33/34			Tva(fbc)	
						Tvba(fbc)	
						Tvt(fbc)	
						TQr	
						ai, tr	
GROUP 3	Tar	2	29/29	29/30	232/200	Tvcgl(abc)	29
	Tas	18	30/32				
	Tac	9	28/27			Tab	
						Tabx	
						Tag	
						Tavb	
						Tavr	
GROUP 4						Tvb(abc)	26**
						Tva(abc)	
						Tvba(abc)	
						Tvt(abc)	
GROUP 5						Qls	16**

*** Qoa, Qos, and Qa = Q3c, Q4c, Q6c, Q6m, Q7c, Q7m, Qal, Qcm, Qf, Qh, Qhp, Ql, Qn, Qof, Qopl, Qopo, Qopp, Qops, Qot, Qpa, Qsc, Qsw, and Qt.**

**** Shear strength group numbers referenced from values in the adjacent quadrangles.**

abc = adverse bedding condition, fine-grained material strength

fbc = favorable bedding condition, coarse-grained material strength

Formation abbreviations from Dibblee (1997), Ponti and others (1985), and Barrows and others (1981).

Table 2.1. Summary of the Shear Strength Statistics for the Ritter Ridge Quadrangle.

SHEAR STRENGTH GROUPS FOR THE RITTER RIDGE 7.5-MINUTE QUADRANGLE				
GROUP 1	**GROUP 2**	**GROUP 3**	**GROUP 4**	**GROUP 5**
my, agn	q, ps, psl	Tvcgl(abc)	Tvb(abc)	Qls
hd, sy	psp, pls, pos	Tab, Tabx	Tva(abc)	
fs, lgdb	sch, hqm, qm	Tag, Tar	Tvba(abc)	
di, dgn	gnb, gn, gr	Tas, Tac	Tvt(abc)	
qd	grc, Tvcgl(fbc)	Tavb, Tavr		
	Tvb(fbc), Tva(fbc)			
	Tvba(fbc), Tvt(fbc)			
	ai, tr, TQr, Qh, Qhp			
	Qoa, Qos, Qof, Qopl			
	Qopo, Qopp, Qops, Qn			
	Qot, Qcm, Qpa, Qsw			
	Q3c, Q4c, Q6c			
	Q6m, Q7c, Q7m			
	Qt, Qa, Ql, Qf, Qal			
	Qsw, Qsc, cf/af			

Table 2.2. Summary of Shear Strength Groups for the Ritter Ridge Quadrangle.

PART II

EARTHQUAKE-INDUCED LANDSLIDE HAZARD POTENTIAL

Design Strong-Motion Record

To evaluate earthquake-induced landslide hazard potential in the study area, a method of dynamic slope stability analysis developed by Newmark (1965) was used. The Newmark method analyzes dynamic slope stability by calculating the cumulative down-slope displacement for a given earthquake strong-motion time history. As implemented for the preparation of earthquake-induced landslide zones, the Newmark method necessitates the selection of a design earthquake strong-motion record to provide the "ground shaking opportunity." For the Ritter Ridge 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 CGS for a 10 percent probability of being exceeded in 50 years (Petersen and others, 1996). The parameters used in the record selection are:

Modal Magnitude:	7.8
Modal Distance:	2.7 to 10.4 km
PGA:	0.55 to 0.95 g

The strong-motion record selected for the slope stability analysis in the Ritter Ridge Quadrangle was the Southern California Edison Lucerne record from the 1992 magnitude 7.3 Landers, California, earthquake was used because it was the closest fit to the above criteria. This record had a source to recording site distance of 1.1 km and a peak ground acceleration (PGA) of 0.80g. Although the modal magnitude and distance from the Lucerne record do not fall within the range of the probabilistic parameters, this record was considered to be sufficiently conservative to be used in the stability analyses. 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 CGS pilot study for earthquake-induced landslides (McCrink and Real, 1996; McCrink, 2001). Applied to the curve in Figure 2.1, these displacements correspond to yield accelerations of 0.14g, 0.18g, and 0.24g. Because these yield acceleration values are derived from the design strong-motion record, they represent the ground shaking opportunity thresholds that are significant in the Ritter Ridge Quadrangle.

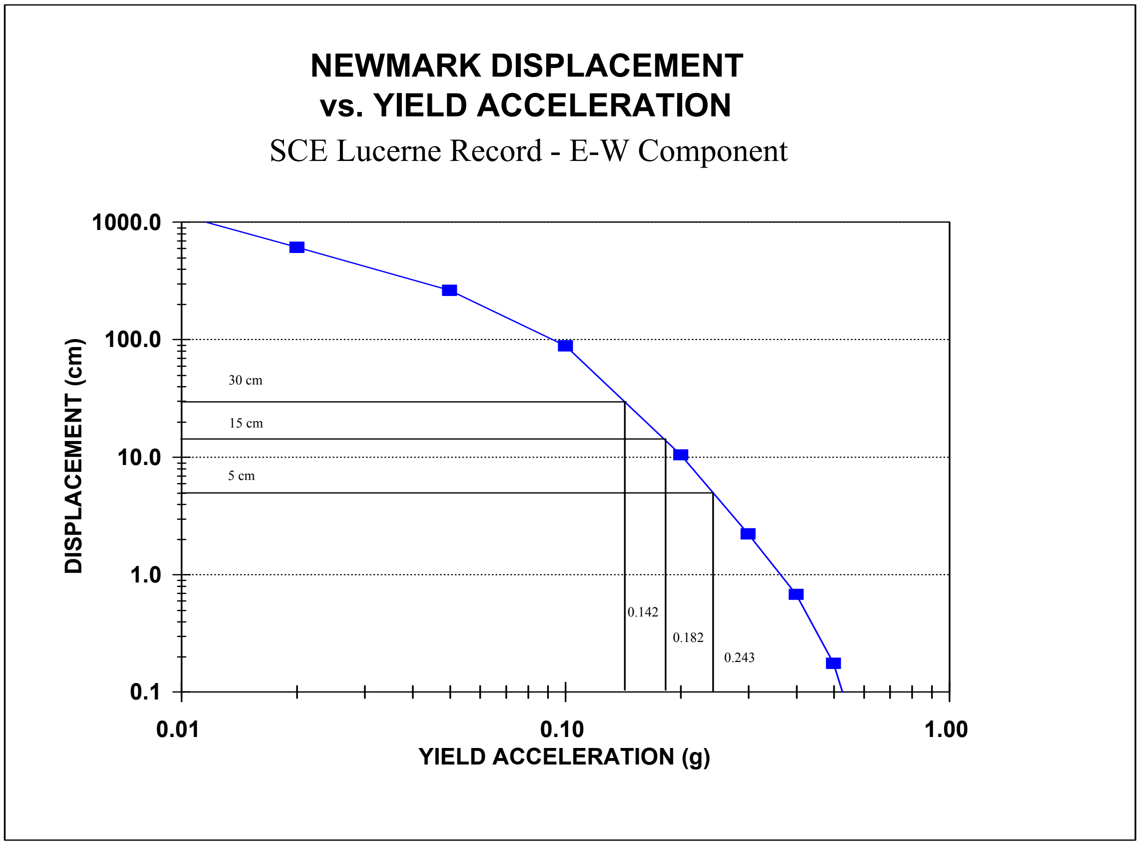


Figure 2.1. Yield Acceleration vs. Newmark Displacement for the Southern California Edison (SCE) Lucerne Record from the 1992 Landers Earthquake.

Slope Stability Analysis

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

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

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

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

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

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

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

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

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.

RITTER RIDGE QUADRANGLE HAZARD POTENTIAL MATRIX

Geologic Material Strength Group (Average Phi)	HAZARD POTENTIAL (Percent Slope)			
	Very Low	Low	Moderate	High
1 (38)	0 to 49 %	49 to 57%	57 to 61%	>61%
2 (34)	0 to 41%	41 to 48%	48 to 52%	>52%
3 (29)	0 to 29%	29 to 35%	35 to 39%	>39%
4 (26)	0 to 24%	24 to 29%	29 to 33%	>33%
5 (16)	0 to 5%	5 to 10%	10 to 14%	>14%

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

EARTHQUAKE-INDUCED LANDSLIDE HAZARD ZONE

Criteria for Zoning

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

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

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

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

Existing Landslides

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

Geologic and Geotechnical Analysis

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

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

1. Geologic Strength Group 5, consisting of all definite and probable landslide areas, is always included in the earthquake-induced landslide zone for all slope gradients.

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 29 percent.

4. Geologic Strength Group 2 is included for all slopes steeper than 41 percent.

5. Geologic Strength Group 1 is included for all slopes greater than 49 percent.

This results in 13 percent of the quadrangle lying within the earthquake-induced landslide hazard zone for the Ritter Ridge Quadrangle. The primary zoned area is within the steeper terrain of the Sierra Pelona on the western side of the quadrangle.

ACKNOWLEDGMENTS

The authors would like to thank the following individuals and organizations for their assistance in obtaining the data necessary to complete this project. Charles Nestle, Greg Johnson, and Robert Larson from Los Angeles County Department of Public Works and Bruce Hick from Earth Systems Consultants provided assistance with data collection. Randy Jibson of the U.S. Geological Survey provided digital terrain data. Terilee McGuire, Lee Wallinder, and Bob Moscovitz provided GIS support. Barbara Wanish and Diane Vaughan prepared the final landslide hazard zone maps and the graphic displays for this report.

REFERENCES

Barrows, A.G., Kahle, J.E. and Beeby, D.J., 1985, Earthquake hazards and tectonic history of the San Andreas Fault Zone, Los Angeles County, California: California Division of Mines and Geology Open-File Report 85-10 LA, 236 p., 21 plates, map scale 1:12,000.

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: 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: Division of Mines and Geology, Special Publication 118, 12 p.

Dibblee, T.W., Jr., 1997, Geologic map of the Sleepy Valley and Ritter Ridge quadrangles, Los Angeles County, California: Dibblee Geological Foundation map DF-66, map scale 1:24,000.

Ehlig, P.L., 1968, Causes of distribution of Pelona, Rand, and Orocopia Schist along the San Andreas and Garlock faults *in* Dickinson, W.R. and Grantz, Arthur, *editors*, Proceeding of the conference on geologic problems of San Andreas Fault System: Stanford Univ. Pub. in Geol. Sci., v.11, p. 294-305.

Ehlig, P.L., 1981, Origin and tectonic history of the basement terrane of the San Gabriel Mountains, Central Transverse Ranges *in* Ernst, W.G., *editor*, The geotectonic development of California, Rubey Volume 1: Prentice-Hall, Inc., Englewood Cliffs, New Jersey, p. 253-283.

Horn, B.K.P., 1981, Hill shading and the reflectance map: Proceedings of the IEEE, v. 69, no. 1, p. 14-47.

Intermap Corporation, 2002, Global Terrain product handbook and quick start guide: http://www.intermap.com/images/handbook/producthandbook.pdf

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., 2001, Mapping earthquake-induced landslide hazards in Santa Cruz County *in* Ferriz, H. and Anderson, R., *editors*, Engineering geology practice in northern California: California Geological Survey Bulletin 210 / Association of Engineering Geologists Special Publication 12, p.77-94.

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.

Newmark, N.M., 1965, Effects of earthquakes on dams and embankments: Geotechnique, v. 15, no. 2, p. 139-160.

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.

Ponti, D.J., Burke, D.B. and Hedel, C.W., 1981, Map showing Quaternary geology of the central Antelope Valley and vicinity, California: U.S. Geological Survey Open-File Report 81-737, map scale 1:62,500.

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.

Southern California Earthquake Center, 2002, Recommended procedures for implementation of DMG Special Publication 117 guidelines for analyzing and mitigating landslide hazards in California: T.F. Blake, R.A. Hollingsworth, and J.P. Stewart, *editors*, Southern California Earthquake Center, University of Southern California, 108 p.

U.S. Geological Survey, 1993, Digital Elevation Models: National Mapping Program, Technical Instructions, Data Users Guide 5, 48 p.

Wang, Y., Mercer, J.B., Tao, V.C., Sharma, J., and Crawford, S., 2001, Automatic generation of bald earth digital elevation models from digital surface models created using airborne IFSAR: http://www.intermap.com/images/papers/asprs2001_Intermap_E.pdf

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., 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

I. K. Curtis Services, November 13, 2000, Frames 826-831, 846-851, and 866-870; color, vertical; approximate scale 1:42,000.

I.K. Curtis Services, 1971, Frames 8178-8191, 2110-2117, and 2118-2123; black and white; vertical; approximate scale 1:12,000.

Geotronics, March 28, 1968, Flight 3, frames 102-107; black and white, vertical; approximate scale 1:24,000.

APPENDIX A
SOURCE OF ROCK STRENGTH DATA

SOURCE	NUMBER OF TESTS SELECTED
Los Angeles County, Department of Public Works	298
Earth Systems Consultants	53
Total Number of Shear Tests	351

SECTION 3
GROUND SHAKING EVALUATION REPORT

Potential Ground Shaking in the Ritter Ridge 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
California Geological Survey
***Formerly with CGS, now with U.S. Geological Survey**

PURPOSE

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

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

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

EARTHQUAKE HAZARD MODEL

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

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

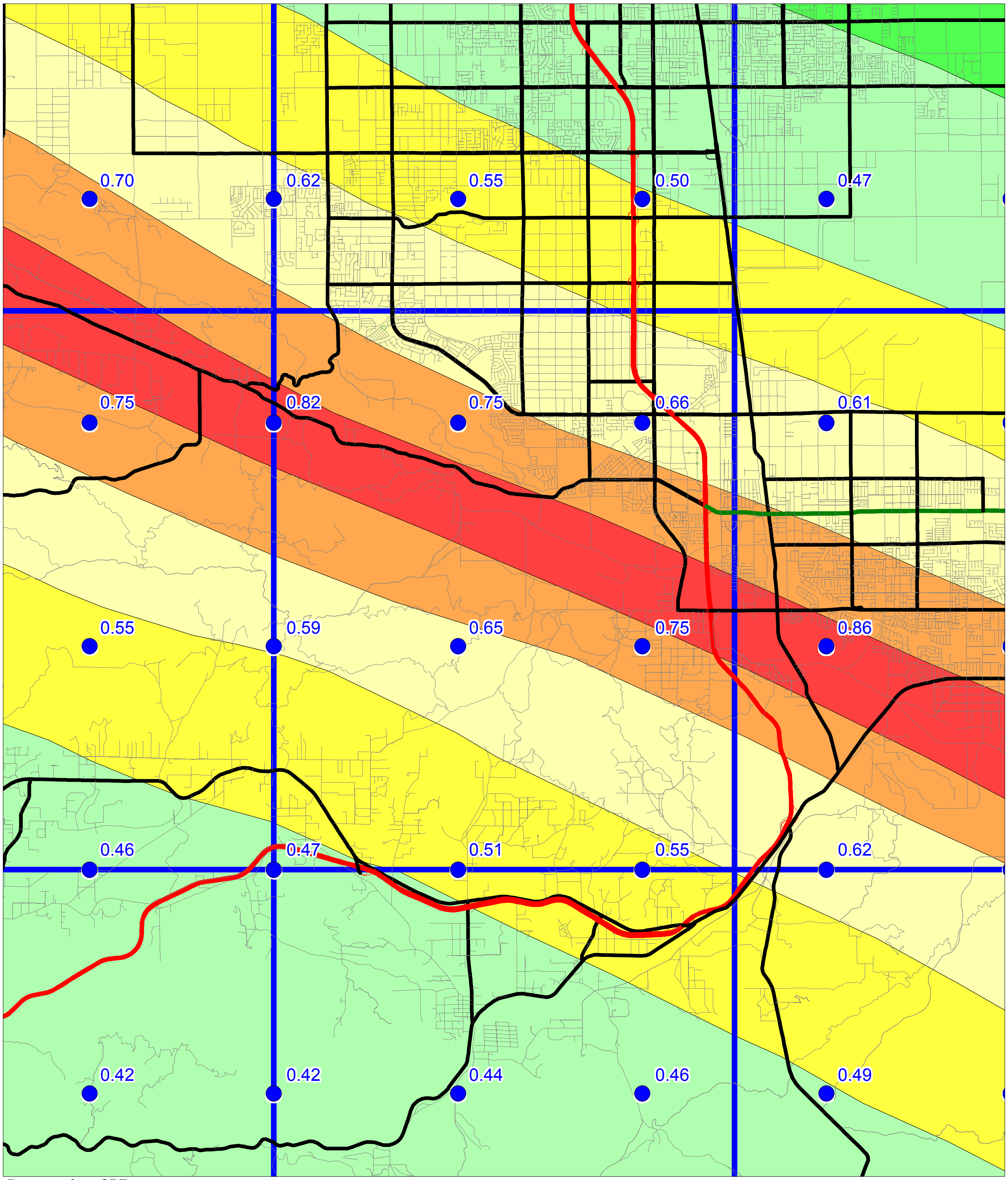
The seismic hazard maps for ground shaking are produced by calculating the hazard at sites separated by about 5 km. Figures 3.1 through 3.3 show the hazard for PGA at 10 percent probability of exceedance in 50 years assuming the entire map area is firm rock, soft rock, or alluvial site conditions respectively.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

RITTER RIDGE 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

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

1998

FIRM ROCK CONDITIONS



Base map from GDT

0 1.5 3
Miles

Department of Conservation
California Geological Survey

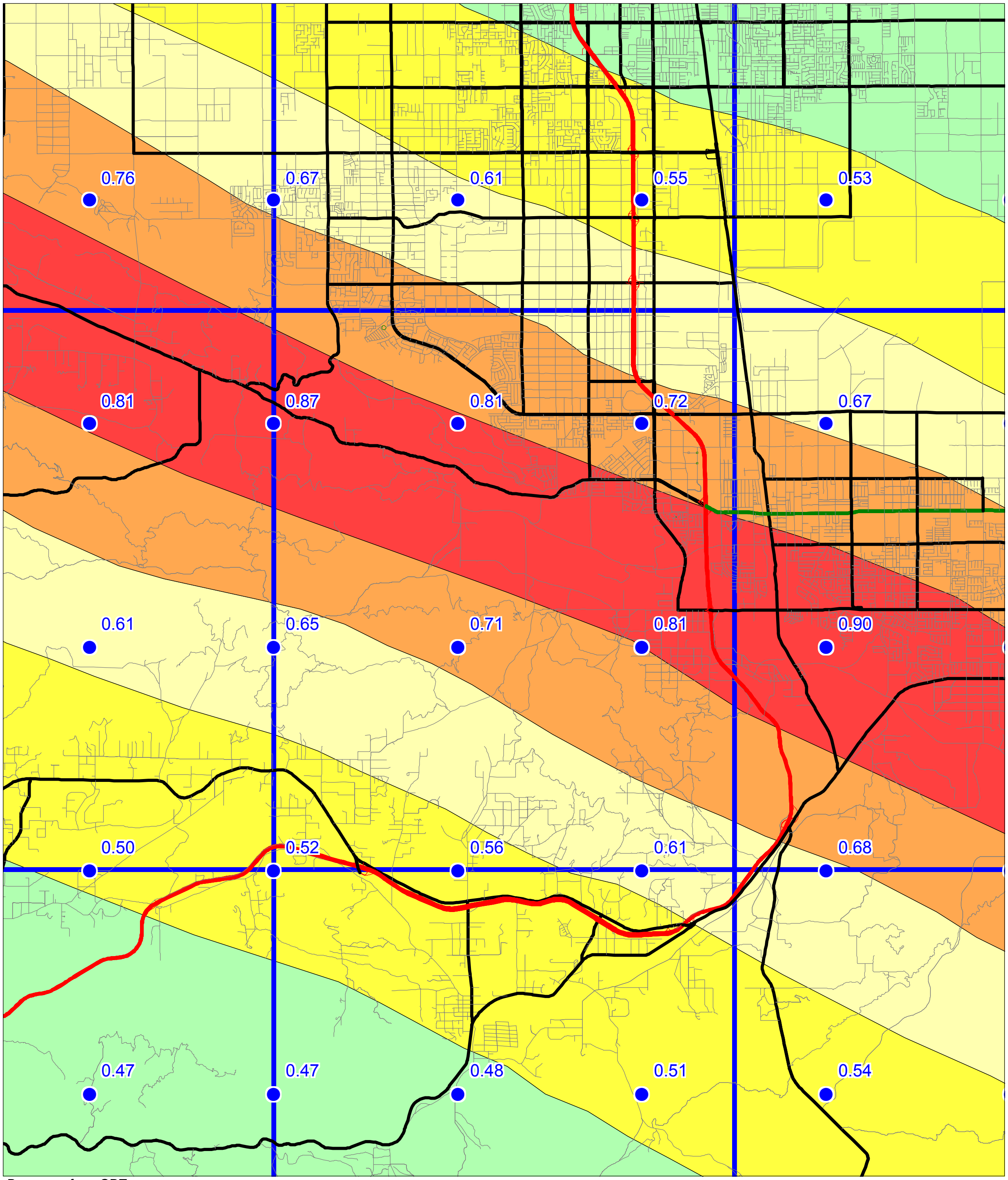
Figure 3.1

RITTER RIDGE 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

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

1998

SOFT ROCK CONDITIONS



Base map from GDT

0 1.5 3
Miles

Department of Conservation
California Geological Survey

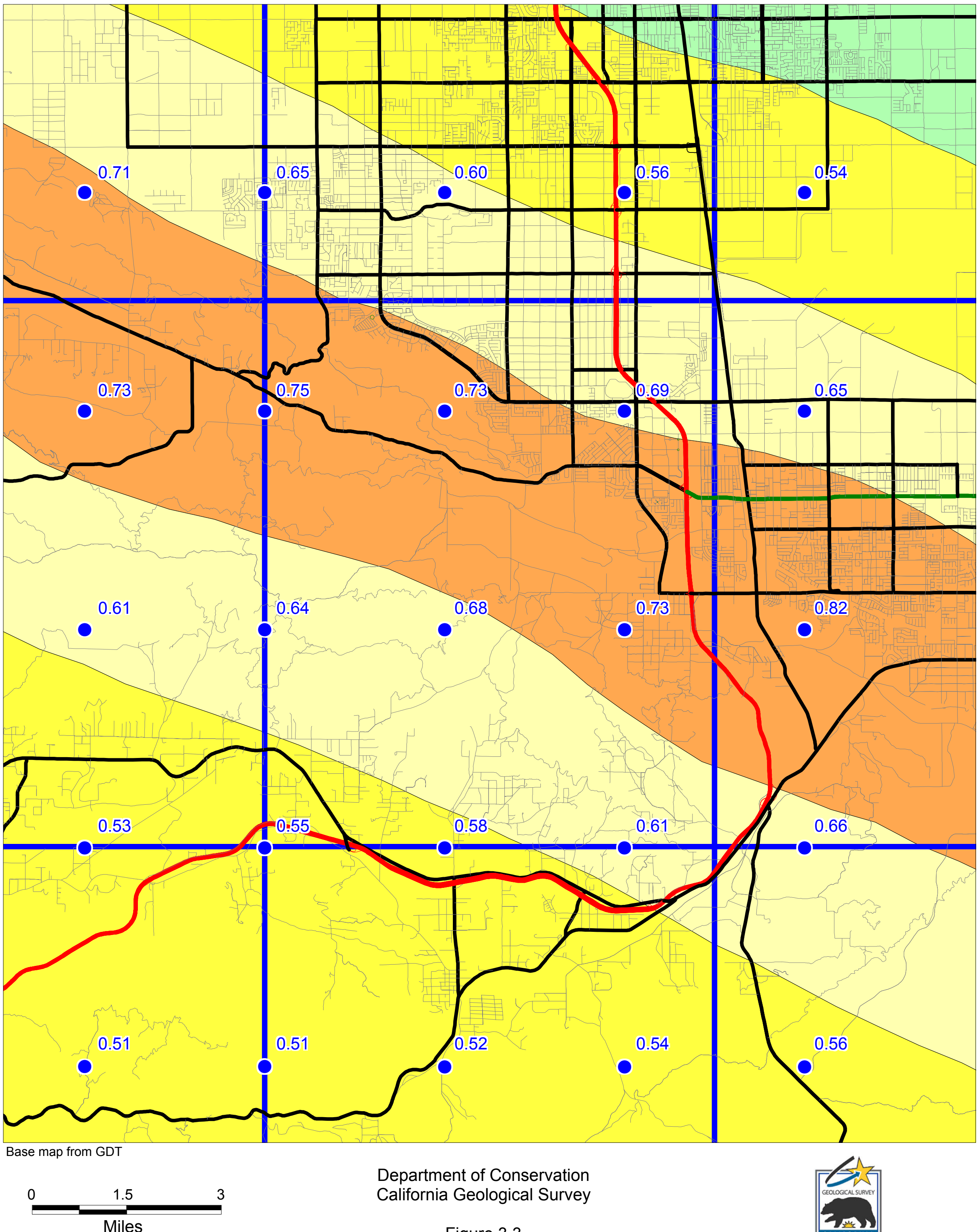
Figure 3.2

RITTER RIDGE 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

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

1998

ALLUVIUM CONDITIONS



Department of Conservation
California Geological Survey

Figure 3.3

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

APPLICATIONS FOR LIQUEFACTION AND LANDSLIDE HAZARD ASSESSMENTS

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

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

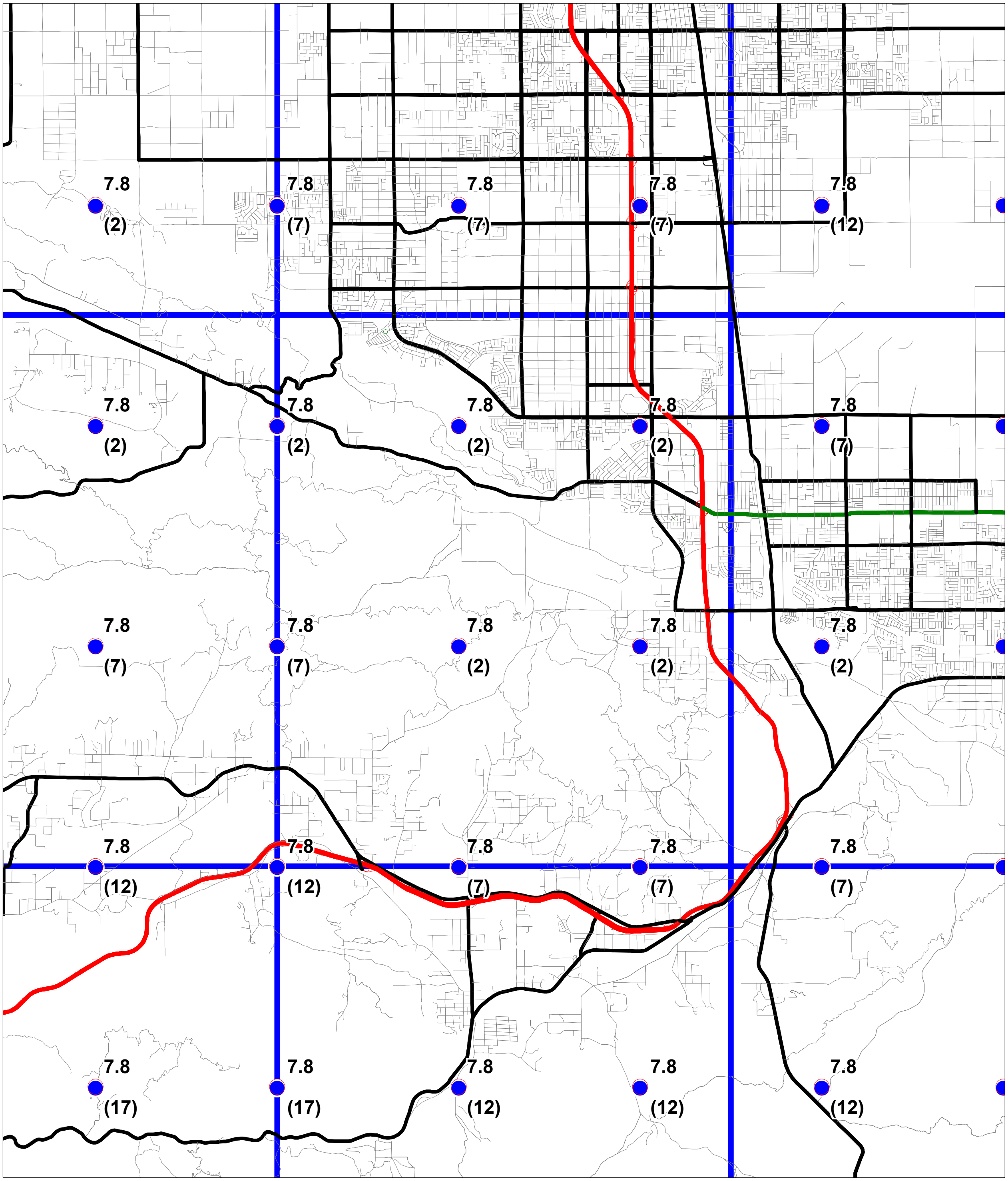
Figure 3.5 shows the magnitude-weighted alluvial PGA based on Idriss' weighting function (Youd and Idriss, 1997). It is important to note that the values obtained from this map are pseudo-accelerations and should be used in the formula for factor of safety without any magnitude-scaling (a factor of 1)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

RITTER RIDGE 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION

1998

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



Base map from GDT

0 1.5 3
Miles

Department of Conservation
California Geological Survey

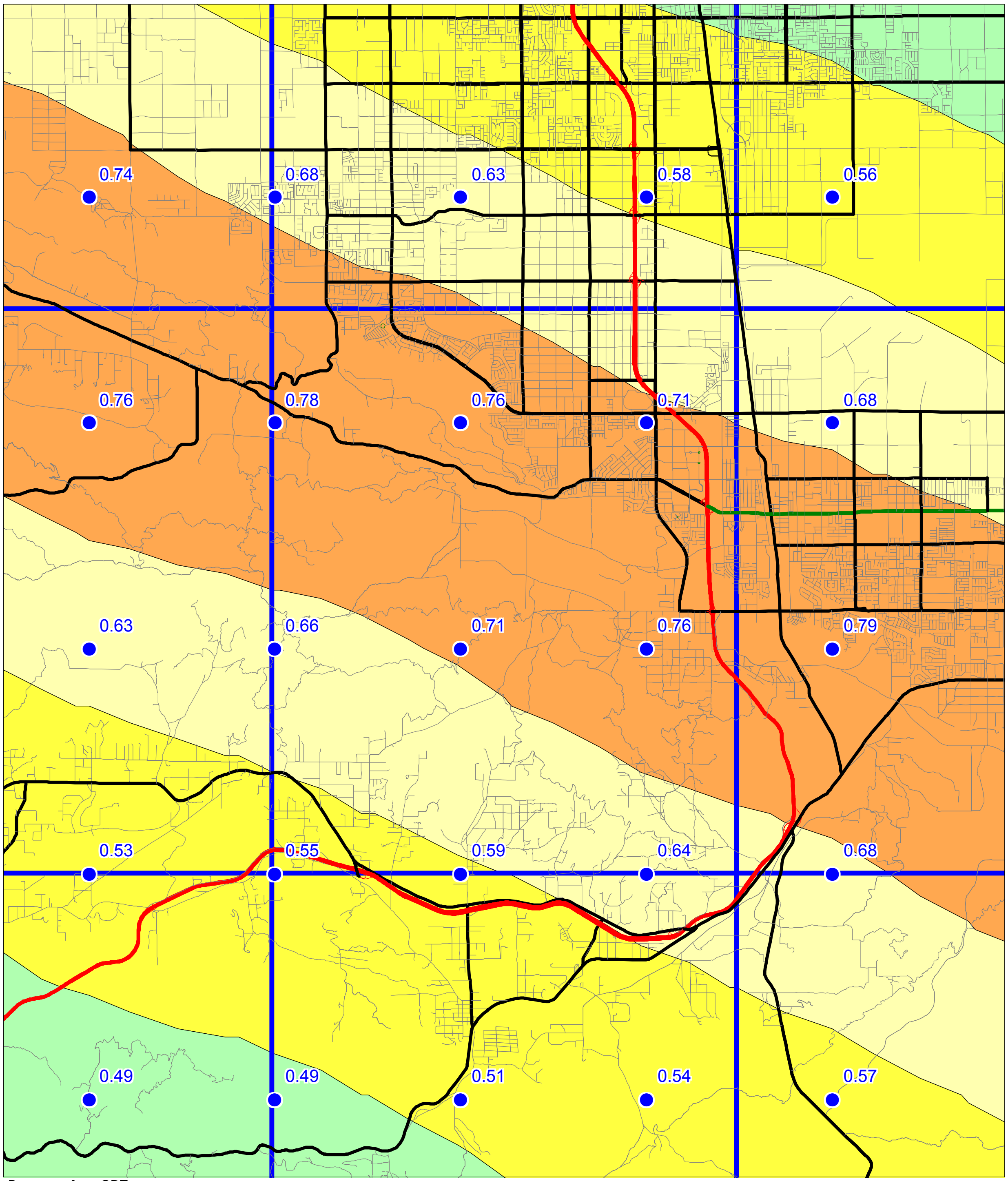
Figure 3.4

RITTER RIDGE 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

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

1998

LIQUEFACTION OPPORTUNITY



Base map from GDT

0 1.5 3
Miles

Department of Conservation
California Geological Survey

Figure 3.5

USE AND LIMITATIONS

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

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

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

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

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

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

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

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.

118°15'

34°37'30"

34°30'

118°7'30"

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

RITTER RIDGE QUADRANGLE

SCALE

1 .5 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 .5 0 1 KILOMETER

N

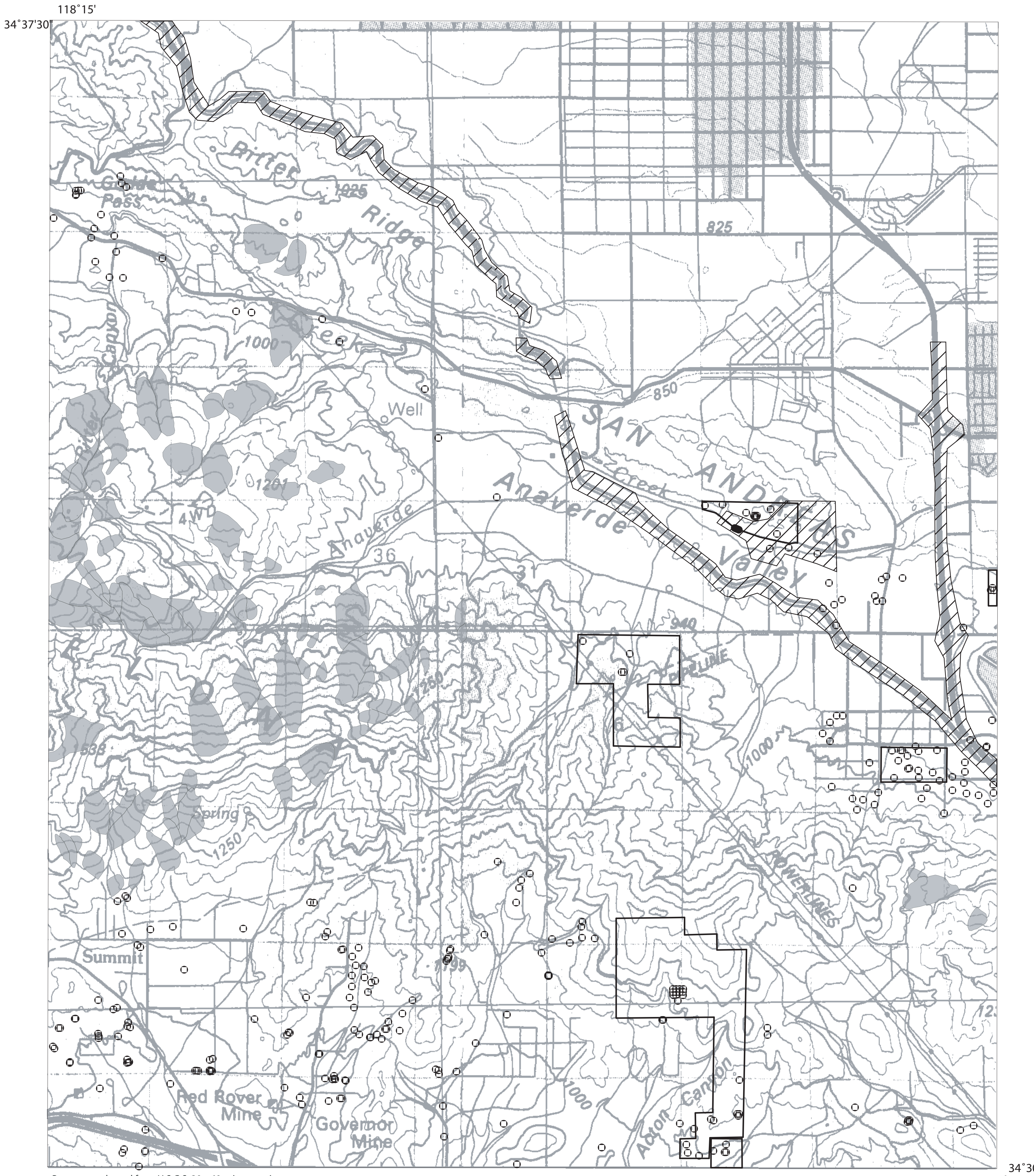
B = Pre-Quaternary bedrock.

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

Plate 1.1 Quaternary Geologic Map of the Ritter Ridge 7.5-Minute Quadrangle, California

Northern, central, and southern map sections are modified from Ponti and others (1981), Barrows and others (1985), and Dibblee (1997), respectively.

Plate 1.2 Depth to historically shallowest ground water and locations of boreholes used in this study, Ritter Ridge 7.5-Minute Quadrangle, California.



RITTER RIDGE QUADRANGLE

SCALE

1	.5	0	1 MILE
1000 0	2000	4000	6000 FEET
1	.5	0	1 KILOMETER

N

Shear test sample location

Landslide

Area of significant grading

Tract report with multiple shear tests

Plate 2.1 Landslide inventory, shear test sample locations and areas of significant grading, Ritter Ridge 7.5-Minute Quadrangle, California