APPENDIX A – EXISTING DRAWINGS

AVAILABLE UPON REQUEST

APPENDIX B – PHOTOS

Photo B.1
Peters Canyon Reservoir Roof Looking South West

Photo B.2
Peters Canyon Reservoir Roof and North Wall

20-EOWWD1-15PhotoB1&2-9711A00.AI

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Photo B.3
Peters Canyon Reservoir Roof Central Vent

Photo B.4
Peters Canyon Reservoir Typical Pilaster

20-EOWWD1-15PhotoB3&4-9711A00.AI

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Photo B.5
Peters Canyon Reservoir CMU wall Vent and Zip-Rib Roof

Photo B.6
Peters Canyon Reservoir - Typical Roofing and Flashing

Photo B.7
Peters Canyon Reservoir West Wall Looking South East

Photo B.8
Peters Canyon Reservoir Typical Purlin and brace at Perimeter Wall

20-EOWWD1-15PhotoB7&8-9711A00.AI

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Photo B.9
Peters Canyon Reservoir Typical Brace Bottom Connection at Perimeter wall

Photo B.10
Peters Canyon Reservoir Typical Framing at Central Vent

20-EOWWD1-15PhotoB9&10-9711A00.AI

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Photo B.11
Peters Canyon Reservoir Purlin to Glulam Connection

Photo B.12
Peters Canyon Reservoir Interior Concrete Columns and Braces

Photo B.13
Peters Canyon Reservoir Hypalon Liner

Photo B.14
Peters Canyon Reservoir Zip-Rib Interior Clip Connection

20-EOWWD1-15Photo13&14-9711A00.AI

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Photo B.15
Peters Canyon Reservoir Typical Hanger Connection at Purlin

Photo B.16
Peters Canyon Reservoir South Wall Looking North-East

Photo B.17
Peters Canyon Reservoir East Wall Looking North

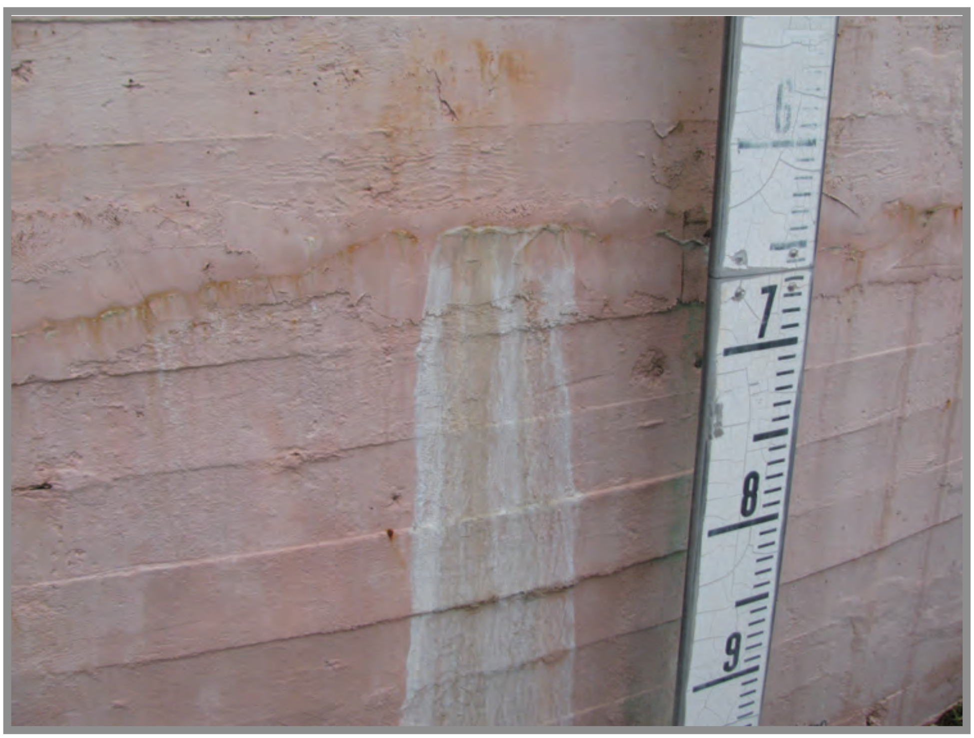


Photo B.18
Vista Panorama Reservoir Wall Elevation with Evidence of Water Leak

APPENDIX C – CONVERSE CONSULTANTS REVIEW LETTER

January 21, 2015

James A. Doering, P.E., S.E.
Principal Structural Engineer
Carollo Engineers, Inc.
3150 Bristol Street, Suite 500
Costa Mesa, California 92626

Subject: **GEOTECHNICAL REVIEW OF SLOPE STABILITY ANALYSIS AND PROVIDING UPDATED SEISMIC DESIGN PARAMETERS**
Existing 6-Million Gallon Reservoir
East Orange County Water District
Orange, California
Converse Project No. 15-31-112-01

Dear Mr. Doering:

In accordance with your request, Converse Consultants (Converse) has prepared this letter to provide our geotechnical review of slope stability analysis and provide updated seismic design parameters for the Geotechnical and Seismic Hazard Assessment Report by American Geotechnical, Inc.

Based on our review of the April 2, 2014 *Geotechnical and Seismic Hazard Assessment Report*, the geotechnical recommendations presented in the referenced report with regards to slope stability analyses are acceptable. This slope stability analyses also seem to be in agreement with a previous *Materials Report for Design Section 10 for State Routes 241 and 261*, dated July 18, 1997.

Our updated seismic design parameters, including fault modeling to account for the Peralta Hills Fault based on recent published information, are presented below. The location of the Peralta Hills Fault with reference to the subject site is shown in Drawing No. 1, *Project Site*.

CBC Seismic Design Parameters

Seismic parameters based on the 2013 California Building Code are calculated using the United States Geological Survey *U.S. Seismic Design Maps* website application and the site coordinates (33.7765 degrees North Latitude, 117.7552 degrees West Longitude). The seismic parameters are presented in the table below.

PROJECT SITE

Converse Consultants

EAST ORANGE COUNTY WATER DISTRICT
EXISTIN 6 MILLION GALLON RESERVOIR
ORANGE, CALIFORNIA
FOR: CAROLLO ENGINEERS, INC.

Project No.	Drawing No.
15-31-112-01	1

Table No. 1, CBC Seismic Design Parameters

Seismic Parameters	2013 CBC
Site Class	C
Mapped Short period (0.2-sec) Spectral Response Acceleration, S_S	1.500 g
Mapped 1-second Spectral Response Acceleration, S_1	0.581 g
Site Coefficient (from Table 1613.5.3(1)), F_a	1.0
Site Coefficient (from Table 1613.5.3(2)), F_v	1.3
MCE 0.2-sec period Spectral Response Acceleration, S_{MS}	1.500 g
MCE 1-second period Spectral Response Acceleration, S_{M1}	0.755 g
Design Spectral Response Acceleration for short period, S_{DS}	1.000 g
Design Spectral Response Acceleration for 1-second period, S_{D1}	0.504 g
Seismic Design Category	D

Site-Specific Response Spectra

The subject site is not located in a Seismic Hazard Zone, defined as a mapped California State Earthquake (previously Alquist-Priolo Earthquake Fault Zone), Liquefaction or Earthquake Induced Landslide zone per latest California Geologic Survey (CGS) state maps. Based on 2013 CBC Section 1616A.1.3, a site-specific ground motion analysis is not required A site-specific response spectrum was developed for the project for a Maximum Considered Earthquake (MCE), defined as a horizontal peak ground acceleration that has a 2 percent probability of being exceeded in 50 years (return period of approximately 2,475 years).

In accordance with ASCE 7-10, Section 21.2 the site-specific response spectra can be taken as the lesser of the probabilistic maximum rotated component of MCE ground motion and the 84th percentile of deterministic maximum rotated component of MCE ground motion response spectra. The design response spectra can be taken as 2/3 of site-specific MCE response spectra, but should not be lower than 80 percent of CBC general response spectra. The risk coefficient C_R has been incorporated at each spectral response period for which the acceleration was computed in accordance with ASCE 7-10, Section 21.2.1.1.

The 2013 CBC mapped acceleration parameters are provided in the following table. These parameters were determined using the United States Geological Survey *U.S. Seismic Design Maps* website application, and in accordance with ASCE 7-10 Sections 11.4, 11.6, 11.8 and 21.2.

Table No. 2, 2013 CBC Mapped Acceleration Parameters

Site Class	C	Seismic Design Category	D
S_S	1.500	**C_{RS}**	1.028
S_1	0.581	**C_{R1}**	1.056
F_a	1	**0.08 F_v/F_a**	0.104
F_v	1.3	**0.4 F_v/F_a**	0.520
S_{MS}	1.500	**T_0**	0.101
S_{M1}	0.755	**T_S**	0.504
S_{DS}	1.000	**T_L**	8
S_{D1}	0.504		

A Site-Specific response analysis, using faults within 100 kilometers of the sites, was developed using the computer program EZ-FRISK by Risk Engineering (v. 7.62) and the 2008 USGS Fault Model database. Attenuation relationships proposed by Boore and Atkinson (2008), Campbell and Bozorgnia (2008), Chiou and Youngs (2008) were used in the analysis. These attenuation relationships are based on Next Generation Attenuation (NGA) project model. Maximum rotated components were determined using Huang (2008) method. An average shear wave velocity at upper 30 meters of soil profile (V_{s30}) of 550 meters per second, depth to bedrock of with a shear wave velocity 1,000 meters per second at 50 meters below grade, and depth of bedrock where the shear wave velocity is 2,500 meters per second at 3,000 meters below grade were selected for EZ-Frisk Analysis.

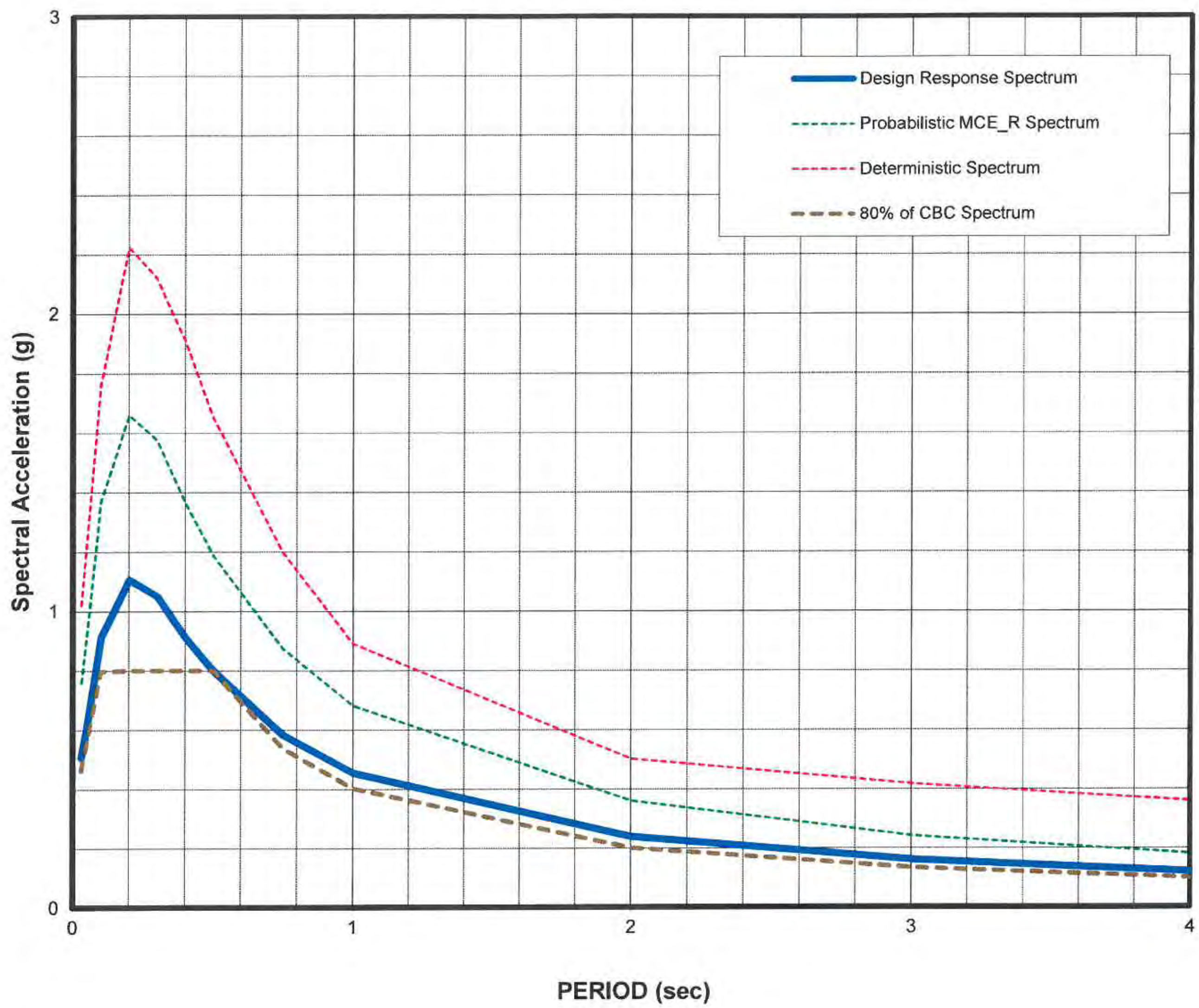
The Peralta Hills fault, which is not found in the available seismic sources database of the EZ-Frisk program, was modeled based on available reference materials from fault studies (Bryant and Fife) as well as USGS Quaternary Fault Google Earth (kmz) files. With the limited data available for the Peralta Hills Fault, horizontal and vertical geometry of the fault as well as deterministic magnitude, and dip orientation along with several other parameters were modeled into the EZ-Frisk seismic sources database to account for the Peralta Hills Fault as part of the site specific seismic design parameters analysis.

Applicable response spectra data are presented in the table below and on Drawing No. 2, *Site-Specific Design Response Spectrum.* These curves correspond to response values obtained from above attenuation relations for horizontal elastic single-degree-of-freedom systems with equivalent viscous damping of 5 percent of critical damping.

Table No. 3, Site-Specific Response Spectrum Data

Period (sec)	2% in 50yr Probabilistic Spectral Acceleration (g)	Risk Coefficient C_R	Probabilistic MCE_R Spectral Acceleration (g)	84th Percentile Deterministic MCE Response Spectra, (g)	Deterministic CBC Lower Level, (g)	Site Specific MCE_R Spectral Acceleration (g)	80% CBC Design Response Spectrum	Site Specific Design Spectral Acceleration (g)
0.03	0.739	1.028	0.760	1.021	0.860	0.760	0.463	**0.506**
0.05	0.896	1.028	0.921	1.223	1.033	0.921	0.558	**0.614**
0.10	1.332	1.028	1.369	1.764	1.465	1.369	0.797	**0.913**
0.20	1.615	1.028	1.660	2.224	1.500	1.660	0.800	**1.107**
0.30	1.528	1.032	1.576	2.120	1.500	1.576	0.800	**1.051**
0.40	1.320	1.035	1.366	1.909	1.500	1.366	0.800	**0.911**
0.50	1.144	1.039	1.188	1.654	1.500	1.188	0.800	**0.800**
0.75	0.834	1.047	0.873	1.198	1.040	0.873	0.537	**0.582**
1.00	0.646	1.056	0.682	0.891	0.780	0.682	0.403	**0.455**
2.00	0.341	1.056	0.360	0.501	0.390	0.360	0.201	**0.240**
3.00	0.229	1.056	0.242	0.417	0.260	0.242	0.134	**0.161**
4.00	0.173	1.056	0.182	0.360	0.195	0.182	0.101	**0.122**

Vertical acceleration at the site may be calculated using the ASCE 7-10, Section 12.4.



Note: Calculated using EZFRISK program Risk Engineering, version 7.62
and USGS 2008 fault model database.

SITE SPECIFIC DESIGN RESPONSE SPECTRUM

East Orange County Water District Existing 6-Million Gallon Reservoir Orange, CA For : Corollo Engineers, Inc.	Project Number: 15-31-112-01
Converse Consultants	Drawing No. 2

The site-specific design response parameters are provided in the following table. These parameters were determined from Design Response Spectra presented in table above, and following guidelines of ASCE Section 21.4.

Table No. 4, Site-Specific Seismic Design Parameters

	Design Parameters (5% Damping)	Lower Limit, 80% of CBC Design Spectra
Site-Specific 0.2-second period Spectral Response Acceleration, S_{MS}	1.660	1.200
Site-Specific1-second period Spectral Response Acceleration, S_{M1}	0.720	0.604
Site-Specific Design Spectral Response Acceleration for short period S_{DS}	1.107	0.800
Site-Specific Design Spectral Response Acceleration for 1-second period, S_{D1}	0.480	0.403

We appreciate the opportunity to be of continued service to Carollo Engineers, Inc. If you have any questions or require additional information, please call the undersigned at (626) 930-1275.

CONVERSE CONSULTANTS

Registered Professional Engineer
Kathiravetpillai Sivathasan
No. 2708
Exp. 6-30-16
Geotechnical
State of California

Siva K. Sivathasan, PhD, PE, GE, DGE, QSD, F. ASCE
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Mark B. Schluter
No. 1415
Certified Engineering Geologist
State of California

Mark B. Schluter, PG, CEG
Senior Engineering Geologist

Dist: 2/Addressee
MM/MBS/SKS/jjl

References

1) *Geotechnical and Seismic Hazard Assessment Report, Existing 6-Million Gallon Reservoir, East Orange County Water District, Handy Creek Road, Orange, California,* prepared by American Geotechnical, Inc., File No. 33615-01, dated April 2, 2014.

2) *Municipal Water District of Orange County Earthquake Vulnerability Study, Five Earthquake Scenario Ground Motion Maps for Northern Orange County, prepared by Earth Consultants International, ECI Project No. 2509, dated June 20, 2005.*

3) *The Peralta Hills Fault, a Transverse Ranges Structure in the Northern Peninsular Ranges, Geology and Mineral Wealth of the California Transverse Ranges, South Coast Geological Society, prepared by Mark E. Bryant and Donald L. Fife, Converse Consultants, Inc., dated 1982.*

4) *Geotechnical Report (Addendum), Proposed Tunnels for Diemer Intertie Project Phase IV, Design, Municipal Water District of Orange County, prepared by W. A. Wahler & Associates, Project BEC105A, dated September, 1978.*

5) *Seismic Refraction Study of the El Modeno Fault, Orange County, California, California Geology, prepared by J. A. Ryan, Jon N. Burke, A. F. Walden, and Daniel P. Wieder, dated January, 1982.*

6) *Revised Final Materials Report for Design Section 10, State Routes 241 and 261, Eastern Transportation Corridor, Orange County, CA, prepared by Silverado Constructors, Submittal No. E10GXX-01, dated July 18, 1997.*

7) *Revised Final Analyses and Calculations Materials Report for Design Section 10, State Routes 241 and 261, Eastern Transportation Corridor, Orange County, CA, prepared by Silverado Constructors, Submittal No. E10GXX-01, dated July 18, 1997.*

8) *Risk Engineering Inc., EZ_FRISK, Version 7.62, 2011, A Computer Program for Site Specific Seismic Hazard Analyses.*

9) *CALIFORNIA BUILDING CODE (CBC), 2013, International Conference of Building Officials.*

APPENDIX A

PERALTA HILLS FAULT REFERENCE INFORMATION

April 2, 2014 File No. 33615-01

Brady Engineering
3710 Ruffin Road
San Diego, CA 92123

Attention: Mr. Sean Sudol, Smarter Water Program Manager

Subject: **GEOTECHNICAL AND SEISMIC HAZARD ASSESSMENT REPORT**
Existing 6-Million Gallon Reservoir
East Orange County Water District
Handy Creek Road
Orange, California

References: See Appendix A

Dear Mr. Sudol:

In accordance with your request, American Geotechnical has completed a geotechnical investigation and seismic hazard assessment for the existing 6-Million gallon reservoir site located on Handy Road in Orange, California, as indicated on Plate 1. The purpose of this investigation was to evaluate the site geotechnical conditions related to slope stability conditions, to identify potential geologic hazards associated with the project site, and make recommendations for site improvements related to hillside stability and surface drainage structures. Our findings, conclusions, and preliminary recommendations for earthwork and foundations are presented below.

1.0 SCOPE OF WORK

The scope of the work performed during this investigation included the following:

- Review of engineering plans for construction of the reservoir;
- Review engineering and hydrogeology reports for the project site prepared by others;
- Performing a preliminary geologic reconnaissance of the site and vicinity;
- Drilling and logging, using visual and tactile methods, four (4) soil borings;

- Collection of undisturbed and bulk samples of representative materials encountered in the soil borings;
- Performing laboratory testing of the selected soil samples;
- Performing engineering analyses of the field and laboratory data;
- Performing a geologic hazard assessment of the project site;
- Evaluation of groundwater conditions beneath the project site;
- Performing slope stability assessments of the existing slopes surrounding the reservoir; and,
- Preparation of this report summarizing our field investigation, laboratory testing, findings, conclusions, and recommendations.

2.0 SITE DESCRIPTION

We understand that the project site (6 MG reservoir) was constructed along a northwest-southeast trending ridgeline through a combination of excavation (cut) and placement of fill soils (fill) and is approximately 290 feet long, 165 feet wide, and approximately 16 to 17 feet deep. The reservoir is a side sloped concrete structure lined with a flexible hypalon membrane (based on visual appearance approximately 40-45 mil thick) with a perimeter masonry block wall supporting the existing roof. There is a perimeter asphalt driveway surrounding the reservoir.

It is understood that the water district is evaluating replacement of the existing roof deck and has requested evaluation of the stability of the hillsides surrounding the reservoir prior to proceeding with site improvements.

3.0 SITE GEOLOGY

The project site is underlain by sedimentary deposits mapped by J.E. Shoellhamer and D.M. Kinney, R.F. Yerkes, and J.G. Vedder (1954) as Eocene to Miocene age " Undifferentiated Vasqueros Formation and Sespe Formation" and Late Miocene age "La Vida Member of the Puente Formation". The geologic map prepared by Shoellhamer et. al. identify that the existing reservoir straddles the contact between the Vasqueros/Sespe and La Vida/Puente sediments and they further define the contact as a "fault contact". This map also identifies that the La Vida/Puente sediments are inclined (dip) to the north at angles ranging from 21° to 29° (angle from horizontal).

Subsequent geologic mapping by P.K. Morton and R.V. Miller (1981) also identifies that the site is underlain by the “Undifferentiated Vasqueros/Sespe Formation” and the "La Vida Member of the Puente Formation" and similarly identifies the contact between the Vasqueros/Sespe and La Vida/Puente sediments as a "fault contact". This map also identifies that the La Vida/Puente sediments dip to the north at an angle of 25° beneath the project site.

A subsequent geologic map prepared by D.M. Morton (2004) continues to depict that the site is underlain by both the “Vasqueros/Sespe Formation” and the "La Vida Member of the Puente Formation"; however, the contact between the two units is no longer identified as a "fault contact". Morton identifies that the La Vida/Puente sediments dip to the north at an angle of 25° beneath the project site.

Geologic mapping of the project site during the site reconnaissance and during the geotechnical investigation identified sediments on the easterly hillside cut slope and native sediments observed in the soil borings as being consistent with the La Vida sediments, while the sediments west of the reservoir property perimeter fence and the Cox Communication facilities were consistent with the Vasqueros/Sespe sediments.

Prior grading for construction of the reservoir likely encountered both the Vasqueros/Sespe and La Vida formations, and construction of the fill sediments around the reservoir currently masks the geologic contact. In addition, the geologic contact between these units could not be observed or distinguished beyond the reservoir property boundary due to the prior grading and existing soil horizon developed at the ground surface. Based on the consistency of the native sediments encountered in the geotechnical soil borings, as well as the previous soil borings advanced by GeoPentech, it is our opinion that the contact between the Vasqueros/Sespe and La Vida/Puente formations exists along the eastern margin of the site beneath the reservoir structure.

4.0 SUBSURFACE INVESTIGATION

Our subsurface investigation included advancing four (4) soil borings (AGSB-1 thru AGSB-4) at the project site on February 10, 2014, at the approximate locations shown in Plate 2.

The materials encountered in the soil borings consisted of approximately 10-feet (Boring AGSB-1) to 26-feet (AGSB-3) of gray silty sand (fill soil) overlying native colluvium consisting of orange to yellow and gray silty sand with some gravel. Native sediments consisting of dark gray silty sand (siltstone) of the La Vida/Puente Formation were encountered beneath the fill soils and beneath the colluvium to the depth of 36.5 feet (limits of exploration) across the project site. Groundwater seepage was not encountered in the soil borings, and regional high groundwater levels are reported to exceed 50-feet below the ground surface.

The soil borings were logged by our field personnel using both visual and tactile methods. Detailed boring logs are presented in Appendix B. Representative samples of the subsurface materials were collected from all borings and forwarded to the laboratory for the purpose of estimating material properties for use in subsequent engineering evaluations.

GeoPentech advanced soil borings along the southern area the project site in 2010 at approximate locations depicted on Plate 3 to evaluate groundwater seepage conditions associated with a shallow hillside slope failure. Their borings extended to depths of 51-feet below the ground surface and encountered similar fill soil, colluvium, and light- to dark gray siltstone sediments identified as La Vida/Puente Formation. Groundwater was not observed in the soil borings by GeoPetech personnel at the time of drilling, and monitoring wells were constructed in each of the borings for long-term monitoring. Information provided from East Orange County Water District personnel indicated that groundwater has not been observed in these monitoring wells to date.

Five different geologic cross-sections (Sections A-A' thru E-E') were developed to depict the underlying fill soil and bedrock conditions at the locations depicted on Plate 3. These cross-sections (see Plates 4 thru 6) were used to assist in selection of critical sections for the slope stability analyses (presented later in this report).

The soil borings were backfilled with soil cuttings derived from the drilling activities to match the existing surface conditions.

5.0 LABORATORY TESTING

Laboratory testing was performed on samples collected during our field exploration. Samples were tested for the purpose of estimating material properties for use in the subsequent engineering evaluation. Tests included in-situ moisture and density, maximum density and optimum moisture content, gradation, direct shear, and chemical testing. A summary of our laboratory test results is presented in Appendix C.

6.0 SEISMIC HAZARDS

The project site is situated within an area of southern California which is traversed by numerous active faults capable of generating moderate to large magnitude earthquakes. The closest active fault to the project site is the Whittier Fault located approximately 7.8 miles to the north. A summary of the local faults, the distances to the project site, estimated maximum magnitude earthquake, and estimated ground movement at the site resulting from an earthquake along each of these faults is included in Appendix D. A summary of the nearby active faults is summarized in Table 1 below:

TABLE 1

SUMMARY OF FAULT CHARACTERIZATIONS AND DISTANCE FROM SITE

FAULT	APPROXIMATE DISTANCE FROM SITE	TYPE OF FAULT	MAXIMUM EARTHQUAKE MAGNITUDE (Mw)
Whittier	7.8 miles	Strike Slip	6.8
Elsinore-Glen Ivy	8.8 miles	Strike Slip	6.8
Chino-Central Ave. (Elsinore)	9.8 miles	Strike Slip	6.7
Elysian Park Thrust	12.2 miles	Thrust	6.7
Compton Thrust	14.1 miles	Thrust	6.8
Newport Inglewood (L.A. Basin Segment)	15.3 miles	Strike Slip	6.9
Newport Inglewood (Offshore Segment)	15.8 miles	Strike Slip	6.9

Note: Data derived from EQFault Analysis

Seismic hazards for any site in southern California include primary hazards (ground rupture and ground shaking) and secondary hazards (liquefaction, ground settlement, lurch cracking, lateral spreading, and landslides). The primary and secondary hazards for the project site are addressed below:

Fault Rupture

Surface rupture occurs when movement along a fault breaks through to the ground surface. The ground rupture almost always follows pre-existing faults, which are zones of weakness, and may occur suddenly during an earthquake or slowly in the form of fault creep. Sudden displacements are more damaging to structures because they are accompanied by ground shaking.

The project area is not located within an Alquist-Priolo Earthquake Fault Zone, and no active faults are mapped to pass through the project site. However, previous geologic mapping has identified the contact between the Vasqueros/Sespe and La Vida/Puente formations to be a "fault contact" and this contact represents a zone of weaker soil conditions within the footprint of the reservoir. As such, there is low to moderate risk of localized ground displacement (on the order of millimeters to centimeters) adjacent to or beneath the reservoir structure as a result of a local large magnitude earthquake.

Ground Shaking

The intensity of the seismic shaking or strong ground motion at the project site during an earthquake depends on the distance between the project area and the epicenter of the earthquake, the magnitude of the earthquake, and the geologic conditions underlying and surrounding the site. Earthquakes occurring on faults closest to the project site would most likely generate the largest ground motions within the project area.

The EQFault analysis (Appendix D) estimates that the degree of ground shaking reported as peak ground acceleration (%g) at the project site would be 0.316g. This data suggests that the project site is at moderate risk of experiencing strong ground shaking for future earthquakes along the local active faults. The EQFault analysis also indicates that the site could experience Intensity IX ground shaking effects as described by the Modified Mercalli Intensity Scale.

A regional probabilistic seismic hazard analysis was performed for the project site utilizing the United States Geologic Survey Probabilistic Seismic Hazard Analysis procedures. This analysis utilizes historic earthquake records combined with specified earthquake return periods for various magnitude earthquakes on individual faults. The combined analysis results in an estimation of the probability of any magnitude earthquake occurring during a given exposure period. Table 2 presents the findings of the probabilistic analysis:

TABLE 2

EARTHQUAKE PROBABILITY ANALYSIS RESULTS

SPECIFIED EARTHQUAKE MAGNITUDE (Magnitude X)	PROBABILITY OF AN EARTHQUAKE EQUAL TO OR GREATER THAN THE SPECIFIED MAGNITUDE (X) OCCURRING WITHIN 50 YEARS AND WITHIN 50 KILOMETERS OF PROJECT SITE
M=5	100%
M=6	60% to 80%
M=6.5	40% to 80%
M=7.0	15% to 40%
M=7.5	3% to 12%
M=8.0	0% to 1%

Further evaluation identified that the project site has a cumulative risk of ground motion originating from an earthquake occurring on any given fault segment for any period of exposure. The analysis indicated that the site has a 10 percent (10%) probability of experiencing or exceeding a ground motion of 0.3g to 0.4g during a 50-year exposure period. This 10% in 50-year risk analysis is consistent with the deterministic results derived from the EQFault analysis.

The probabilistic analysis further indicated that the site has a 2 percent (2%) probability of experiencing or exceeding a ground motion of 0.5g to 0.6g for the same 50-year exposure period.

Liquefaction and Differential Compaction

Liquefaction is a phenomenon in which saturated granular sediments temporarily lose their shear strength during periods of earthquake-induced strong ground shaking. The susceptibility of a site to liquefaction is a function of the depth, density, and water content of the sediments and the magnitude of an earthquake. Saturated, unconsolidated silts, sands, silty sands, and gravels within 50 feet of the ground surface are most susceptible to liquefaction. Typical effects of liquefaction include loss of bearing strength, lateral spreading, and settlement. Differential compaction occurs when unsaturated, cohesionless soil is densified by earthquake vibrations, causing differential settlement.

The sediments beneath the project site consist of compacted fill soils and dense silty sand deposits, and the water table exceeds a depth of 50-feet below the ground surface; therefore, the project site has a low susceptibility for liquefaction and differential compaction.

Earthquake-Induced Lurch Cracking, Lateral Spreading, and Landslides

The project site is situated along an existing hillside cut slope; therefore, the project site has a low to moderate susceptibility for lurch cracking, lateral spreading, or landslide activity during a strong earthquake event.

The existing hillside fill slopes have been buried with a thick mantle of vegetation and tree trimmings/debris resulting in a very soft and loose slope surface condition. In addition, there are numerous gopher holes present throughout the hillside areas and there are no perimeter curbs or surface drains on the existing paved perimeter road to intercept and reduce surface water runoff from flowing directly over the hillside slopes.

A preliminary slope stability assessment was performed for the existing hillside fill slopes surrounding the reservoir, and the findings are discussed in the following section of this report.

Tsunamis and Seiches

The project site is a reservoir site, therefore, the surrounding hillside slopes have a high susceptibility for inundation from seiches (water leaving the reservoir through vents or by partial wall/roof failure); however, given the great distance from the ocean and elevation of the ground surface (approximately 790 feet msl) the susceptibility due to tsunamis is very low.

7.0 SLOPE STABILITY ANALYSIS

A preliminary slope stability assessment was performed for the existing hillside slopes surrounding the reservoir and two (2) cross-sections (Sections D-D' and E-E') were selected as "critical slopes" for further assessment. Cross-section E-E' was separated into two distinct areas identified as: (1) "upper slope area" (hillside slope from the reservoir to just above the entrance service road) and (2) "lower slope area" (hillside slope from the entrance service road to the northerly property boundary) as depicted on Plate 7.

The slope stability analysis was performed on Sections D-D' and E-E' for the following conditions:

1) No groundwater present within 50 feet of the ground surface (dry soil-no leak conditions).
2) No groundwater present within 50 feet of the ground surface (dry soil-no leak conditions) under seismic loading.
3) Groundwater present at or below the fill soil-native soil contact (long-term minor leak condition).
4) Groundwater present at or below the fill soil-native soil contact (long-term minor leak condition) under seismic loading.
5) Groundwater present within the fill soils (moderate, long-term leak condition).
6) Groundwater present within the fill soils (moderate, long-term leak condition) under seismic loading.
7) Groundwater present within the fill soils rising to near the ground surface (catastrophic severe leak condition).
8) Groundwater present within the fill soils rising to near the ground surface (catastrophic severe leak condition) under seismic loading.

The stability of the site based on the available information was analyzed using the GSTABL computer program. The following shear strength parameters were utilized in our analyses:

Material	Cohesion (psf)	Angle of Internal Friction (Deg.)
Fill Soil	0	37.5
Colluvium	0	36.0
Bedrock	400	30.0

The soil shear strength parameters indicated above are based on direct shear test results presented in Appendix C.

The input and output data of the slope stability analyses are presented in Appendix E. The results of the stability analyses are also summarized in Table E1, Appendix E. As shown in Table E1, the preliminary assessment identifies that Sections D-D', E-E' (upper), and E-E' (lower) have a factor-of-safety exceeding 1.5 under static dry fill soil (no leak conditions) and minor-leak conditions (where groundwater is confined to at or below the fill/native soil contact region).

Section D-D' and Section E-E' (upper) have reduced factor-of-safety of 1.448 and 1.413, respectively, under moderate leak, partially saturated conditions (groundwater rising half-way in the fill soils). However, Section E-E' (lower) has a significantly reduced factor-of-safety of 0.667 under these same partially saturated conditions.

Further reductions in the factor-of-safety under static, fully saturated conditions (groundwater rising in the fill soils to near ground surface) occur in all cross-sections with Section D-D' reducing to 0.822, Section E-E' (upper) reducing to 0.941, and Section E-E' (lower) reducing to 0.667.

These analyses identified that the lower portion of hillside slope for Section E-E (located from the entrance road northward to the toe of the fill slope) has a factor-of-safety below 1.5 under static conditions with moderate to severe leak conditions.

Further slope stability evaluation under seismic loaded (pseudostatic) conditions identified that the factor-of-safety for Sections D-D', E-E' (upper) and E-E' (lower) remain above to 1.1 under dry fill soil conditions (no leak) or minor-leak conditions (where groundwater is confined to the fill/native soil contact region).

As water is introduce into the fill soils the factor-of-safety under seismic loaded, partially saturated conditions reduces to below 1.0 for all cross-sections evaluated. For moderate and severe leak conditions (groundwater rising half-way in the fill soils or all the way to the ground surface), the factor-of-safety for Section D-D' reduces to 0.978 and 0.560, respectively.

Similarly, the factor-of-safety for Section E-E' (upper) reduces to 1.010 and 0.708 for moderate and severe leak conditions, respectively. The factor-of-safety for Section E-E' (lower) reduces to 0.429 for both moderate and severe leak conditions.

The pseudostatic analysis identified that the hillside slopes for Sections D-D' and E-E' have a factor-of-safety below 1.0 under partially saturated conditions and appear unstable under moderate to severe groundwater conditions.

8.0 CONCLUSIONS AND RECOMMENDATIONS

8.1 Slope Stability

Geotechnical exploration, analyses, experience, and judgment result in the conclusion that the existing reservoir site is stable from a geotechnical and geologic perspective under the current site conditions. Our investigation indicated that the site is underlain by fill over native colluvium and bedrock materials. No groundwater was encountered up to the depths of our exploration. Assuming that the groundwater remains at or below the contact between the fill and native, our slope stability analyses indicated more than the required factor of safeties of 1.5 and 1.1 under static and seismic conditions, respectively. In other words, the site slopes are stable under the current conditions or even under a minor leak in the water tank that results in the groundwater rising up to the contact between the fill and native soils.

Further analyses indicate that the hillside slopes would have reduced factor-of-safeties if the ground water rises above the contact between fill and native soils. A significant long-term leak in the tank can result in saturation of soil around the tank and eventual perched groundwater conditions above the bedrock contact. Under the scenario of this groundwater condition, the site slopes would have reduced factor of safeties with the potential instability.

Various treatment options are available to improve the stability of site slopes. These options include re-grading of the slopes with soil reinforcements such as geogrids. If desired, further site investigation and analysis can be performed to provide detailed recommendations for such options. However, in our opinion, monitoring site ground water conditions and performing preventive measures are more practical for the site.

We recommend that the groundwater conditions be monitored around the existing water tank, as a minimum. Noting that the native sediments underlying the reservoir dip to the north, and that the two (2) existing monitoring wells are situated "up dip" from the reservoir and may not detect water releases from beneath the reservoir, it is recommended a minimum of two (2) additional monitoring wells be installed at the site. The first monitoring well should be installed along the top of the easterly fill slope between American Geotechnical soil borings AGSB-2 and AGSB-3 to monitor potential water level rise in the underlying fill soils. The second monitoring well should be installed along the northerly fill slope just upslope from American Geotechnical soil boring AGSB-4. This monitoring well would be situated "down-dip" of the reservoir and could be an early indicator of water release from the reservoir seeping into the underlying native sediments (as well as the fill soils). It is suggested that the monitoring be performed at least every three months. If shallow ground water conditions are detected, the tank should be checked for any leaks along with other preventing measures.

We also recommend that the site drainage around the tank be improved to prevent water infiltration into the fill mass and improve the site stability. The absence of an existing curb and surface water control along the northern or southern perimeter road areas which surround the reservoir allows rain runoff to flow directly onto the hillsides and into the underlying soils. Introduction of water into the fill soils results in a reduction of the factor of safety for stability of the hillside fill slopes and should be avoided by runoff control and drainage improvements. It is recommended that a perimeter curb be constructed along the entire top of fill slope to intercept all rain runoff to a catch basin and into a discharge pipe which discharges the water away from the hillside slope.

8.2 Seismic Considerations

A moderate to large earthquake (magnitude 5.5 or greater) could result in intense to severe ground shaking at the site, and there is a potential for sympathetic movement (horizontal and/or vertical offset) on the order of millimeters to centimeters to occur along the geologic contact/fault contact located beneath the reservoir as a result of this ground motion. This differential movement along the geologic contact (potential lateral or vertical propagation of reactivated or new fissures) could be partially mitigated if there was a layer of fill soils beneath the reservoir concrete slab. However, details of the earthwork beneath the reservoir (such as depth of over-excavation and compaction) are not known, and as such are considered to be less than 1-foot thick (if any) and would provide minimal mitigation effects.

The closest known active fault to the site is the offshore segment of the Whittier Fault, located approximately 8.4 miles from the site. The following seismic parameters, based the 2013 Edition of the California Building Code (CBC), Chapter 16, Section 1613, are provided below for consideration in the design and analysis.

1. Site Class : C

2. Site Coefficients
   - F_a : 1.0
   - F_v : 1.3

3. Mapped spectral accelerations
   - S_s (for short periods) : 1.500
   - S_1 (for 1-second period) : 0.581

4. Site adjusted spectral accelerations
   - S_{MS} (for short periods) : 1.500
   - S_{M1} (for 1-second period) : 0.755

5. Design spectral accelerations
   - S_{DS} (for short periods) : 1.000
   - S_{D1}(for 1-second period) : 0.504

It should be realized that the purpose of the seismic design/analysis utilizing the above parameters is to safeguard against major structural failures and loss of life, but not to prevent damage altogether. Even if the structural engineer provides designs in accordance with the applicable codes for seismic design, the possibility of damage cannot be ruled out if moderate to strong shaking occurs as a result of a large earthquake. This is the case for essentially all structures in southern California.

8.3 Asphalt Pavement

The existing asphalt paving ranges from 1-inch to 2-inches of asphalt placed on less than 4-inches of aggregate base (or placed directly on the fill soils) and is highly deteriorated and cracked which allows water to percolate directly into the underlying fill soils. It is recommended that the perimeter access road be removed and replaced with a proper pavement section with a minimum of 3-inches of asphalt over a minimum of 6-inches of compacted aggregate base (based on the R-Value of 30 and Traffic Index of 5).

After removing the existing asphalt within the new pavement area, the upper 1 foot of subgrade soil should be reworked, moisture conditioned, and compacted to a minimum of 90 percent of relative compaction. The actual depth of recompaction can be determined by the project soil engineer at the time of construction and based on the site condition. Prior to start of the subgrade compaction, all utility lines should be located and marked in the field so that they can be protected and/or relocated, if necessary. All debris and perishable material should be removed from the site.

After completion of recompaction of subgrade materials, an aggregate should be placed over the reworked/compacted fill. The aggregate base is assumed to have a minimum R-value of 78 and should conform to Caltrans Standard Specifications Section 26 or Green Book specifications (Section 200-2.2). The base should be placed with a minimum compaction of 95 percent. In all new pavement areas, adequate surface drainage should be provided.

8.4 Concrete

Laboratory testing indicated that the surface soil at the site has low levels of sulfates, and as such no special sulfate resistant concrete mix design is required for any proposed concrete construction. However, we recommend that low-permeable concrete be utilized at the site for better performance. For this purpose, the water-to-cement ratio in the concrete should be limited to 0.5 (0.45 preferred). Use of utilizing Type V cement is also preferred. Limited use of a water-reducing agent may be included to increase workability. The concrete should be properly cured to minimize risk of shrinkage cracking. The code dictates at least seven days of moist curing. Two to three weeks is preferred to minimize cracking. Special surface-applied curing compounds can be used subject to acceptance by the design engineer. One-inch hard rock mixes are recommended. Pea-gravel mixes are specifically not recommended but could be utilized for relatively non-critical improvements (e.g., flatwork) and other improvements, provided the mix designs consider limiting shrinkage. Contractors/other designers should take care in all aspects of designing mixes, detailing, placing, finishing, and curing concrete. The mix designers and contractor are advised to consider all available steps to reduce cracking. The use of shrinkage compensating cement or fiber reinforcing should be considered. Alternatively, the concrete mix can also incorporate W.R. Grace/Eclipse shrinkage reducing admixture dosed for maximum benefit. Mix designs proposed by the contractor should be considered subject to review by the project engineer.

8.5 Corrosion Potential

In addition to sulfate tests, Chloride, pH, and resistivity tests on near-surface site soil were performed. Results of these tests are presented in Appendix C. Appropriate design considerations should be made to reduce the risk of damage from corrosion.

9.0 REMARKS

Only a portion of subsurface conditions have been reviewed and evaluated. Conclusions, recommendations, and other information contained in this report are based upon the assumption that subsurface conditions do not vary appreciably between and adjacent to the observation points. Although no significant variation is anticipated, it must be recognized that variations can occur.

This report has been prepared for the sole use and benefit of our client. The intent of this report is to advise our client on geotechnical matters involving the proposed improvements. It should be understood that the geotechnical consulting provided and the contents of this report are not perfect. Any errors or omissions noted by any party reviewing this report and/or any other geotechnical aspect of the project should be reported to this office in a timely fashion. The client is the only party intended by this office to directly receive the advice. Subsequent use of this report can only be authorized by the client. Any transferring of information or other directed use by the client should be considered "advice by the client."

Geotechnical engineering is characterized by uncertainty. Geotechnical engineering is often described as an inexact science or art. Conclusions and recommendations presented herein are based upon the evaluation of technical information gathered, experience, and professional judgment. The conclusions and recommendations presented should be considered "advice." Other consultants could arrive at different conclusions and recommendations. Typically, "minimum" recommendations have been presented. Although some risk will always remain, lower risk of future problems would usually result if more restrictive criteria were adopted. Final decisions on matters presented are the responsibility of the client and/or the governing agencies. No warranties in any respect are made as to the performance of the project.

Respectfully submitted,

AMERICAN GEOTECHNICAL, INC.

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Enclosures: Plates 1-7
Appendix A – References
Appendix B – Boring Logs
Appendix C – Summary of Laboratory Data
Appendix D – EQFault and Probabilistic Ground Motion Data
Appendix E – Slope Stability Analysis

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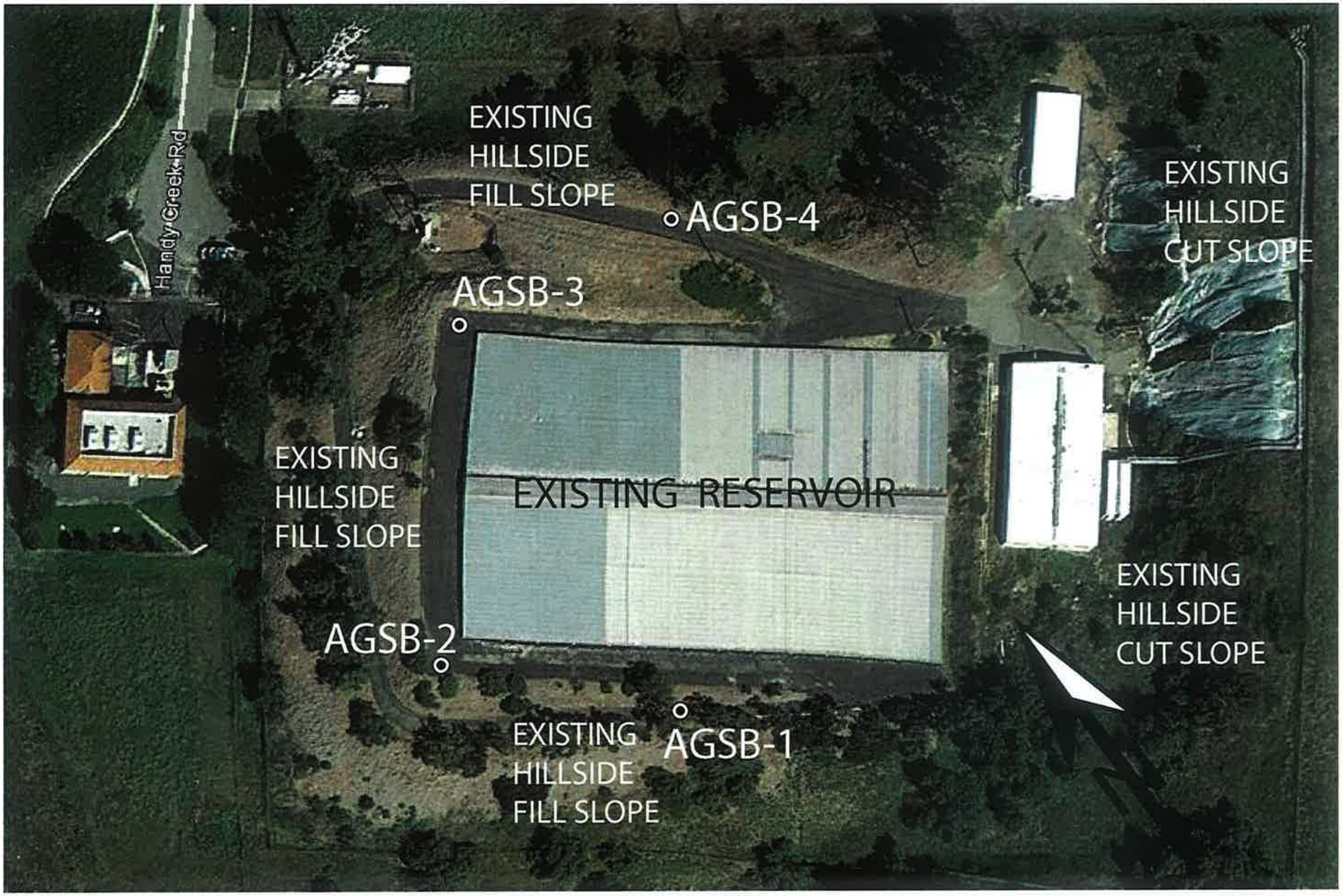
Source: Mapquest

American Geotechnical, Inc. 22725 Old Canal Road, Yorba Linda, CA 92887 Phone: (714) 685-3900, Fax: (714) 685-3909	EAST ORANGE COUNTY WATER DISTRICT PETERS CANYON FACILITY HANDY CREEK ROAD RESERVOIR ORANGE, CA	PROJECT LOCATION MAP F.N. 33615.01 — February, 2014	Plate 1



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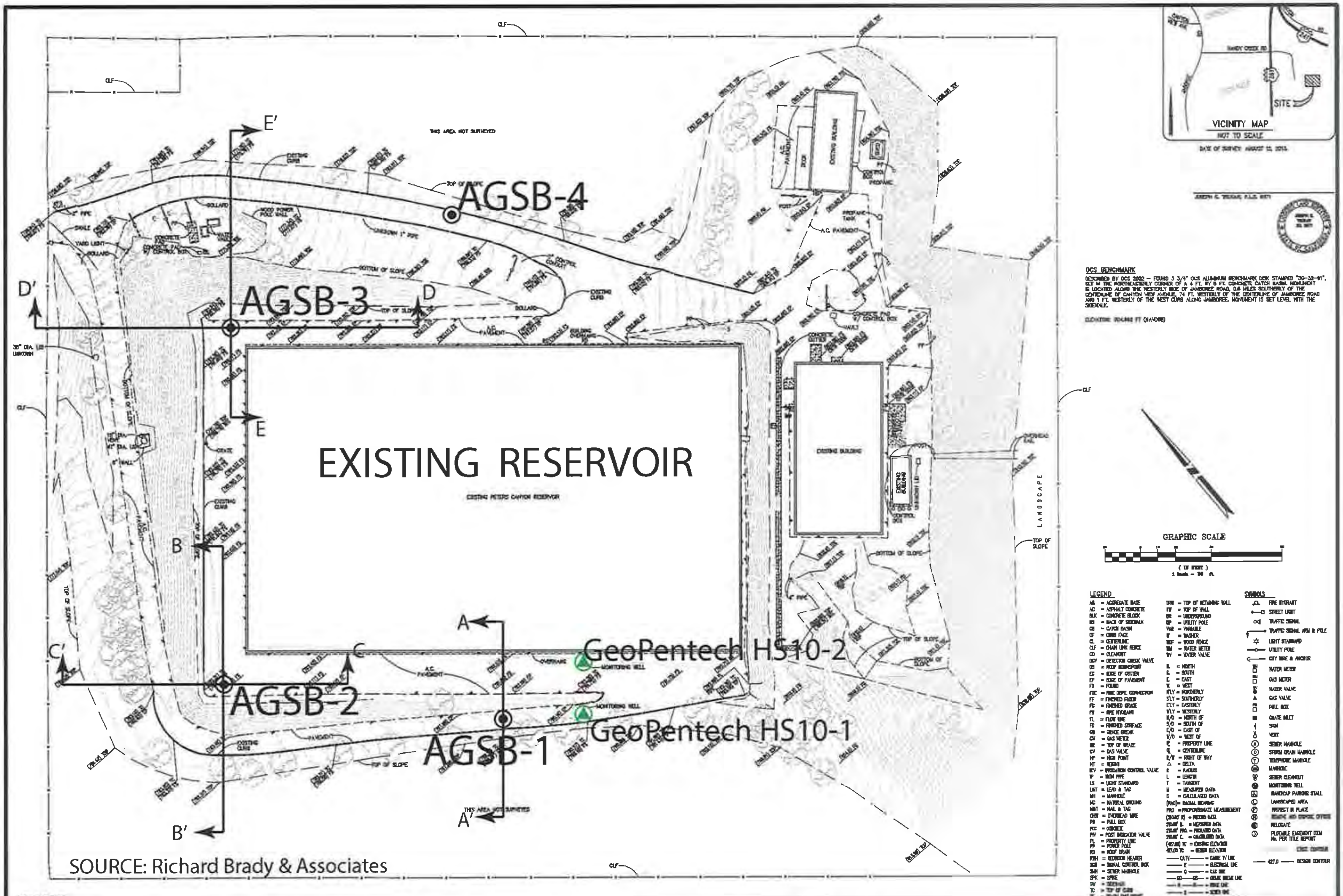

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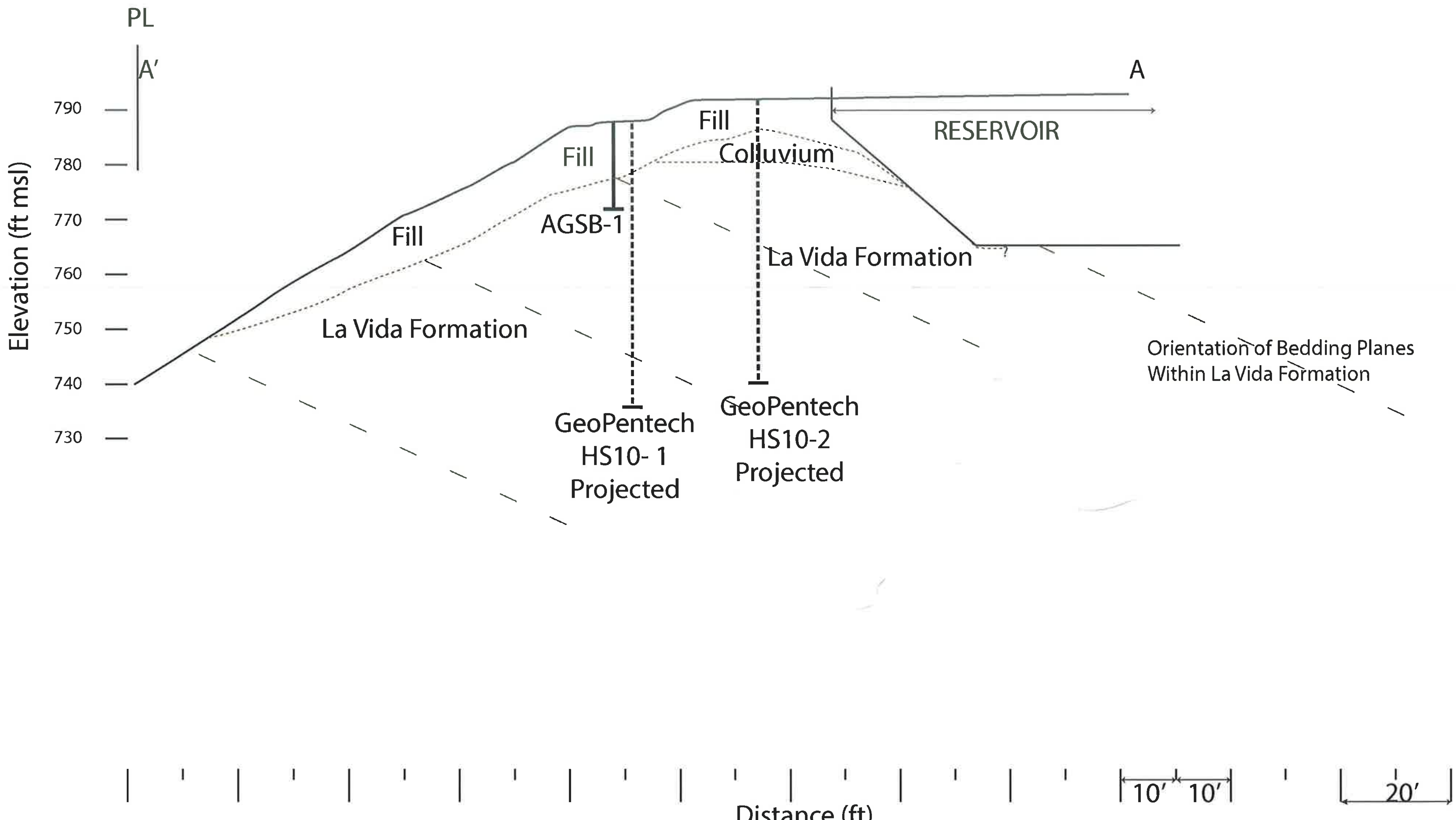
HANDY CREEK ROAD RESERVOIR
ORANGE, CA

SITE TOPOGRAPHIC MAP

F.N. 33615.01 | February, 2014

Plate 3



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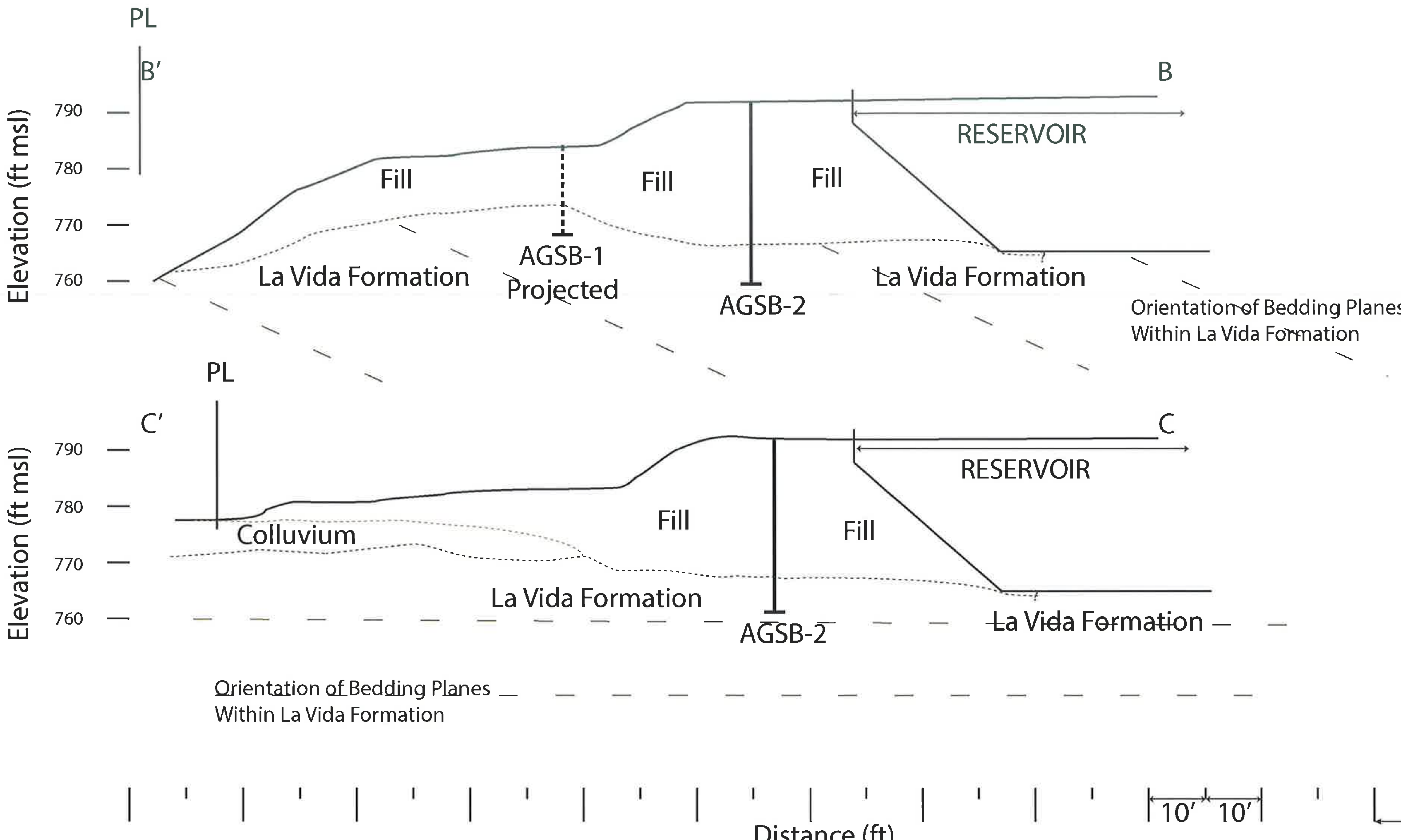
HANDY CREEK ROAD RESERVOIR
ORANGE, CA

GEOLOGIC CROSS-SECTION A-A'

F.N. 33615.01

February, 2014

Plate 4



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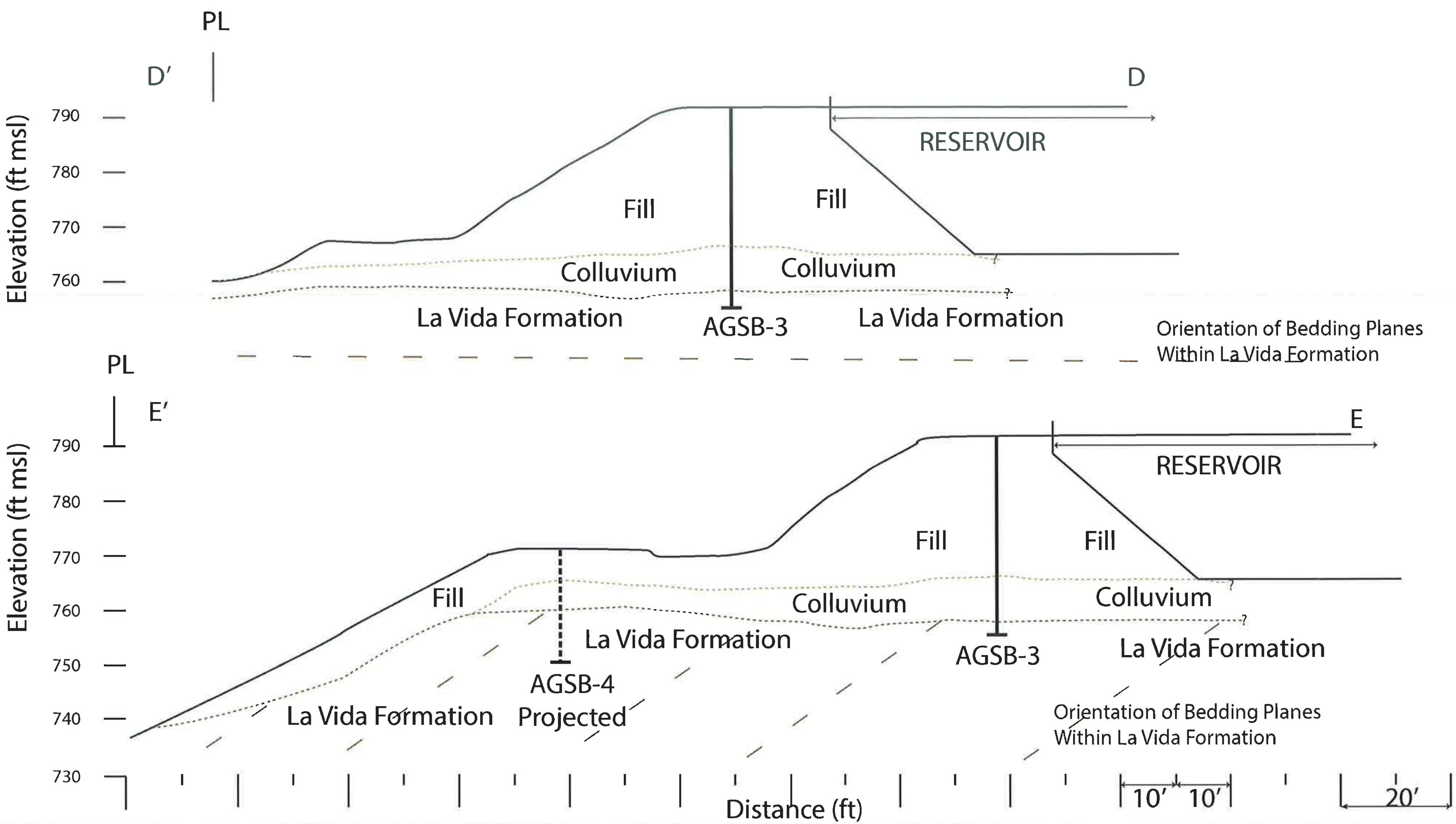
GEOLOGIC CROSS-SECTIONS B-B′ and C-C′

F.N. 33615.01

February, 2014

Plate 5



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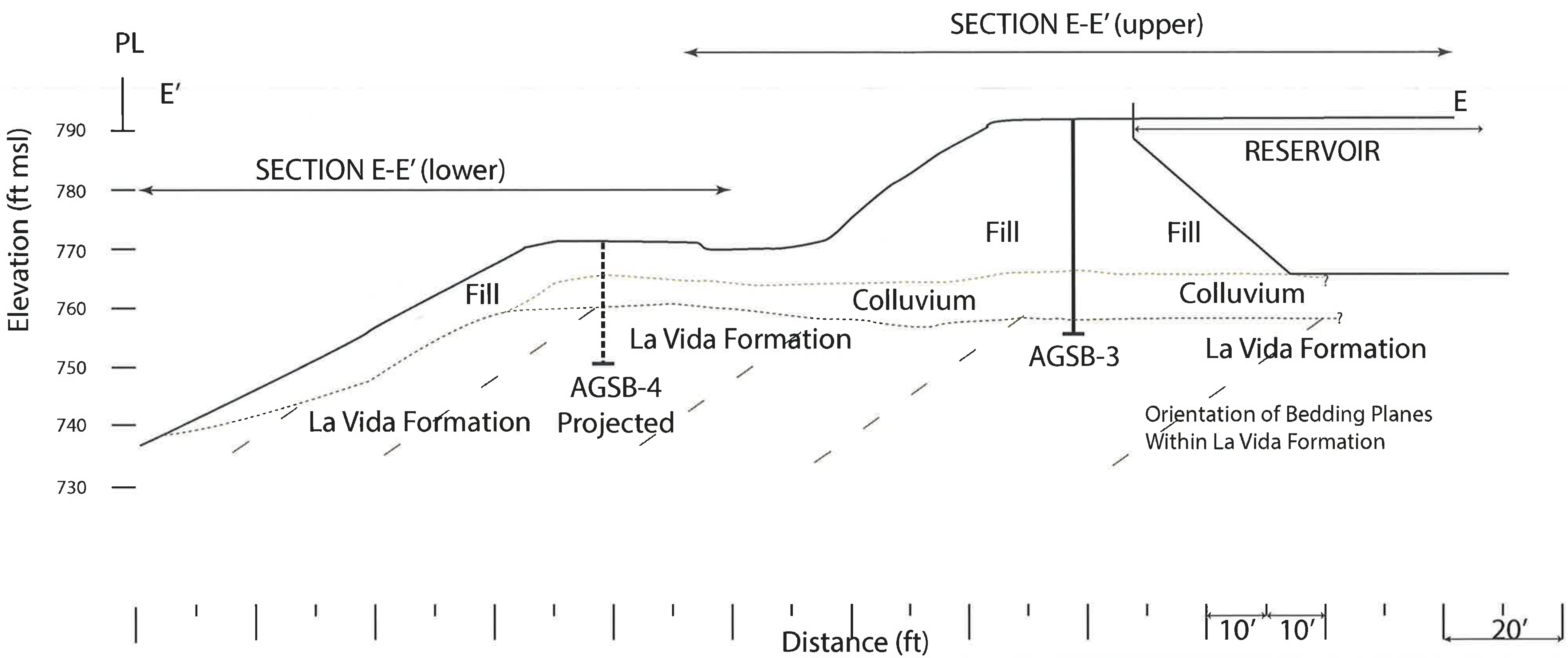
GEOLOGIC CROSS-SECTIONS D-D' and E-E'

F.N. 33615.01

February, 2014

Plate 6



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ORANGE, CA

GEOLOGIC CROSS-SECTION E-E'
FOR SLOPE STABILITY ANALYSIS

F.N. 33615.01

February, 2014

Plate 7

APPENDIX A

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7. Boyle Engineering, Construction Plans For The Earthwork In Connection With 6 M.G. Storage Reservoir for the East Orange County Water District Title Sheet 1 of 7, undated.
8. Boyle Engineering, E.O.C.W.D. Reservoir Plot Plan and Horizontal Control Plan Sheet 2 of 7, undated.
9. Boyle Engineering, E.O.C.W.D. 6 M/G. Reservoir Fill Disposal Areas Plan Sheet 7 of 7, undated.
10. Boyle Engineering, E.O.C.W.D. Reservoir Plot Plan and Horizontal Control Plan Sheet 2A of 6, undated.
11. Boyle Engineering, E.O.C.W.D. Reservoir Plot Plan and Horizontal Control Plan Sheet 2 of 7, undated, revised 9/21/65 for Trailer Pad Construction.

APPENDIX B

Boring Logs

BORING LOG

Project Name: EOCWD Peters Canyon Facility 6MG Reservoir **File Number:** 33615-01

Logging By: c.glick **Drill Date(s)** February 10, 2014

Boring Location: Southern Access Road, Approx. 40-feet Southwest of Existing Monitoring Well

Ground Elev. (ft): **Total Depth (ft):** 16'

Drill Company: __J&H Drilling______ **Drill Method:** _CME-75__ **Vertical Drop (in):** __30"______

Drive Weights: 140 lb. **Boring Diameter (in):** 8

Instrumentation Details:

BORING No. AG-SB-1

Depth (Feet)	In-situ Samples	Bulk Samples	Blow Counts	Dry Unit Wt (PCF)	Moisture Content (%)	LITHOLOGIC DESCRIPTION
0'						**1-1/2 Inch Asphalt/6-inch of Aggregate Base** **GRAVELLY CLAY**, olive-gray-brown, damp, dense (FILL)
						SILTY SAND, gray, damp, dense with some gravel (FILL)
5'			24/22 SPT 12/19/21			
10'			43/28 SPT 40/50/5"			**SILTY SAND (SILTSTONE)**, gray, damp, dense (La Vida Formation) moderate carbonate development
15'			33/50			Bottom of exploration 16-feet, no water in boring
20'						

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BORING LOG

Project Name: EOCWD Peters Canyon Facility 6MG Reservoir **File Number:** 33615-01

Logging By: c.glick **Drill Date(s)** February 10, 2014

Boring Location: Southwest Corner of Perimeter Access Road

Ground Elev. (ft): **Total Depth (ft):** 31'

Drill Company: J&H Drilling **Drill Method:** CME-75 **Vertical Drop (in):** 30"

Drive Weights: 140 lb. **Boring Diameter (in):** 8

Instrumentation Details:

BORING No. AG-SB-2

Depth (Feet)	In-situ Samples	Bulk Samples	Blow Counts	Dry Unit Wt (PCF)	Moisture Content (%)	LITHOLOGIC DESCRIPTION
0'						**1-Inch Asphalt** **SILTY SAND**, olive-gray, damp, dense with some gravel (FILL)
5'			23/30 SPT 14/20/23			
10'			25/26 SPT 18/24/26			
15'			16/26			**SILTY SAND**, orange-gray, damp, dense (FILL)
						SILTY SAND, olive, damp, dense with some gravel (FILL)
20'			18/14			

American Geotechnical, Inc.

BORING LOG

Project Name: EOCWD Peters Canyon Facility 6MG Reservoir **File Number:** 33615-01

Logging By: c.glick **Drill Date(s)** February 10, 2014

Boring Location: Southwest Corner of Perimeter Access Road

Ground Elev. (ft): **Total Depth (ft):** 31'

Drill Company: J&H Drilling **Drill Method:** CME-75 **Vertical Drop (in):** 30"

Drive Weights: 140 lb. **Boring Diameter (in):** 8

Instrumentation Details:

BORING No. AG-SB-2 (continued)

Depth (Feet)	In-situ Samples	Bulk Samples	Blow Counts	Dry Unit Wt (PCF)	Moisture Content (%)	LITHOLOGIC DESCRIPTION
20'						**SILTY SAND**, olive, damp, dense with some gravel (FILL)
	SPT 10/14/22					
25	SPT 50/6"		50/6"			**SILTY SAND (SILTSTONE)**, olive-gray, damp, dense (La Vida Formation)
30'	SPT 47/50/4"					**SILTY SAND (SILTSTONE)**, gray, damp, dense (La Vida Formation)
						Bottom of exploration 31-feet, no water in boring
35'						
40'						

American Geotechnical, Inc.

BORING LOG

Project Name: EOCWD Peters Canyon Facility 6MG Reservoir **File Number:** 33615-01

Logging By: c.glick **Drill Date(s)** February 10, 2014

Boring Location: Northwest Corner of Perimeter Access Road

Ground Elev. (ft): **Total Depth (ft):** 36.5'

Drill Company: J&H Drilling **Drill Method:** CME-75 **Vertical Drop (in):** 30"

Drive Weights: 140 lb. **Boring Diameter (in):** 8

Instrumentation Details:

BORING No. AG-SB-3

Depth (Feet)	In-situ Samples	Bulk Samples	Blow Counts	Dry Unit Wt (PCF)	Moisture Content (%)	LITHOLOGIC DESCRIPTION
0'						**1-Inch Asphalt** **SILTY SAND**, olive-gray, damp to moist, dense with some gravel (FILL) interbedded lenses of medium-grained sand
5'			25/32 SPT 10/16/21			
10'			16/25 SPT 20/20/25			
15'			15/30 SPT 12/20/26			**SILTY SAND**, orange-gray, moist, dense (FILL) interbedded with lenses of olive-gray silty sand
20'			19/24			**SILTY SAND**, olive, damp to moist, dense (FILL)

BORING LOG

Project Name: EOCWD Peters Canyon Facility 6MG Reservoir **File Number:** 33615-01

Logging By: c.glick **Drill Date(s)** February 10, 2014

Boring Location: Northwest Corner of Perimeter Access Road

Ground Elev. (ft): **Total Depth (ft):** 36.5'

Drill Company: J&H Drilling **Drill Method:** CME-75 **Vertical Drop (in):** 30"

Drive Weights: 140 lb. **Boring Diameter (in):** 8

Instrumentation Details:

BORING No. AG-SB-3 (continued)

Depth (Feet)	In-situ Samples	Bulk Samples	Blow Counts	Dry Unit Wt (PCF)	Moisture Content (%)	LITHOLOGIC DESCRIPTION
20'						**SILTY SAND**, olive, damp, dense (FILL)
	■		SPT 20/25/26			interbedded lenses of yellow sand and gray sand
25	■		13/16/29			
	■		SPT 23/24/26			**SAND**, yellow and gray, damp, dense (COLLUVIUM)
						mottled texture with some carbonate development
30'	■		SPT 21/22/27			
	■		18/23			**SILTY SAND (SILTSTONE)**, gray, damp, dense (La Vida Formation)
35'	■		SPT 30/35/50			
						Bottom of exploration 36.5-feet, no water in boring
40'						

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BORING LOG

Project Name: EOCWD Peters Canyon Facility 6MG Reservoir **File Number:** 33615-01

Logging By: c.glick **Drill Date(s)** February 10, 2014

Boring Location: Northern Access Road

Ground Elev. (ft): **Total Depth (ft):** 22.5'

Drill Company: J&H Drilling **Drill Method:** CME-75 **Vertical Drop (in):** 30"

Drive Weights: 140 lb. **Boring Diameter (in):** 8

Instrumentation Details:

BORING No. AG-SB-4

Depth (Feet)	In-situ Samples	Bulk Samples	Blow Counts	Dry Unit Wt (PCF)	Moisture Content (%)	LITHOLOGIC DESCRIPTION
0'						**1-Inch Asphalt** **SILTY SAND**, mottled olive-gray and orange, moist, dense (FILL)
5'			22/35 SPT 11/27/31			**SILTY SAND**, orange, damp, dense, some gravel (COLLUVIUM)
10'			19/35			**SILTY SAND**, orange, damp, dense (COLLUVIUM)
15'			17/20 SPT 15/17/18			
20'			24/30			**SILTY SAND (SILTSTONE)**, dark gray, damp, dense (La Vida Formation)

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BORING LOG

Project Name: EOCWD Peters Canyon Facility 6MG Reservoir **File Number:** 33615-01

Logging By: c.glick **Drill Date(s)** February 10, 2014

Boring Location: Northern Access Road

Ground Elev. (ft): **Total Depth (ft):** 22.5'

Drill Company: __J&H Drilling______ **Drill Method:** _CME-75__ **Vertical Drop (in):** ___30"______

Drive Weights: 140 lb. **Boring Diameter (in):** 8

Instrumentation Details:

Depth (Feet)	In-situ Samples	Bulk Samples	Blow Counts	Dry Unit Wt (PCF)	Moisture Content (%)	BORING No. AG-SB-4 (continued) LITHOLOGIC DESCRIPTION
20'						**SILTY SAND (SILTSTONE)**, dark gray, damp, dense (La Vida Formation)
	■	SPT 16/19/24				
						Bottom of exploration 22.5-feet, no water in boring
25						
30'						
35'						
40'						

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APPENDIX C

Summary of Laboratory Testing

Exca. No.	Depth (feet)	In-Situ Dry Density (Lbs/cu. ft.)	In-Situ Moisture Content (%)	Maximum Dry Density (Lbs/cu. ft.)	Optimum Moisture Content (%)	Relative* Compaction (%)	Degree of** Saturation (%)	Soil Chemical Testing: Chloride (mg/kg)	pH (-)	Resistivity (Ohm-cm)	Sulfate (mg/kg)
AGSB-1	2.0-5.0	-	-	117.2	13.8	-	-	-	-	-	-
AGSB-1	5.5-6.0	98.1	7.4	-	-	84	28	-	-	-	-
AGSB-1	10.5-11.0	104.9	12.5	-	-	-	56	-	-	-	-
AGSB-1	15.5-16.0	94.4	21.8	-	-	-	75	-	-	-	-
AGSB-2	1.0-5.0	-	-	-	-	-	-	16.2	7.9	3570	285
AGSB-2	5.5-6.0	93.6	20.4	-	-	81	69	-	-	-	-
AGSB-2	12.0-15.0	-	-	115.2	14	-	-	-	-	-	-
AGSB-2	10.5-11.0	96.3	11.2	-	-	84	40	-	-	-	-
AGSB-2	15.5-16.0	95.4	12.6	-	-	83	45	-	-	-	-
AGSB-2	20.5-21.0	87.0	13.6	-	-	76	39	-	-	-	-
AGSB-2	25.0-25.5	108.3	6.8	-	-	-	33	-	-	-	-
AGSB-3	5.5-6.0	99.4	15.0	-	-	84	58	-	-	-	-
AGSB-3	10.5-11.0	102.8	18.7	-	-	87	79	-	-	-	-
AGSB-3	15.0-19.0	-	-	118	13.4	-	-	-	-	-	-
AGSB-3	15.5-16.0	104.4	11.2	-	-	88	49	-	-	-	-
AGSB-3	20.5-21.0	95.4	21.6	-	-	81	76	-	-	-	-
AGSB-3	25.5-26.0	96.4	17.4	-	-	-	63	-	-	-	-
AGSB-4	5.5-6.0	103.2	8.6	-	-	-	37	-	-	-	-
AGSB-4	10.5-11.0	100.1	10.0	-	-	-	39	-	-	-	-
AGSB-4	15.5-16.0	103.4	11.3	-	-	-	49	-	-	-	-

Note: * Relative compaction was calculated using the nearest maximum dry density
Note: ** Degree of saturation was calculated using specific gravity of 2.70

SUMMARY OF LABORATORY TESTING DATA

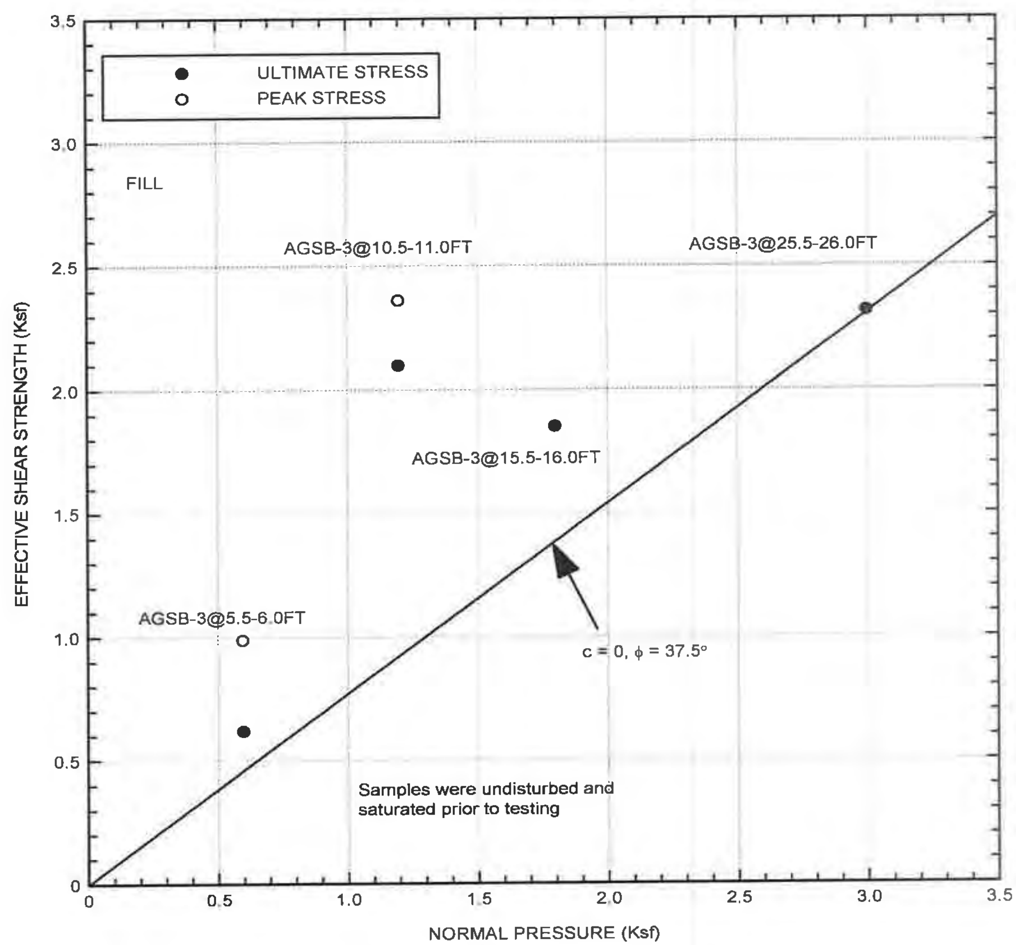
AMERICAN GEOTECHNICAL	EOCWD	F.N. 33615.01	APRIL 2014	TABLE C1

Exca. No.	Depth (ft)	Soil Classi-fication USCS	Grain Size Distribution				% Passing No. 200 (%)	Atterberg Limits		
			Gravel (%)	Sand (%)	Silt (%)	Clay (%)		LL (%)	PL (%)	PI (%)
AGSB-1	2-5	CL	0	45.1	39.9	15	54.9	32	20	12
AGSB-2	12-15	CL	0	55.9	33.9	10.2	44.1	-	-	-
AGSB-3	5-10	CL	0	44.4	38.3	17.3	55.6	-	-	-
AGSB-3	15-19	CL	0	49.1	39.2	11.7	50.9	31	22	9

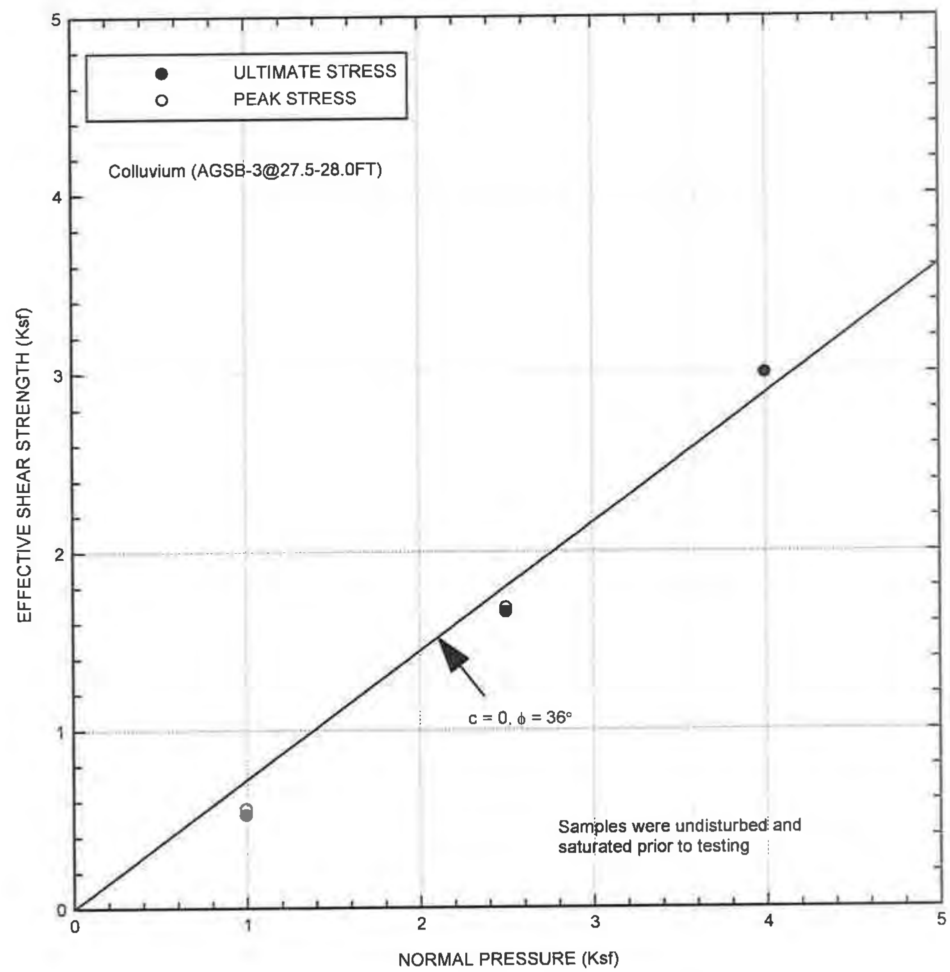
SUMMARY OF LABORATORY TESTING DATA

AMERICAN GEOTECHNICAL | EOCWD | F.N. 33615.01 | APRIL 2014

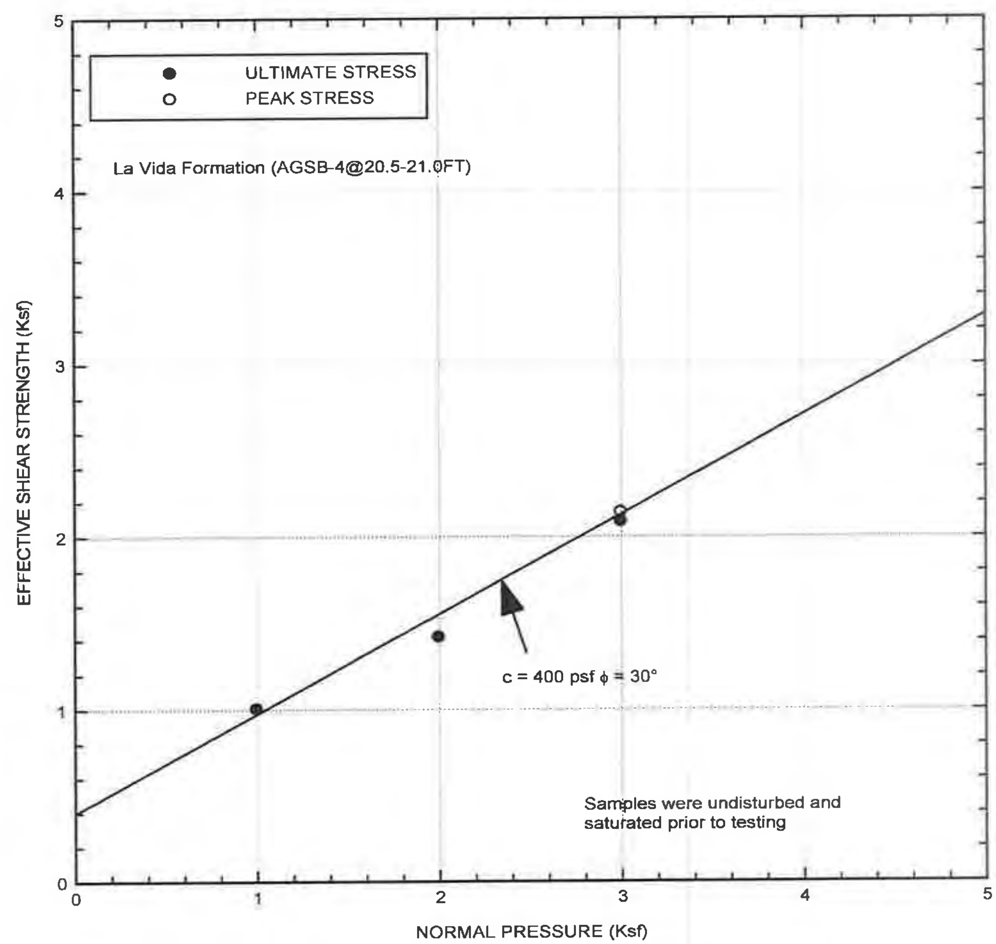
TABLE C2



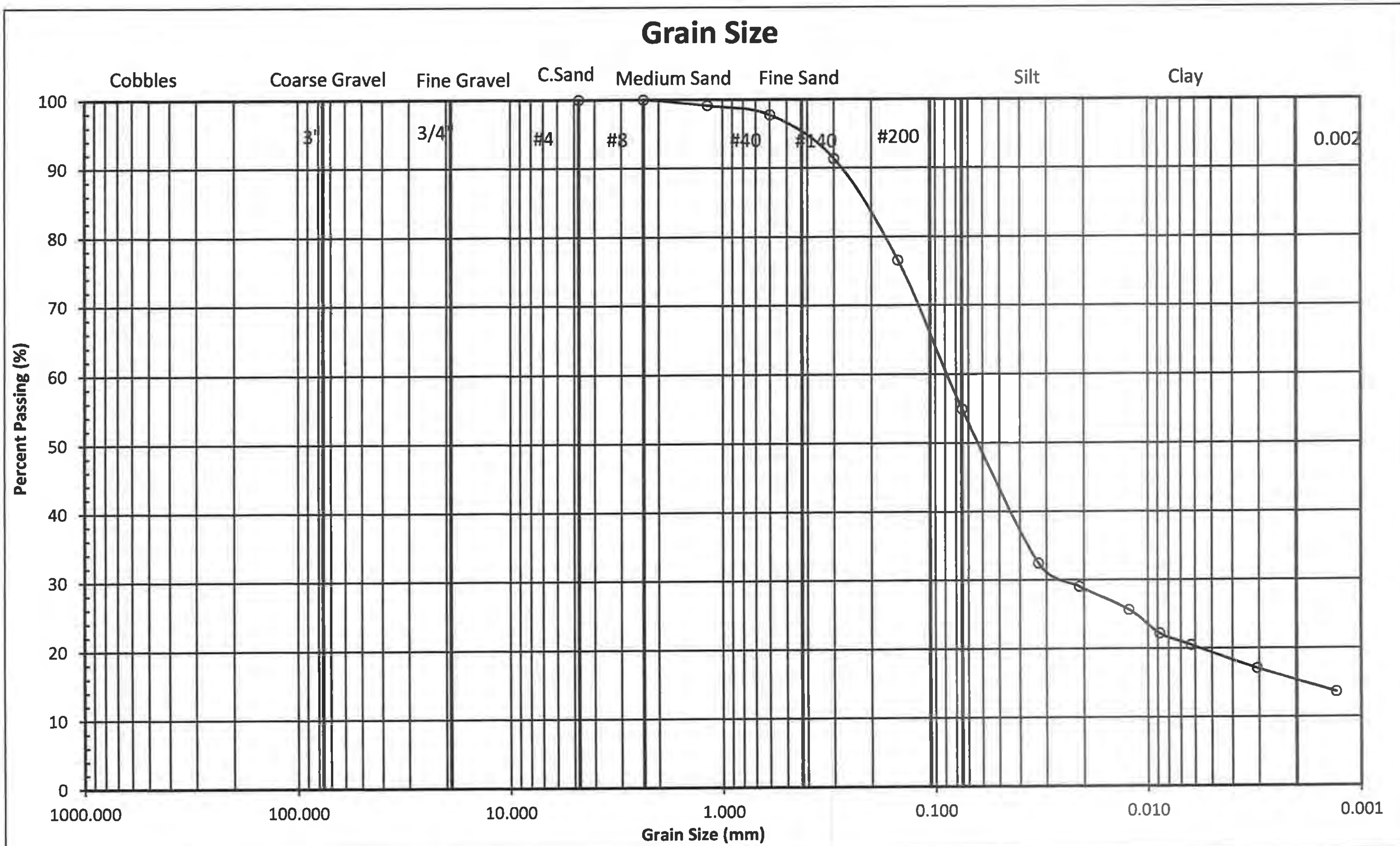
DIRECT SHEAR TEST PLOT				FIGURE C1
AMERICAN GEOTECHNICAL	EOCWD	F.N. 33615.01	APRIL 2014	



DIRECT SHEAR TEST PLOT				FIGURE C2
AMERICAN GEOTECHNICAL	EOCWD	F.N. 33615.01	APRIL 2014	



DIRECT SHEAR TEST PLOT				FIGURE C3
AMERICAN GEOTECHNICAL	EOCWD	F.N. 33615.01	APRIL 2014	



Project Name: EOCWD
Location: Handy Creek Road
File No: 33615-01
Date: 2/17/2014
Excavation: AGSB-1 Bag 1
Depth: 2' - 5'
By: SM

% Gravel =	0.0
% Sand =	45.1
% Silt =	39.9
% Clay =	15.0
Sum =	100.0

LL= 32 PL= 20 PI= 12

%>#200 = 45.1
%<#200 = 54.9

Soil Classification: Sandy Lean Clay (CL)

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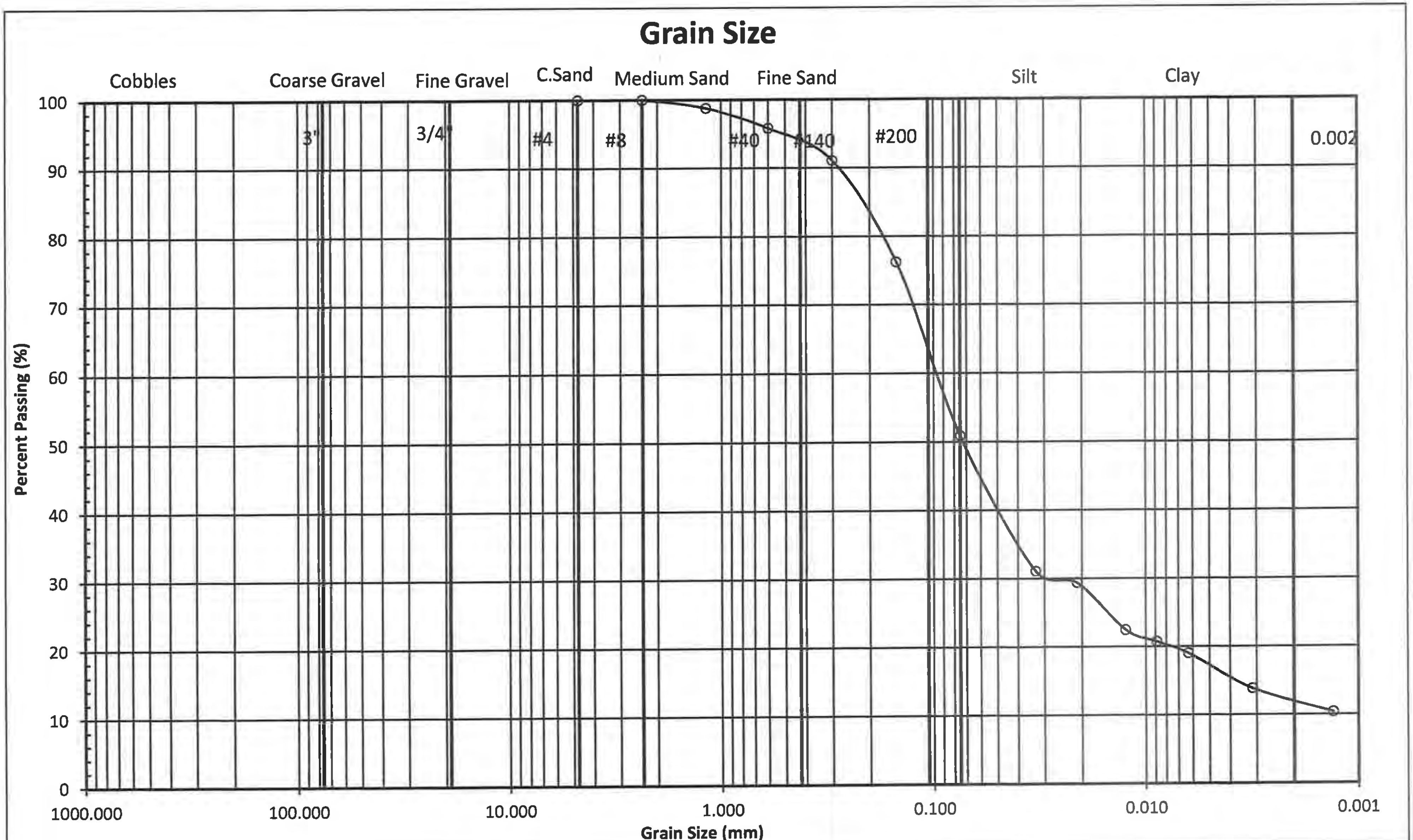
3100 Fite Circle Suite 103 Sacramento CA 95827 - (916) 368-2088 - FAX (916) 368-2188
5600 Spring Mountain Road Suite 201 Las Vegas NV 89146 - (702) 562-5046 - FAX (702) 562-2457



Project Name: EOCWD
Location: Handy Creek Road
File No: 33615-01
Date: 2/18/2014
Excavation: AGSB-3 Bag-2
Depth: 15' - 19'
By: KV

% Gravel =	0.0
% Sand =	49.1
% Silt =	39.2
% Clay =	11.7
Sum =	100.0

LL= 31 PL= 22 PI= 9

%>#200 = 49.1
%<#200 = 50.9

Soil Classification: Sandy Lean Clay (CL)

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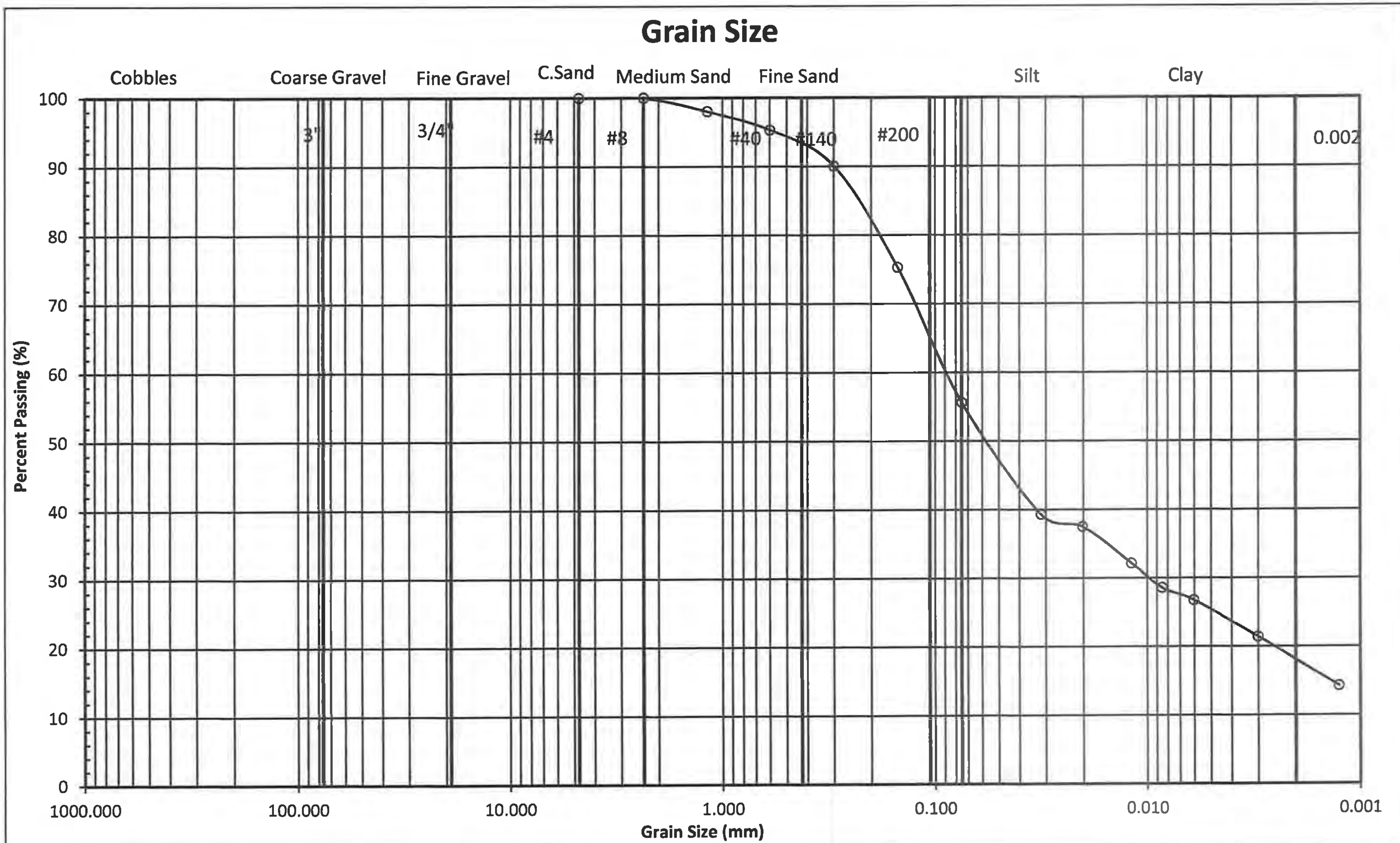

Project Name: EOCWD
Location: Handy Creek Road
File No: 33615-01
Date: 2/28/2014
Excavation: AGSB-3 Bag-1
Depth: 5' - 10'
By: KV

% Gravel =	0.0
% Sand =	44.4
% Silt =	38.3
% Clay =	17.3
Sum =	100.0

LL= N/A PL= N/A PI=

%>#200 = 44.4
%<#200 = 55.6

Soil Classification: No atterberg assigned

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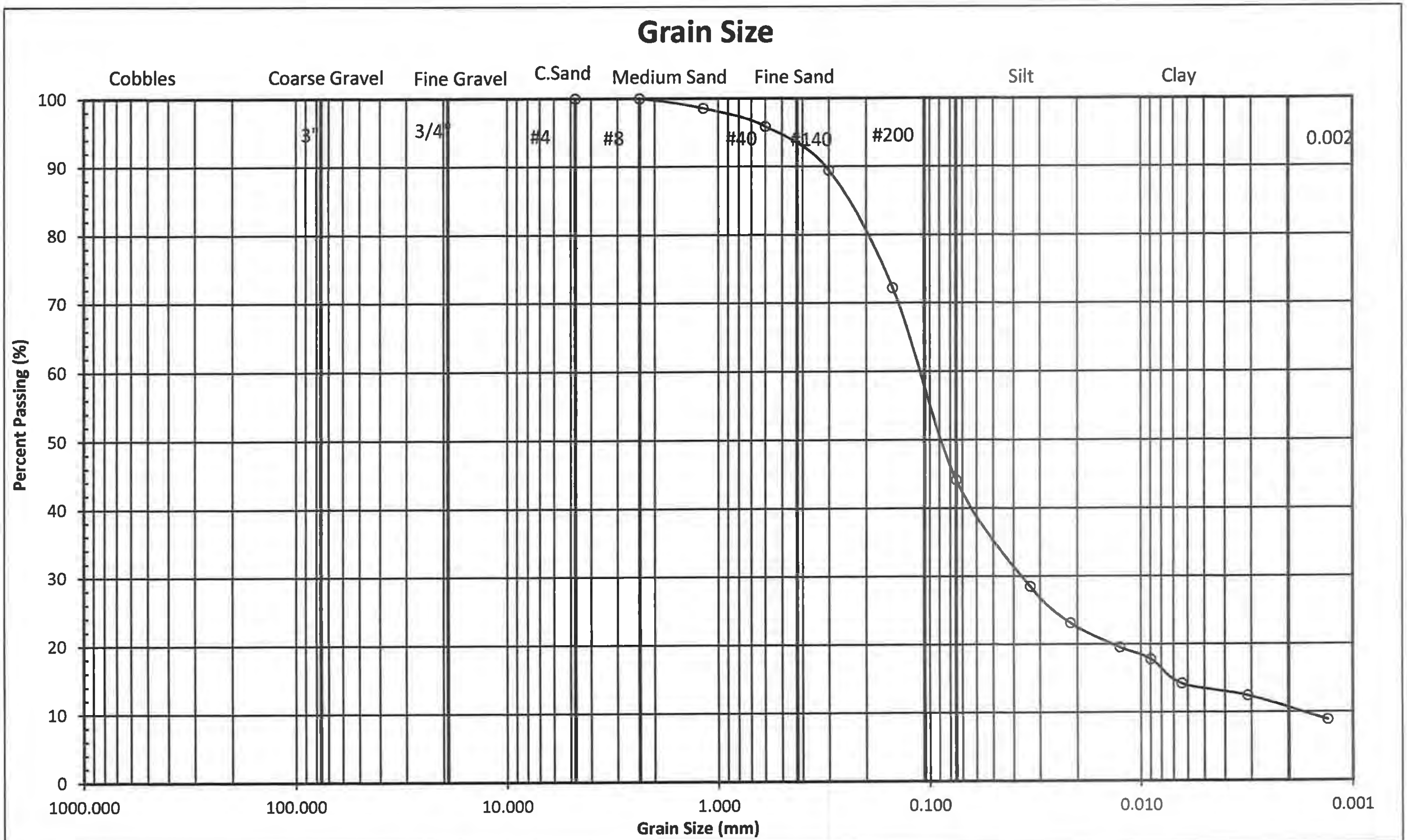

Project Name: EOCWD
Location: Handy Creek Road
File No: 33615-01
Date: 2/17/2014
Excavation: AGSB-2 Bag 2
Depth: 12' - 15'
By: KV

% Gravel =	0.0
% Sand =	55.9
% Silt =	33.9
% Clay =	10.2
Sum =	100.0

LL= N/A PL= N/A PI=

%>#200 = 55.9
%<#200 = 44.1

Soil Classification: Non-Plasitc

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APPENDIX D

EQFault and Probabilistic Ground Motion Data

```
*************************
*                       *
*    E Q F A U L T      *
*                       *
*    Version 3.00       *
*                       *
*************************
```

DETERMINISTIC ESTIMATION OF
PEAK ACCELERATION FROM DIGITIZED FAULTS

JOB NUMBER: 33615-01

DATE: 02-21-2014

JOB NAME: EOCWD 6MG Reservoir

CALCULATION NAME: Test Run Analysis

FAULT-DATA-FILE NAME: CDMGFLTE.DAT

SITE COORDINATES:
SITE LATITUDE: 33.7765
SITE LONGITUDE: 117.7552

SEARCH RADIUS: 100 mi

ATTENUATION RELATION: 15) Campbell & Bozorgnia (1997 Rev.) - Soft Rock
UNCERTAINTY (M=Median, S=Sigma): M Number of Sigmas: 0.0
DISTANCE MEASURE: cdist
SCOND: 0
Basement Depth: 5.00 km Campbell SSR: 1 Campbell SHR: 0
COMPUTE PEAK HORIZONTAL ACCELERATION

FAULT-DATA FILE USED: CDMGFLTE.DAT

MINIMUM DEPTH VALUE (km): 3.0

EQFAULT SUMMARY

DETERMINISTIC SITE PARAMETERS

Page 1

ABBREVIATED FAULT NAME	APPROXIMATE DISTANCE mi (km)	ESTIMATED MAX. EARTHQUAKE EVENT: MAXIMUM EARTHQUAKE MAG.(Mw)	PEAK SITE ACCEL. g	EST. SITE INTENSITY MOD.MERC.
WHITTIER	7.8(12.5)	6.8	0.316	IX
ELSINORE-GLEN IVY	8.8(14.2)	6.8	0.282	IX
CHINO-CENTRAL AVE. (Elsinore)	9.8(15.7)	6.7	0.287	IX
ELYSIAN PARK THRUST	12.2(19.6)	6.7	0.219	IX
COMPTON THRUST	14.1(22.7)	6.8	0.193	VIII
NEWPORT-INGLEWOOD (L.A.Basin)	15.3(24.6)	6.9	0.166	VIII
NEWPORT-INGLEWOOD (Offshore)	15.8(25.5)	6.9	0.159	VIII
SAN JOSE	20.1(32.3)	6.5	0.095	VII
ELSINORE-TEMECULA	25.2(40.6)	6.8	0.079	VII
CUCAMONGA	25.8(41.6)	7.0	0.094	VII
SIERRA MADRE	25.8(41.6)	7.0	0.094	VII
PALOS VERDES	26.2(42.2)	7.1	0.096	VII
RAYMOND	31.1(50.1)	6.5	0.049	VI
SAN JACINTO-SAN BERNARDINO	32.6(52.4)	6.7	0.051	VI
CLAMSHELL-SAWPIT	32.9(53.0)	6.5	0.044	VI
VERDUGO	34.1(54.8)	6.7	0.049	VI
SAN JACINTO-SAN JACINTO VALLEY	34.1(54.9)	6.9	0.056	VI
CORONADO BANK	36.5(58.8)	7.4	0.078	VII
HOLLYWOOD	36.7(59.0)	6.4	0.035	V
SAN ANDREAS - Southern	38.5(61.9)	7.4	0.073	VII
SAN ANDREAS - San Bernardino	38.5(61.9)	7.3	0.067	VI
SAN ANDREAS - Mojave	39.1(63.0)	7.1	0.055	VI
SAN ANDREAS - 1857 Rupture	39.1(63.0)	7.8	0.099	VII
CLEGHORN	40.6(65.3)	6.5	0.031	V
SANTA MONICA	43.5(70.0)	6.6	0.031	V
NORTH FRONTAL FAULT ZONE (West)	45.7(73.6)	7.0	0.039	V
SIERRA MADRE (San Fernando)	47.9(77.1)	6.7	0.029	V
SAN GABRIEL	48.1(77.4)	7.0	0.037	V
MALIBU COAST	48.2(77.5)	6.7	0.029	V
SAN JACINTO-ANZA	48.2(77.6)	7.2	0.044	VI
ROSE CANYON	48.6(78.2)	6.9	0.034	V
NORTHRIDGE (E. Oak Ridge)	50.5(81.3)	6.9	0.031	V
ELSINORE-JULIAN	50.8(81.8)	7.1	0.038	V
ANACAPA-DUME	57.0(91.7)	7.3	0.035	V
SANTA SUSANA	57.8(93.1)	6.6	0.020	IV
PINTO MOUNTAIN	62.4(100.5)	7.0	0.026	V
HOLSER	62.7(100.9)	6.5	0.016	IV
NORTH FRONTAL FAULT ZONE (East)	62.9(101.3)	6.7	0.019	IV
HELENDALE - S. LOCKHARDT	65.3(105.1)	7.1	0.026	V
OAK RIDGE (Onshore)	68.8(110.8)	6.9	0.019	IV

DETERMINISTIC SITE PARAMETERS

Page 2

ABBREVIATED FAULT NAME	APPROXIMATE DISTANCE mi (km)	ESTIMATED MAX. EARTHQUAKE EVENT: MAXIMUM EARTHQUAKE MAG.(Mw)	PEAK SITE ACCEL. g	EST. SITE INTENSITY MOD.MERC.
SIMI-SANTA ROSA	70.2(112.9)	6.7	0.016	IV
SAN ANDREAS - Coachella	74.6(120.0)	7.1	0.021	IV
SAN CAYETANO	74.6(120.1)	6.8	0.015	IV
SAN JACINTO-COYOTE CREEK	75.0(120.7)	6.8	0.016	IV
LENWOOD-LOCKHART-OLD WOMAN SPRGS	75.7(121.9)	7.3	0.025	V
SAN ANDREAS - Carrizo	77.1(124.1)	7.2	0.022	IV
EARTHQUAKE VALLEY	79.0(127.1)	6.5	0.012	III
BURNT MTN.	80.0(128.8)	6.4	0.010	III
JOHNSON VALLEY (Northern)	80.5(129.6)	6.7	0.013	III
LANDERS	81.4(131.0)	7.3	0.023	IV
EUREKA PEAK	81.8(131.7)	6.4	0.010	III
SANTA YNEZ (East)	85.7(138.0)	7.0	0.016	IV
OAK RIDGE(Blind Thrust Offshore)	86.4(139.1)	6.9	0.013	III
EMERSON So. - COPPER MTN.	87.3(140.5)	6.9	0.014	IV
CHANNEL IS. THRUST (Eastern)	87.9(141.5)	7.4	0.019	IV
VENTURA - PITAS POINT	89.1(143.4)	6.8	0.012	III
GRAVEL HILLS - HARPER LAKE	89.4(143.8)	6.9	0.014	III
CALICO - HIDALGO	93.3(150.2)	7.1	0.015	IV
MONTALVO-OAK RIDGE TREND	93.3(150.2)	6.6	0.009	III
GARLOCK (West)	93.9(151.1)	7.1	0.015	IV
M.RIDGE-ARROYO PARIDA-SANTA ANA	95.0(152.9)	6.7	0.010	III
BLACKWATER	96.1(154.6)	6.9	0.012	III
ELSINORE-COYOTE MOUNTAIN	97.7(157.3)	6.8	0.011	III
PLEITO THRUST	97.7(157.3)	7.2	0.014	IV
PISGAH-BULLION MTN.-MESQUITE LK	98.1(157.8)	7.1	0.014	IV
SAN JACINTO - BORREGO	98.1(157.9)	6.6	0.009	III
RED MOUNTAIN	98.7(158.9)	6.8	0.010	III

****

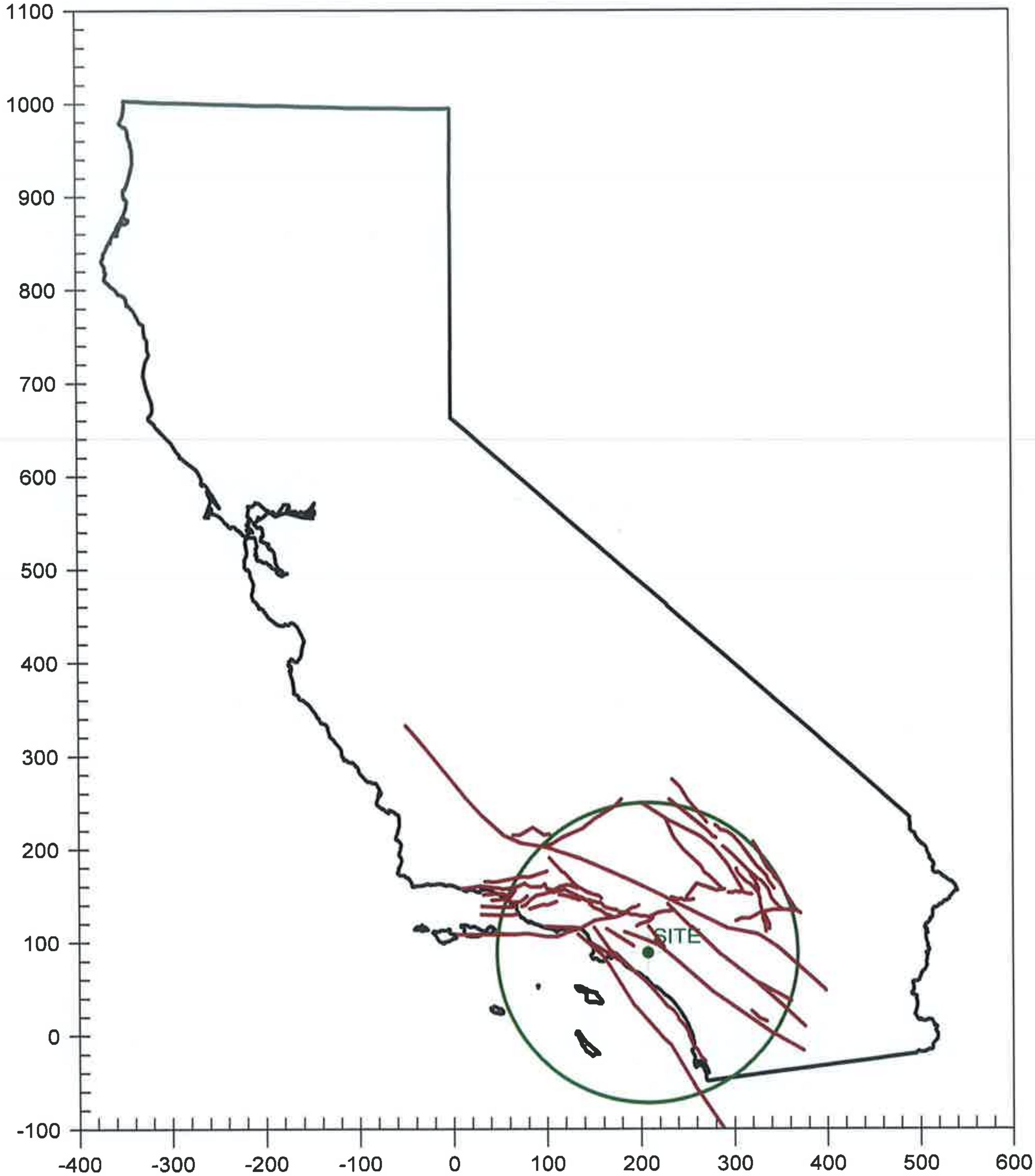
-END OF SEARCH- 67 FAULTS FOUND WITHIN THE SPECIFIED SEARCH RADIUS.

THE WHITTIER FAULT IS CLOSEST TO THE SITE.
IT IS ABOUT 7.8 MILES (12.5 km) AWAY.

LARGEST MAXIMUM-EARTHQUAKE SITE ACCELERATION: 0.3162 g

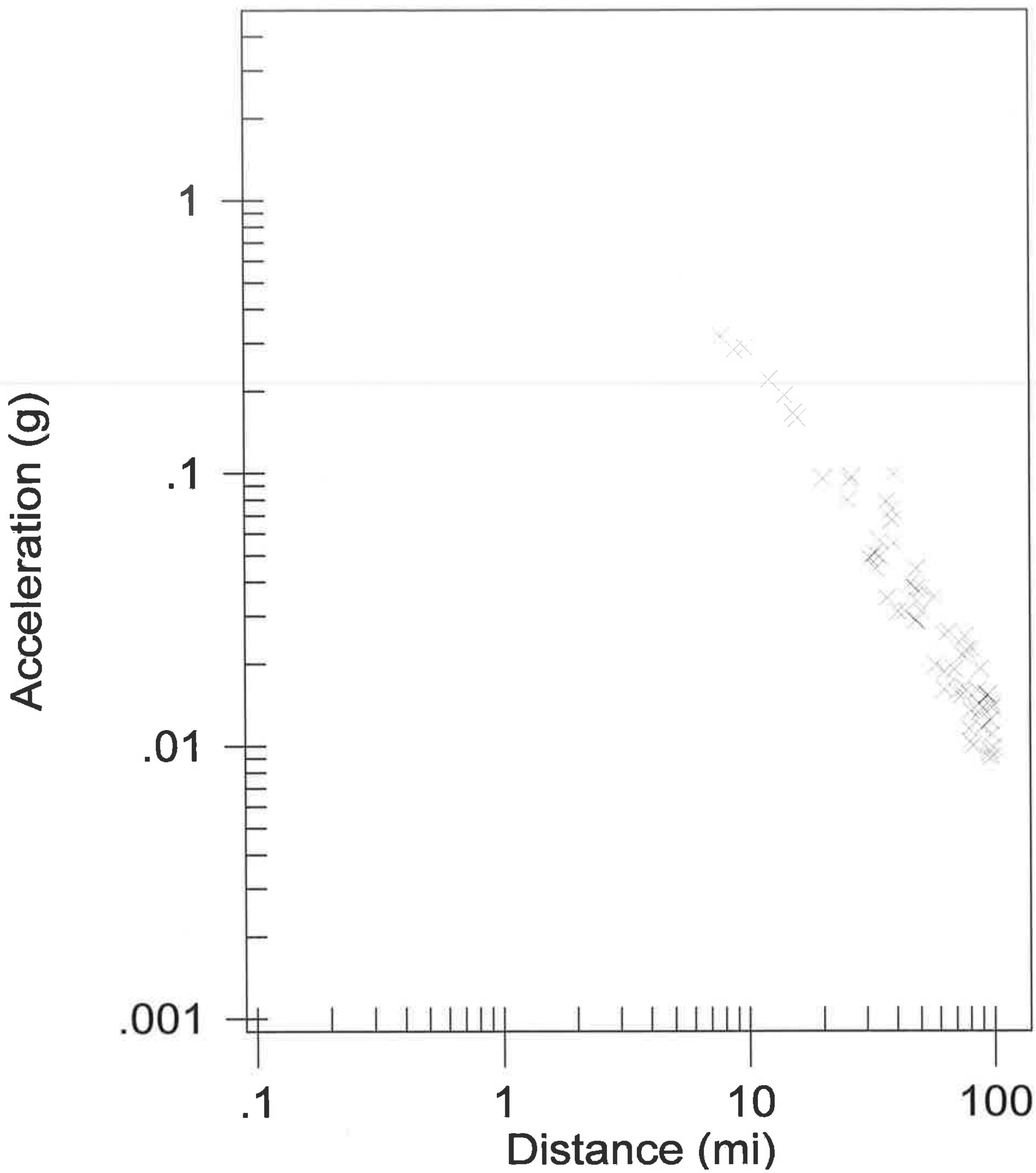
CALIFORNIA FAULT MAP

EOCWD 6MG Reservoir



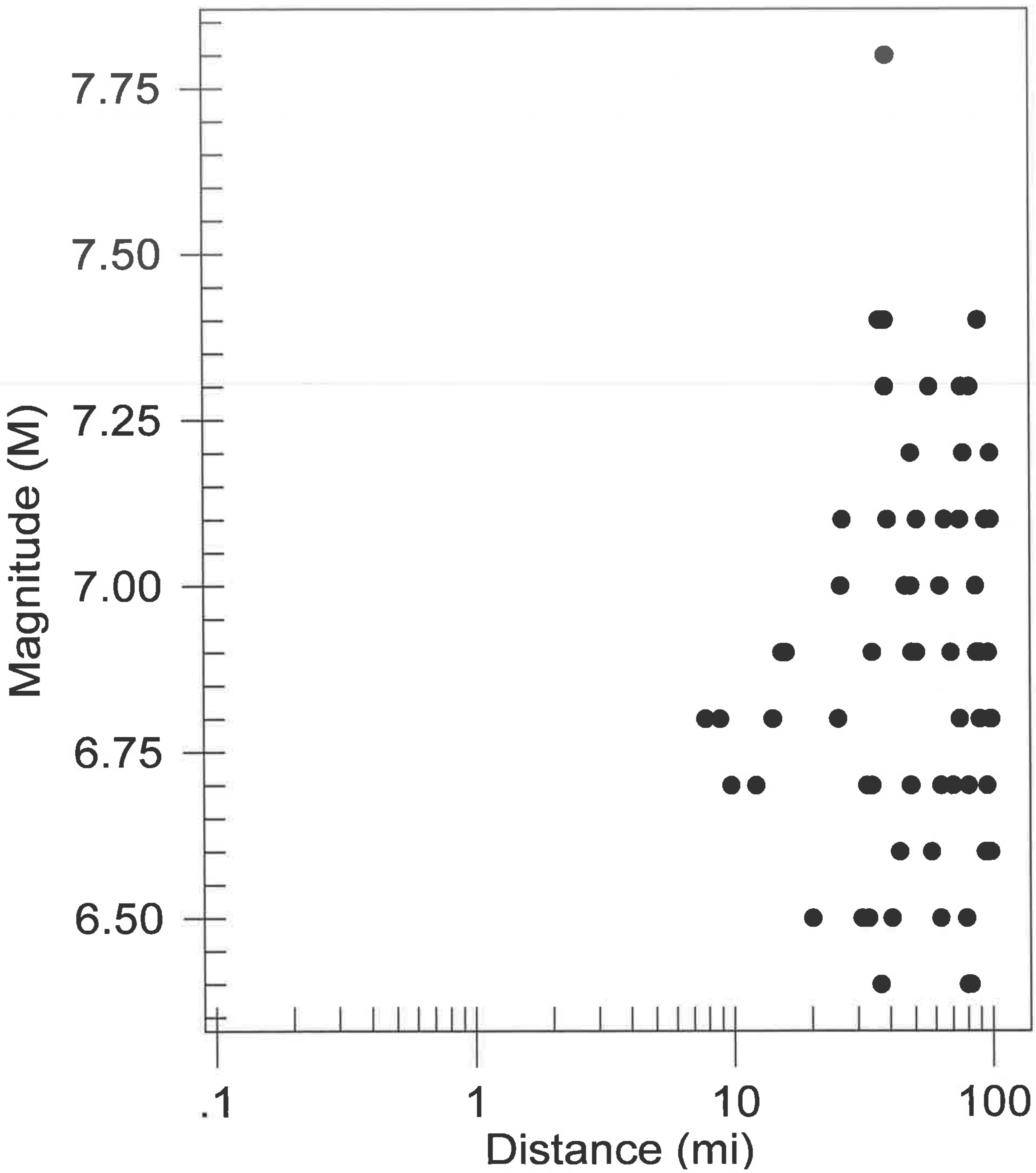
MAXIMUM EARTHQUAKES

EOCWD 6MG Reservoir



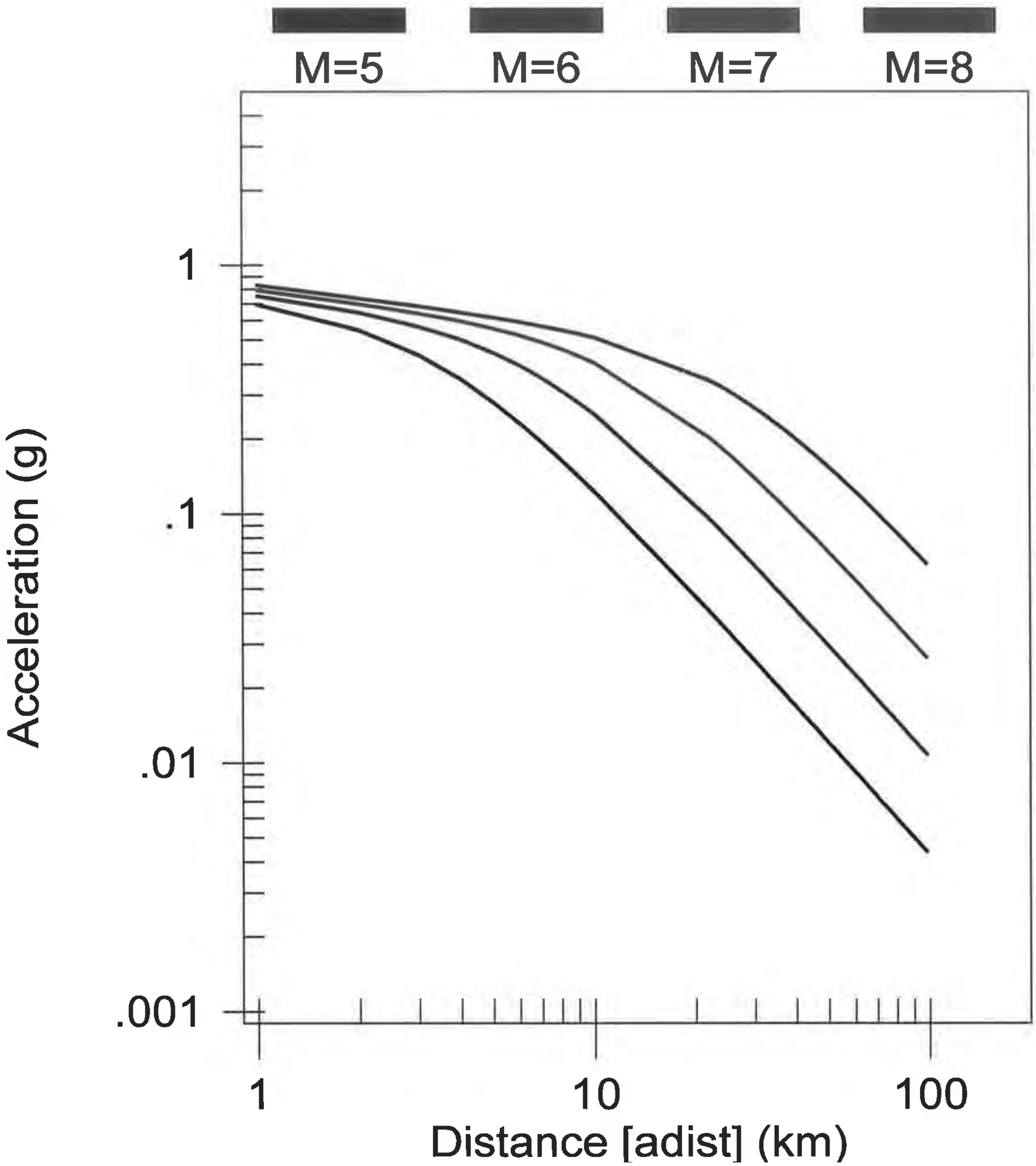
EARTHQUAKE MAGNITUDES & DISTANCES

EOCWD 6MG Reservoir



STRIKE-SLIP FAULTS

15) Campbell & Bozorgnia (1997 Rev.) - Soft Rock



DIP-SLIP FAULTS

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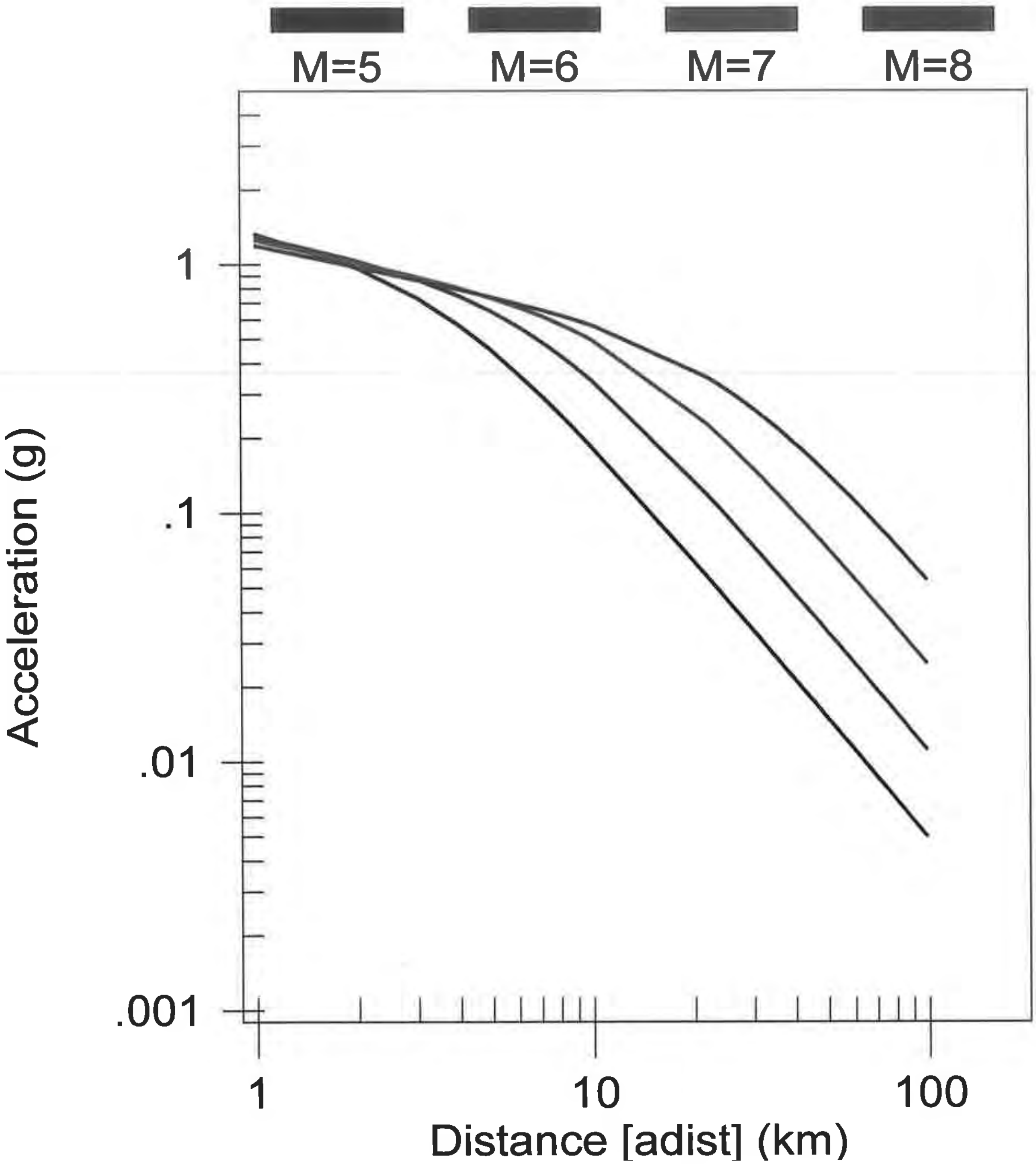
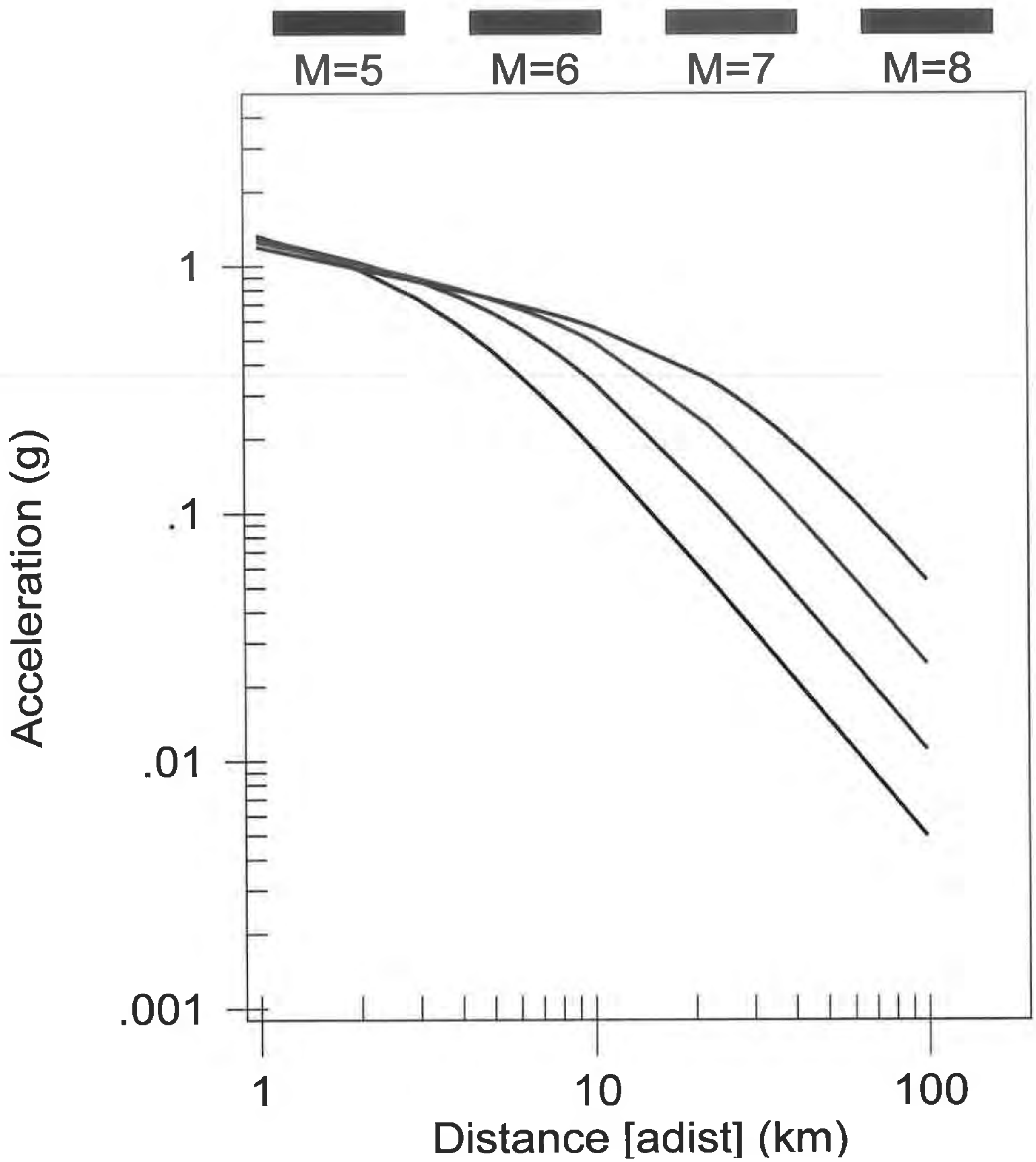


BLIND-THRUST FAULTS

15) Campbell & Bozorgnia (1997 Rev.) - Soft Rock



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Earthquake Hazards Program

US Seismic Hazard 2008

Layers Tools

Hazard maps

Transparency

Peak ground acceleration (%g) with 10% probability of exceedance in 50 years

Peak ground acceleration (%g) with 2% probability of exceedance in 50 years

0.2-second acceleration with 10% probability of exceedance in 50 years

0.2-second acceleration with 2% probability of exceedance in 50 years

1.0-second acceleration with 10% probability of exceedance in 50 years

1.0-second acceleration with 2% probability of exceedance in 50 years

Hazard map faults

Basemap

Transparency

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Earthquake Hazards Program

US Seismic Hazard 2008

Layers Tools

Hazard maps

Transparency

Peak ground acceleration (%g) with 10% probability of exceedance in 50 years

Peak ground acceleration (%g) with 2% probability of exceedance in 50 years

0.2-second acceleration with 10% probability of exceedance in 50 years

0.2-second acceleration with 2% probability of exceedance in 50 years

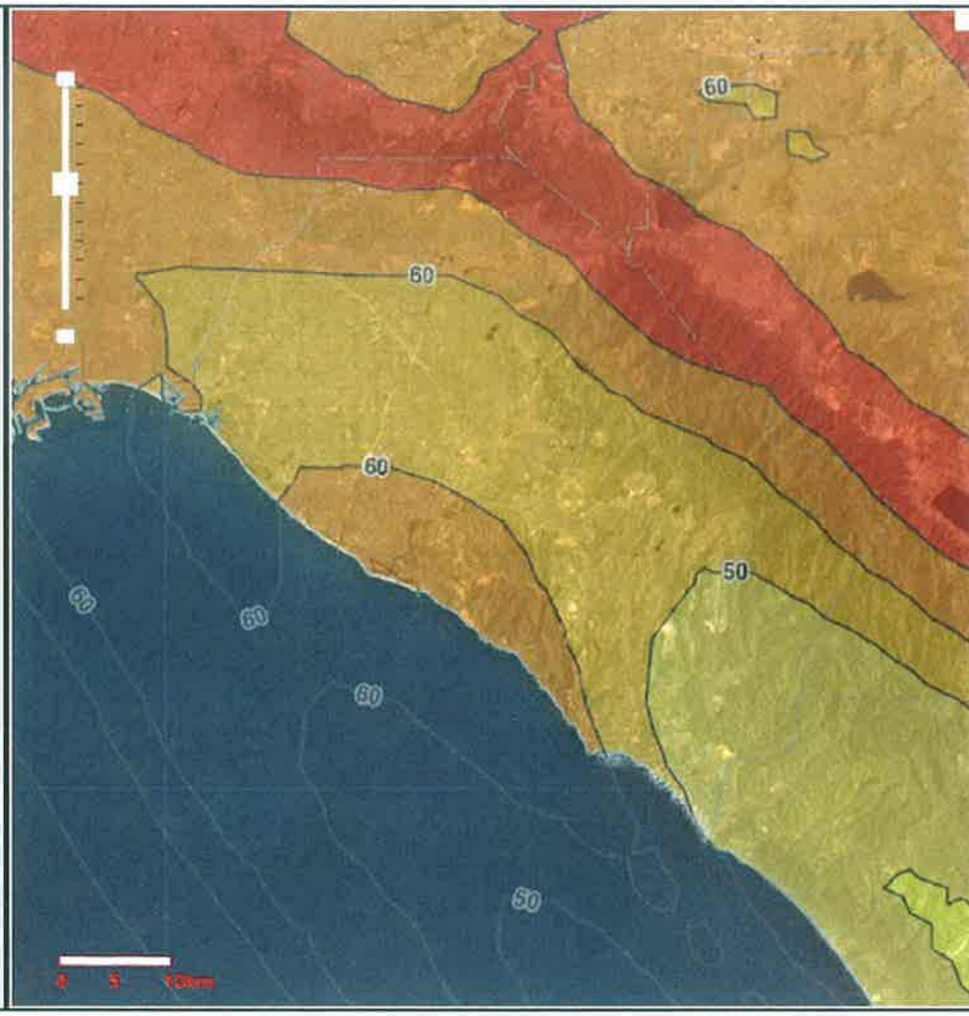
1.0-second acceleration with 10% probability of exceedance in 50 years

1.0-second acceleration with 2% probability of exceedance in 50 years

Hazard map faults

Basemap

Transparency



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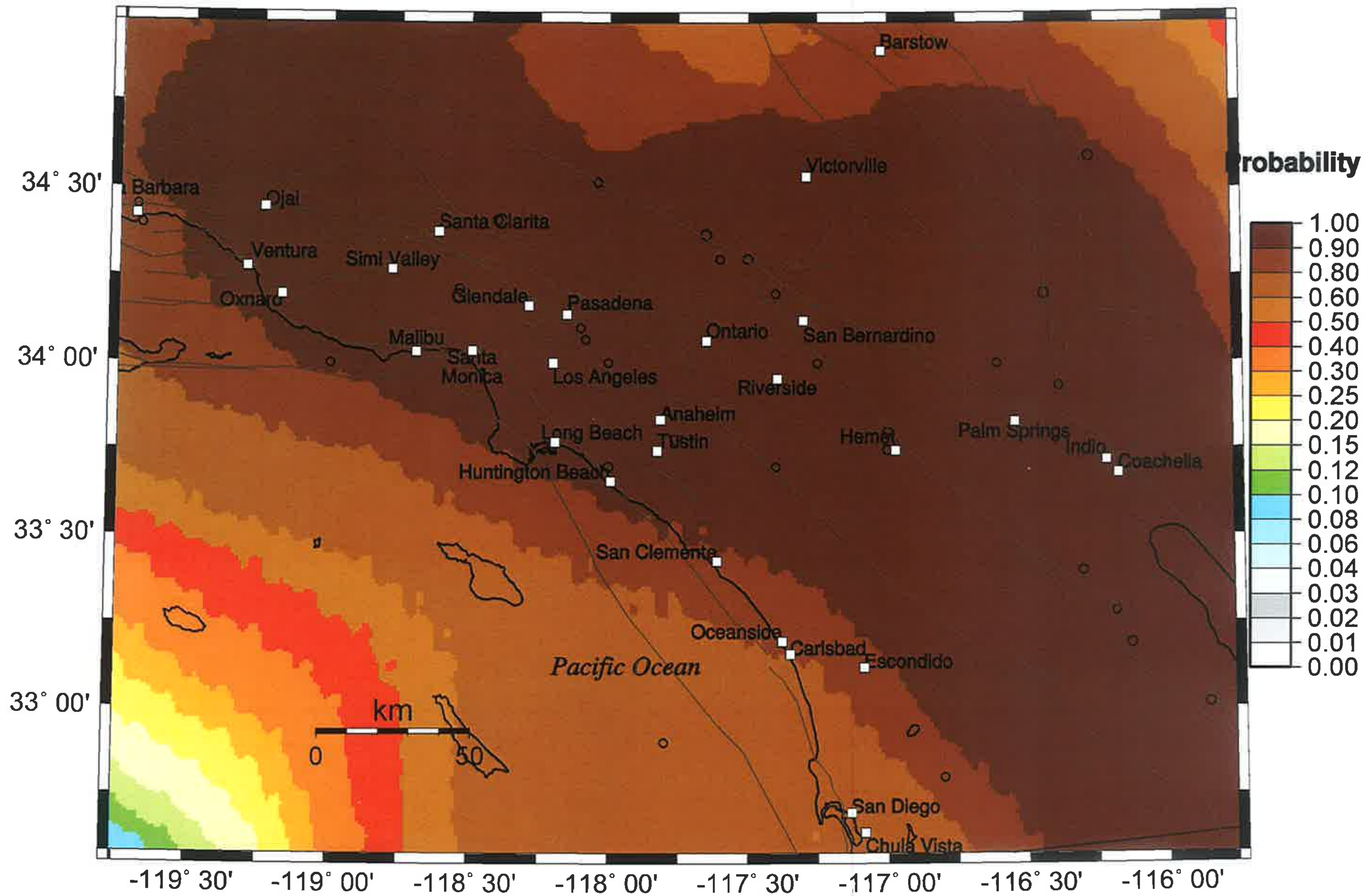
Probability of earthquake with M > 5.0 within 50 years & 50 km

U.S. Geological Survey 2009 PSHA Model

Site: -117.76 d E 33.78

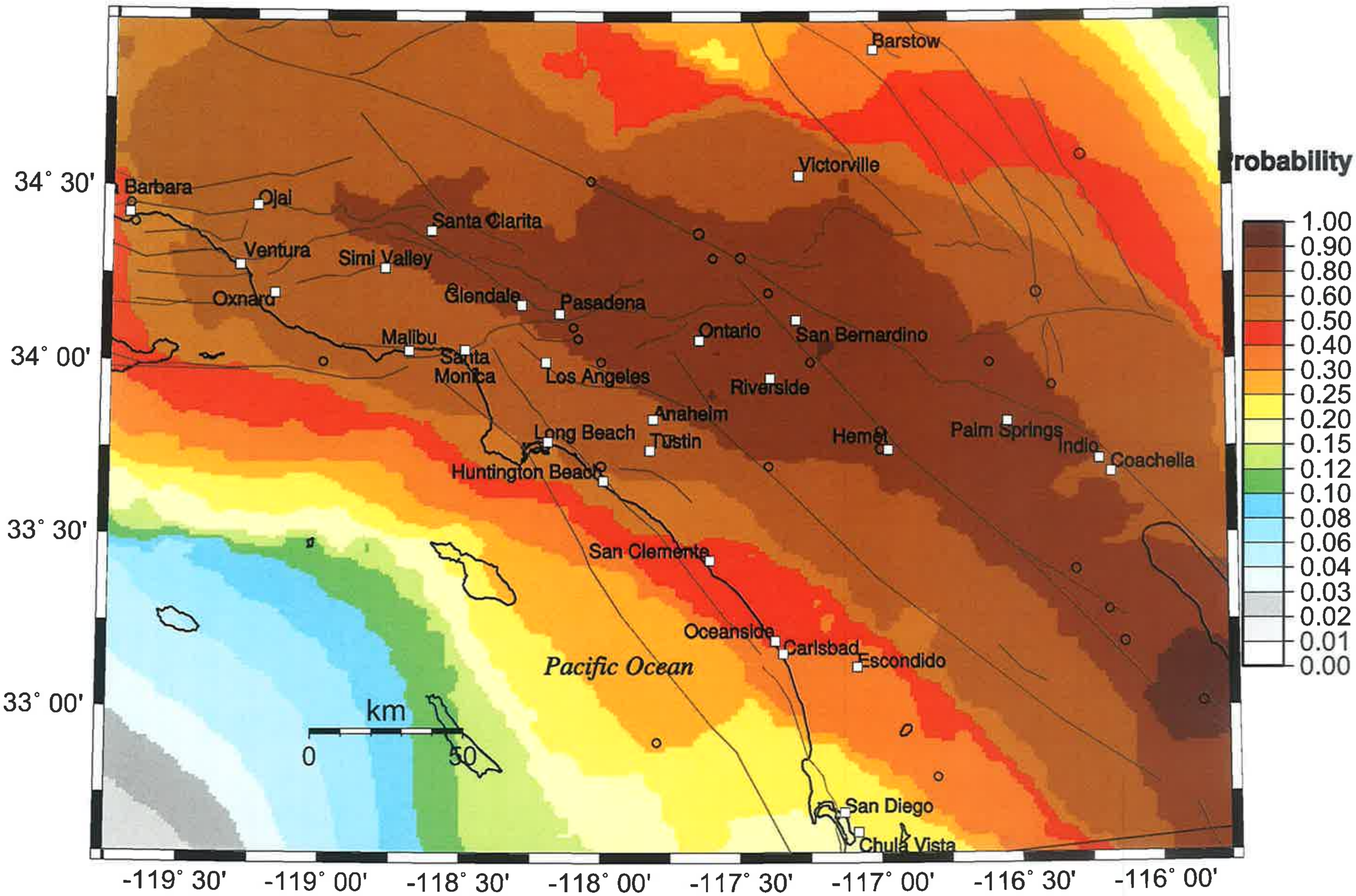


GMT 2014 Feb 20 18:56:45 EQ probabilities from USGS OFR 08-1128 PSHA. 50 km maximum horizontal distance. Site of interest: triangle. Fault traces are brown; rivers blue. Epicenters M>=6.0 circles.

Probability of earthquake with M > 6.0 within 50 years & 50 km

U.S. Geological Survey 2009 PSHA Model

Site: -117.76 d E 33.78

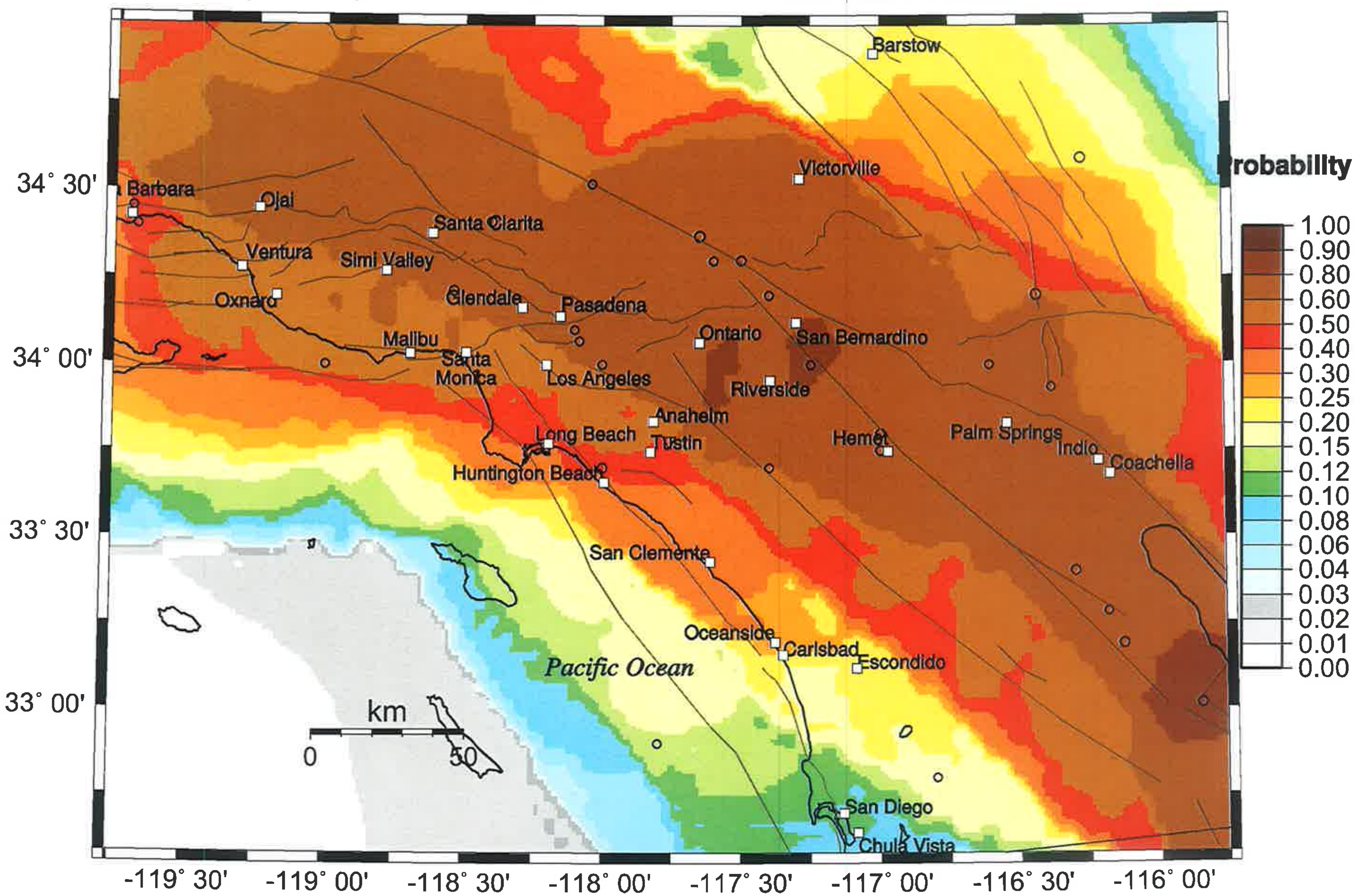


GMT 2014 Feb 20 18:59:17 EQ probabilities from USGS OFR 08-1128 PSHA. 50 km maximum horizontal distance. Site of Interest: triangle. Fault traces are brown; rivers blue. Epicenters M>=6.0 circles.

Probability of earthquake with M > 6.5 within 50 years & 50 km

U.S. Geological Survey 2009 PSHA Model

Site: -117.76 d E 33.78

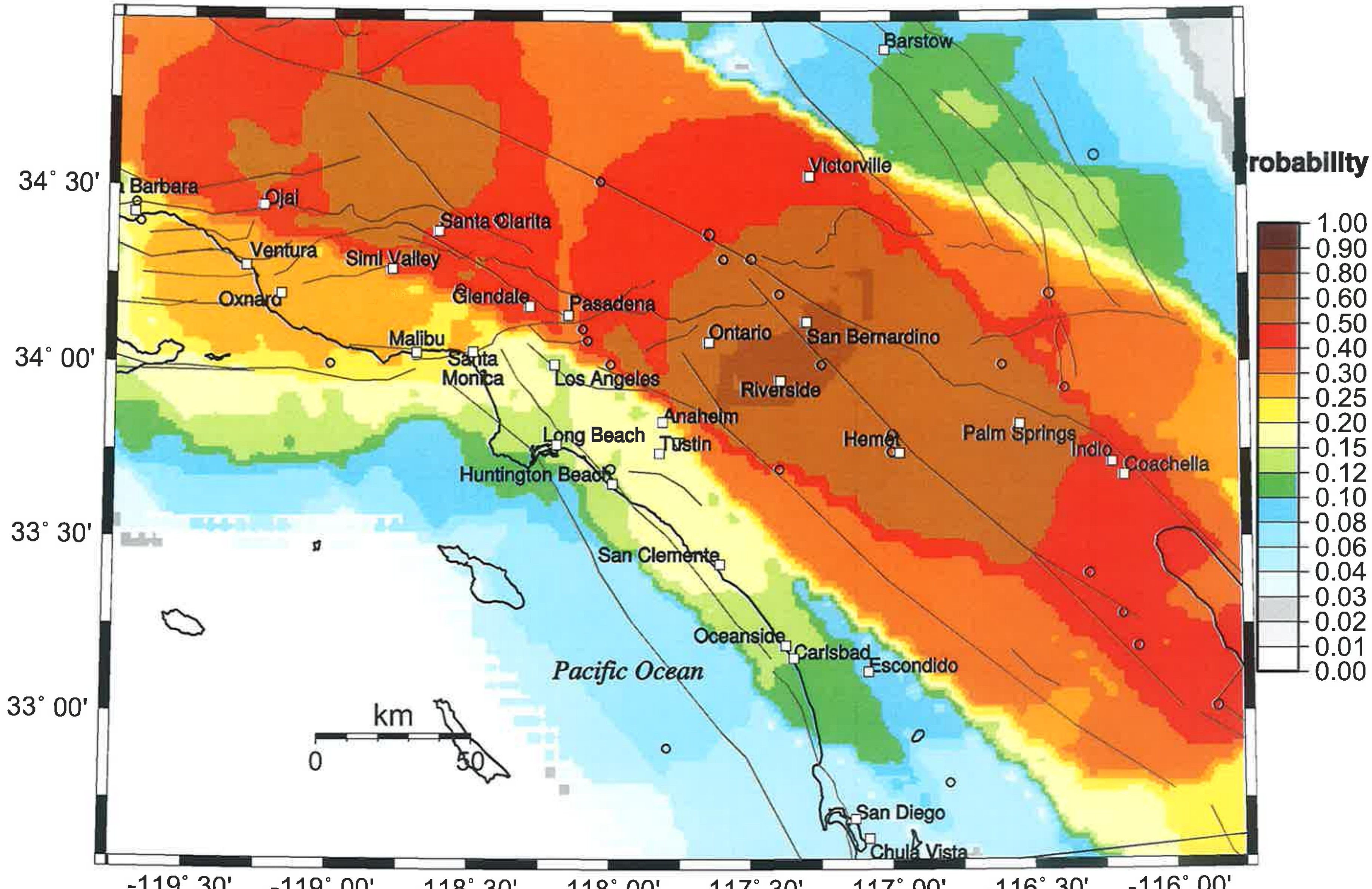


GMT 2014 Feb 20 19:02:22 EQ probabilities from USGS OFR 08-1128 PSHA. 50 km maximum horizontal distance. Site of Interest: triangle. Fault traces are brown; rivers blue. Epicenters M>=6.0 circles.

Probability of earthquake with M > 7.0 within 50 years & 50 km

U.S. Geological Survey 2009 PSHA Model

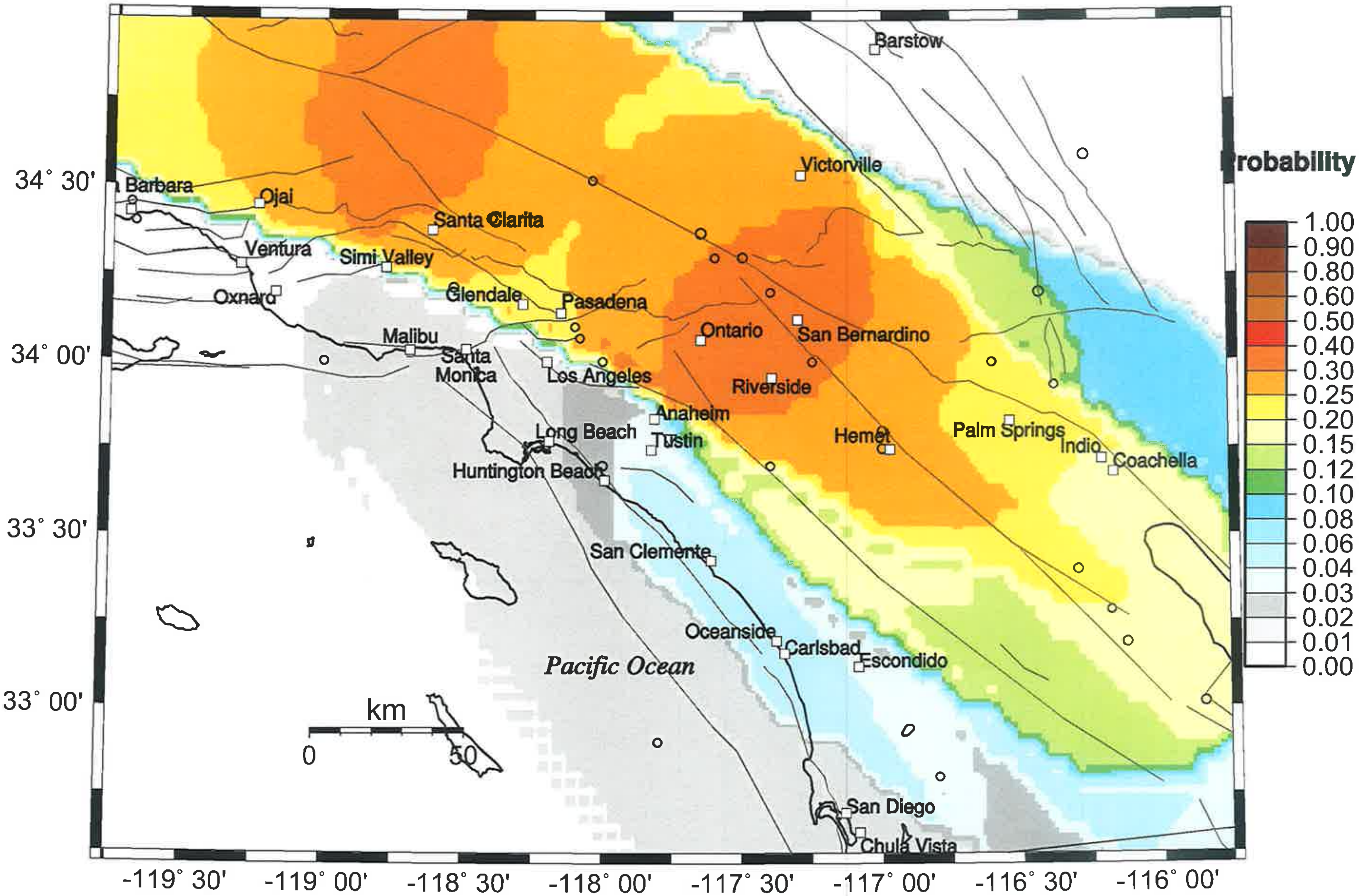
Site: -117.76 d E 33.78



GMT 2014 Feb 20 19:00:54 EQ probabilities from USGS OFR 08-1128 PSHA. 50 km maximum horizontal distance. Site of Interest: triangle. Fault traces are brown; rivers blue. Epicenters M>=6.0 circles.

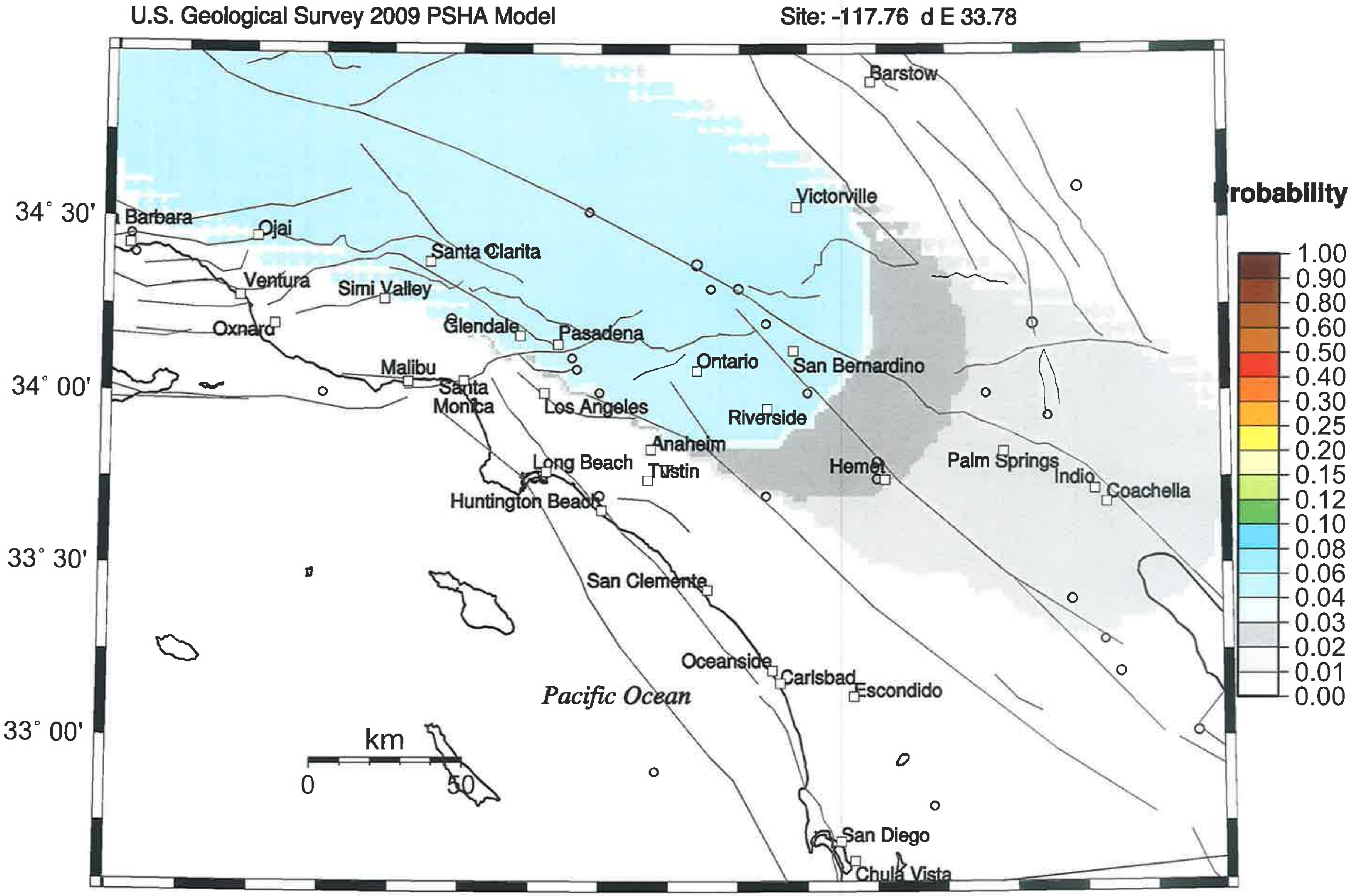
Probability of earthquake with M > 7.5 within 50 years & 50 km

U.S. Geological Survey 2009 PSHA Model   Site: -117.76 d E 33.78



GMT 2014 Feb 20 19:01:38 EQ probabilities from USGS OFR 08-1128 PSHA. 50 km maximum horizontal distance. Site of interest: triangle. Fault traces are brown; rivers blue. Epicenters M>=6.0 circles.

Pr [Crustal Earthquake with M > 8.0 within 50 years & 50 km]



GMT 2014 Feb 20 19:03:01 EQ probabilities from USGS OFR 08-1128 PSHA. 50 km maximum horizontal distance. Site of Interest: triangle. Fault traces are brown; rivers blue. Epicenters M>=6.0 circles.

American Geotechnical, Inc.

File No. 33615-01
April 2, 2014

APPENDIX E

Slope Stability Ana

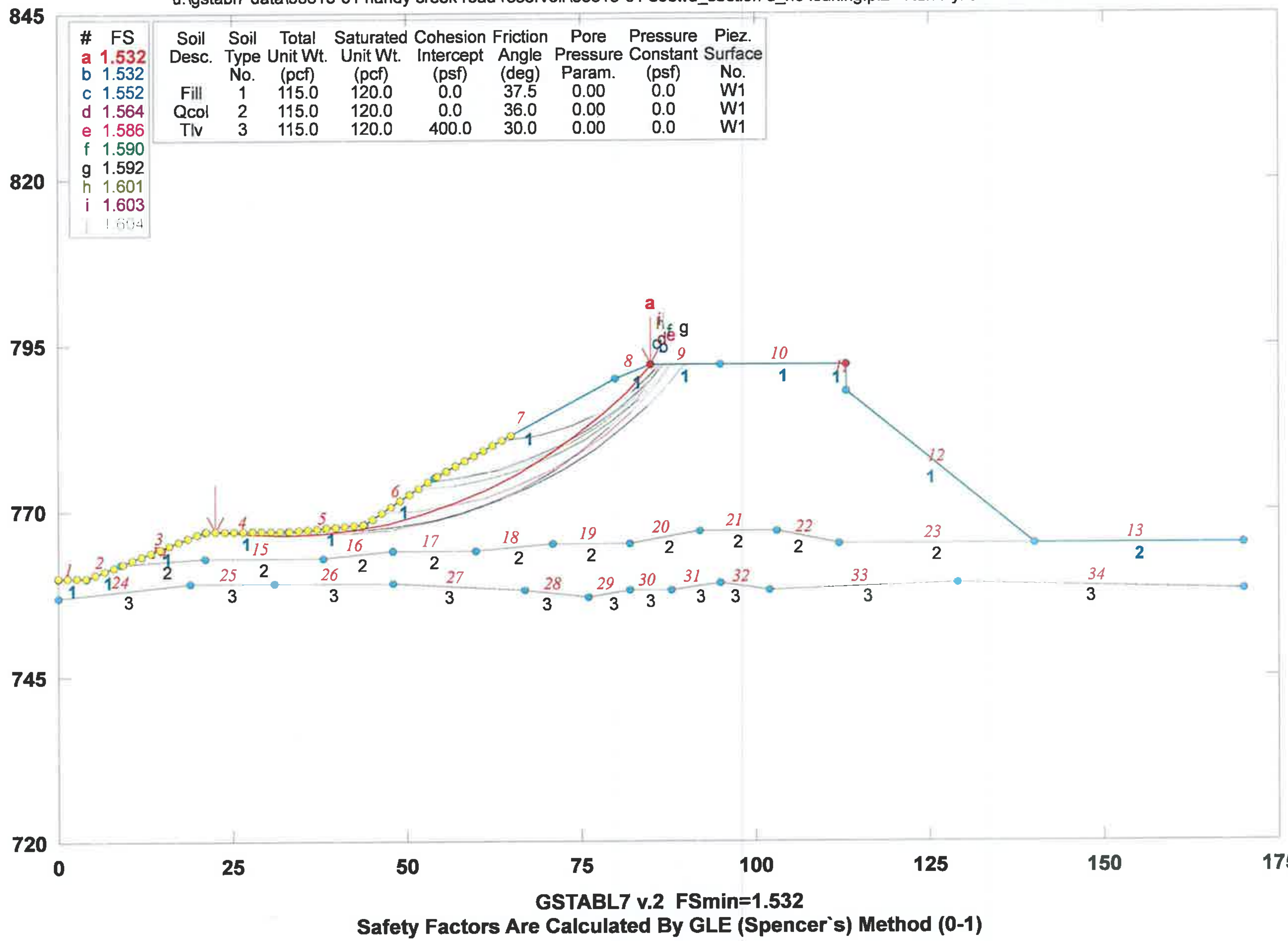
F.N. 33615-01 East Orange County Water District
Peters Canyon Facility
Handy Creek Road Reservoir

Summary of Slope Stability Analyses

Section	Case #	Description	Factor-of-Safety (Static)	Factor-of-Safety (Pseudostatic)
D-D'	1	No leak	1.532	1.105
D-D'	2	Minor leak	1.532	1.105
D-D'	3	Moderate leak	1.448	0.978
D-D'	4	Severe leak	0.822	0.560
E-E'	1	Lower bank - No leak	1.577	1.130
E-E'	2	Lower bank - Minor leak	1.577	1.130
E-E'	3	Lower bank - Moderate leak	0.667	0.429
E-E'	4	Lower bank - Severe leak	0.667	0.429
E-E'	1	Upper bank - No leak	1.642	1.194
E-E'	2	Upper bank - Minor leak	1.642	1.194
E-E'	3	Upper bank - Moderate leak	1.413	1.010
E-E'	4	Upper bank - Severe leak	0.941	0.708

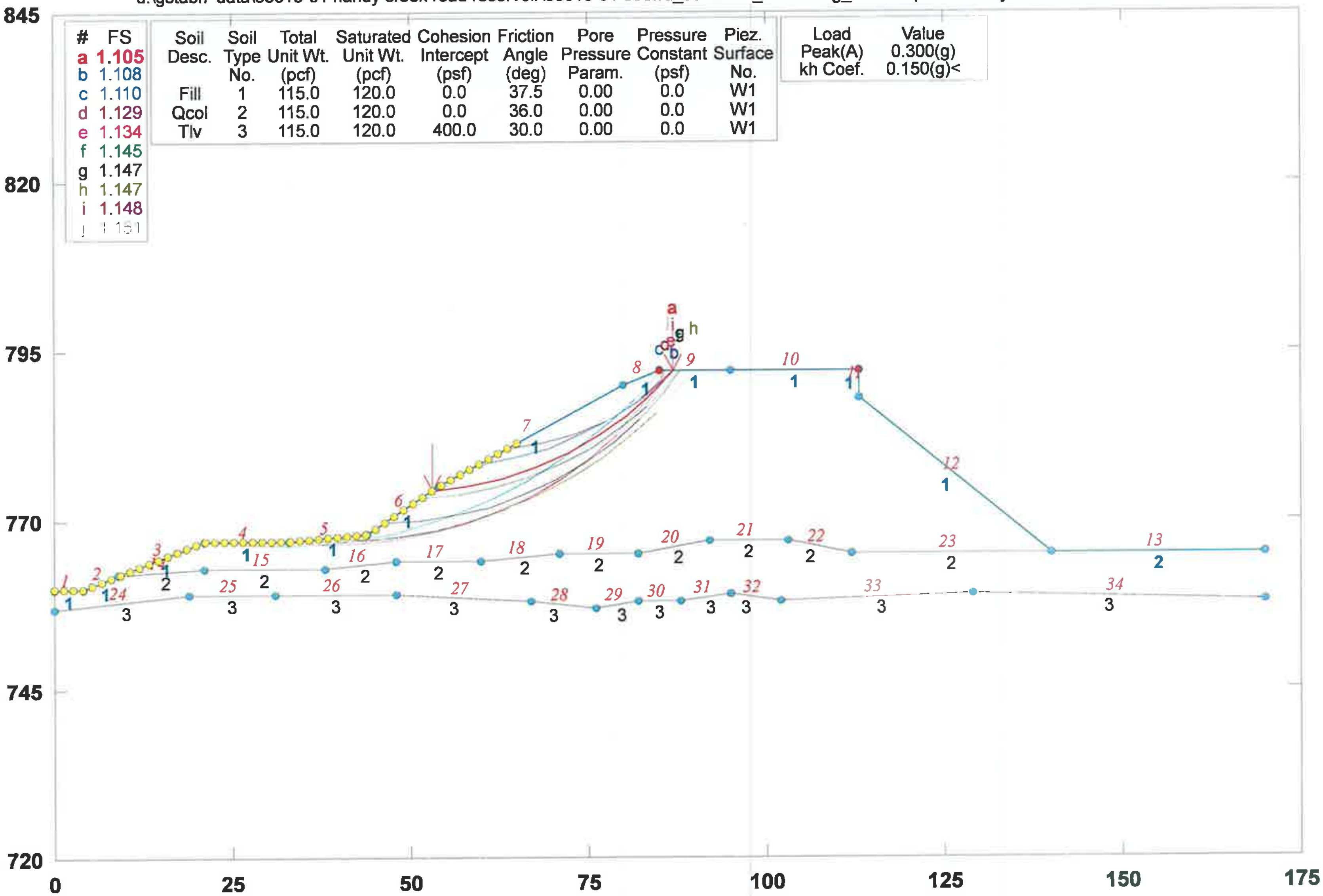
33615-01 Handy Creek Rd. Reservoir Section D-D' - No Leaking - Static

u:\gstabl7 data\33615-01 handy creek road reservoir\33615-01 eocwd_section d_no leaking.pl2 Run By: JH 3/11/2014 10:42AM



33615-01 Handy Creek Rd. Reservoir Section D-D' - No Leaking - Seismic

u:\gstabl7 data\33615-01 handy creek road reservoir\33615-01 eocwd_section d_no leaking_seismic.pl2 Run By: JH 3/11/2014 10:46AM



GSTABL7 v.2 FSmin=1.105

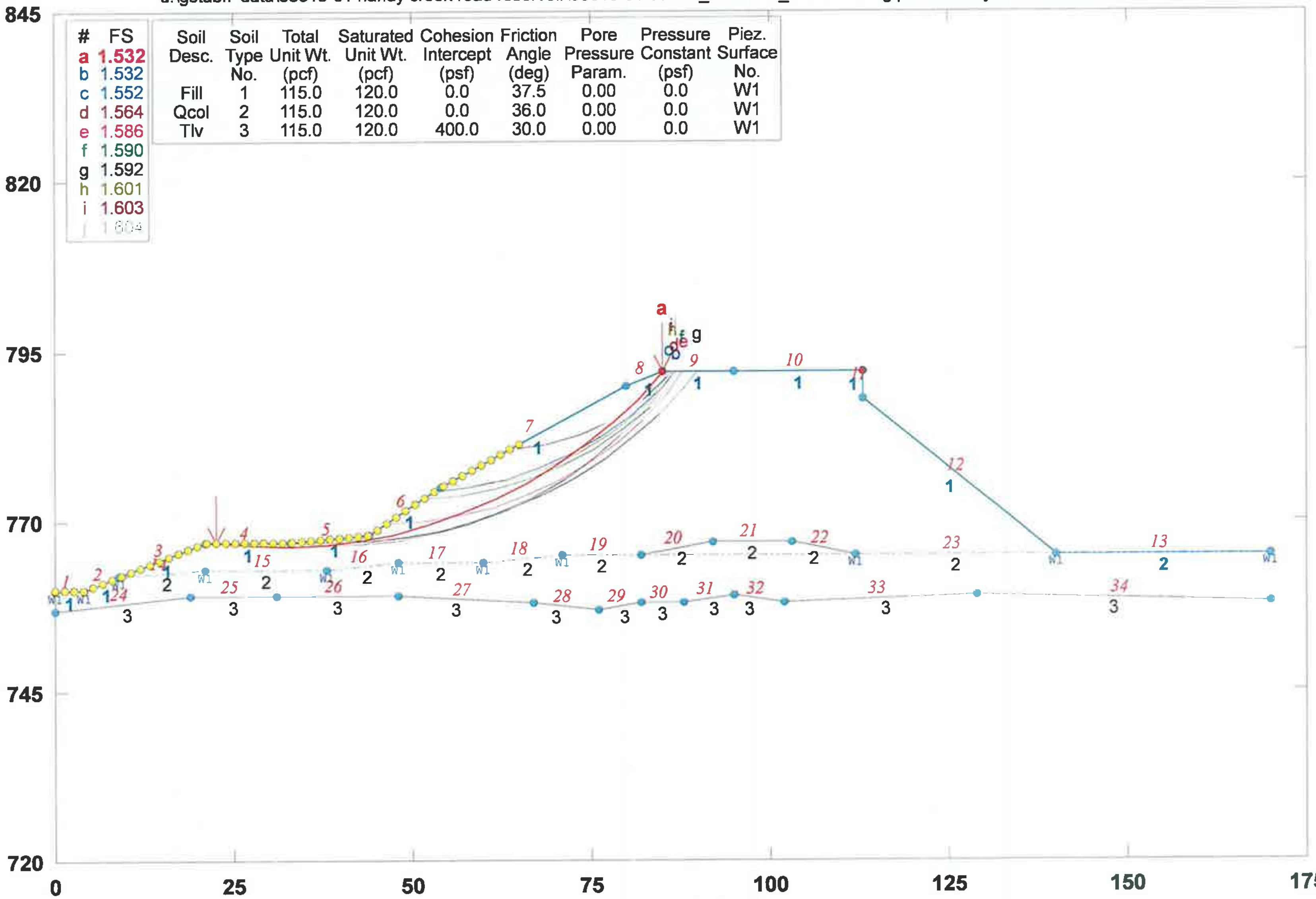
Safety Factors Are Calculated By GLE (Spencer`s) Method (0-1)

33615-01 Handy Creek Rd. Reservoir Section D-D' - Minor Leaking - Static

u:\gstabl7 data\33615-01 handy creek road reservoir\33615-01 eocwd_section d_minor leaking.pl2 Run By: JH 3/11/2014 10:46AM

#	FS
a	1.532
b	1.532
c	1.552
d	1.564
e	1.586
f	1.590
g	1.592
h	1.601
i	1.603
j	1.604

Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
Fill	1	115.0	120.0	0.0	37.5	0.00	0.0	W1
Qcol	2	115.0	120.0	0.0	36.0	0.00	0.0	W1
Tlv	3	115.0	120.0	400.0	30.0	0.00	0.0	W1

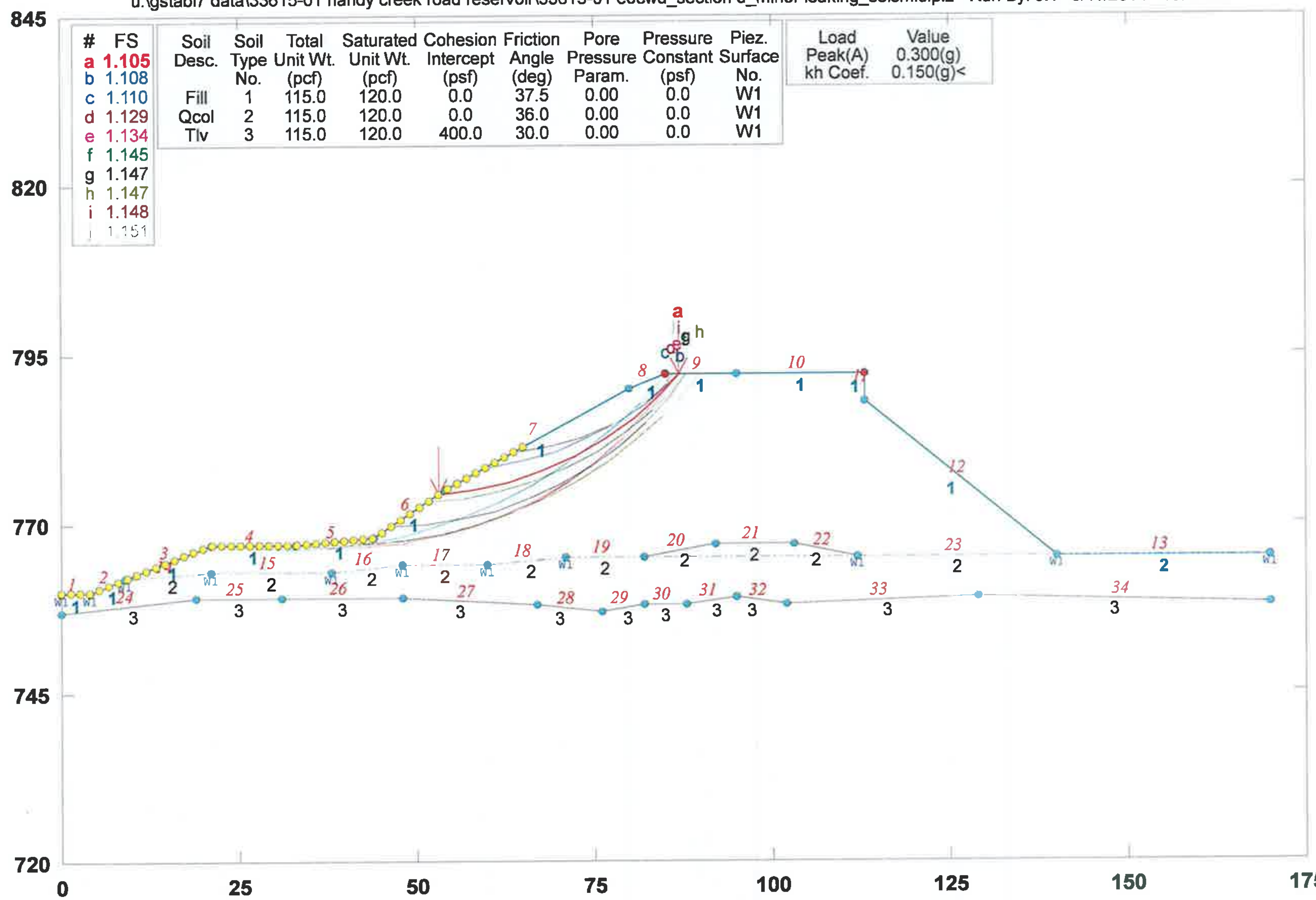


GSTABL7 v.2 FSmin=1.532

Safety Factors Are Calculated By GLE (Spencer`s) Method (0-1)

33615-01 Handy Creek Rd. Reservoir Section D-D' - Minor Leaking - Seismic

u:\gstabl7 data\33615-01 handy creek road reservoir\33615-01 eocwd_section d_minor leaking_seismic.pl2 Run By: JH 3/11/2014 10:47AM

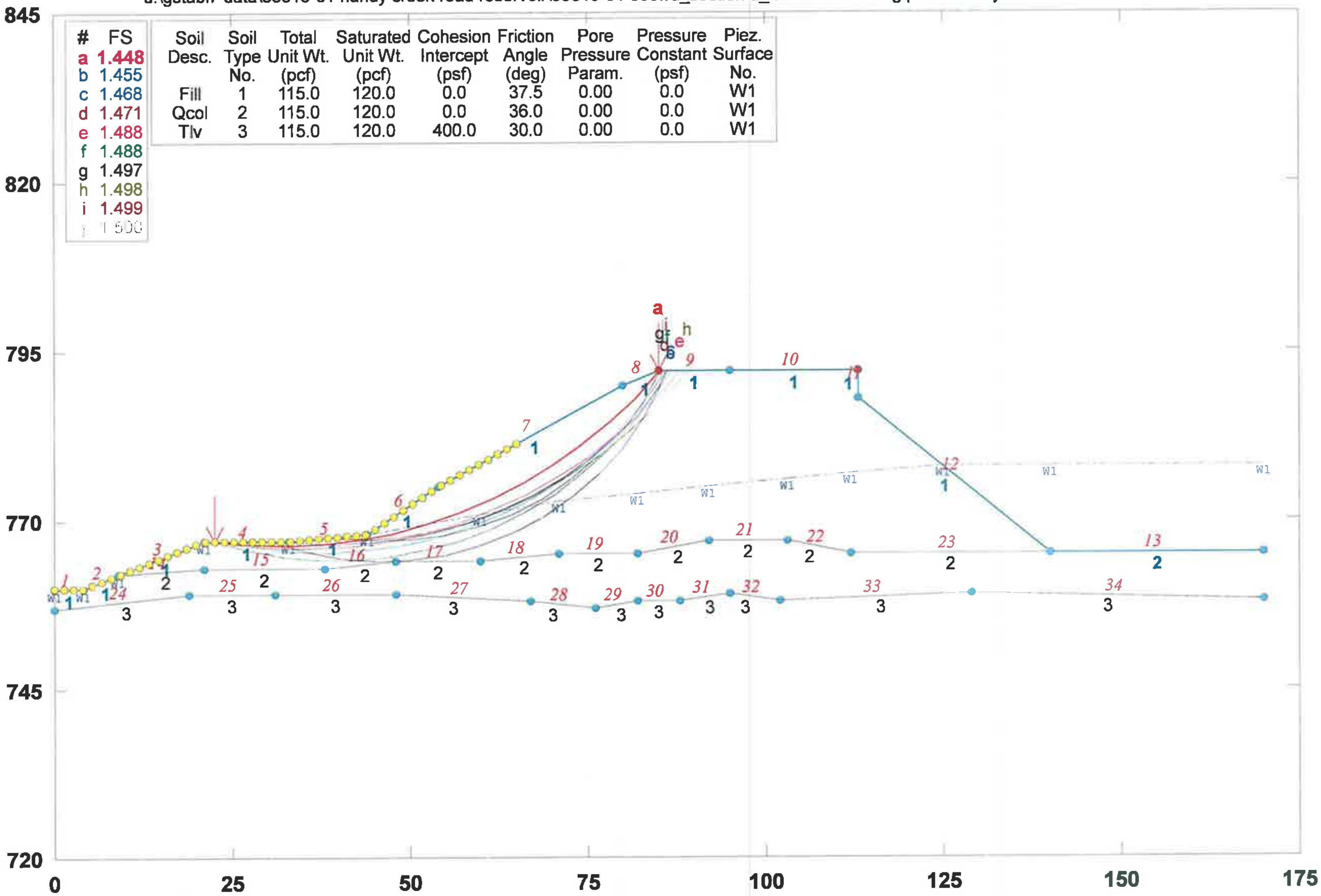


GSTABL7 v.2 FSmin=1.105

Safety Factors Are Calculated By GLE (Spencer`s) Method (0-1)

33615-01 Handy Creek Rd. Reservoir Section D-D' - Moderate Leaking - Static

u:\gstabl7 data\33615-01 handy creek road reservoir\33615-01 eocwd_section d_moderate leaking.pl2 Run By: JH 3/11/2014 10:54AM



GSTABL7 v.2 FSmin=1.448

Safety Factors Are Calculated By GLE (Spencer`s) Method (0-1)

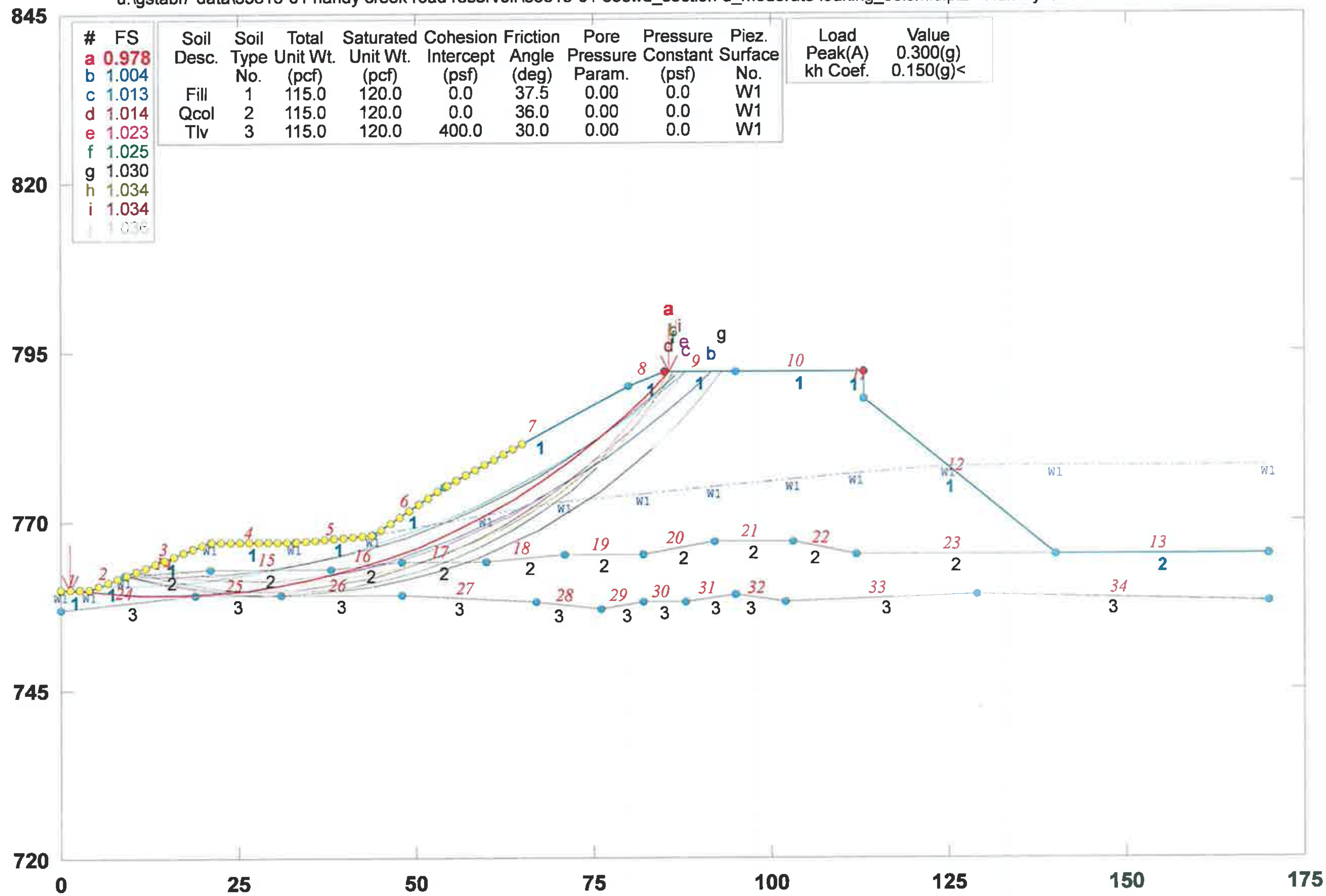
33615-01 Handy Creek Rd. Reservoir Section D-D' - Moderate Leaking-Seismic

u:\gstabl7 data\33615-01 handy creek road reservoir\33615-01 eocwd_section d_moderate leaking_seismic.pl2 Run By: JH 3/11/2014 10:55AM

#	FS
a	0.978
b	1.004
c	1.013
d	1.014
e	1.023
f	1.025
g	1.030
h	1.034
i	1.034
[illegible]	[illegible]

Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
Fill	1	115.0	120.0	0.0	37.5	0.00	0.0	W1
Qcol	2	115.0	120.0	0.0	36.0	0.00	0.0	W1
Tlv	3	115.0	120.0	400.0	30.0	0.00	0.0	W1

Load	Value
Peak(A)	0.300(g)
kh Coef.	0.150(g)<



GSTABL7 v.2 FSmin=0.978

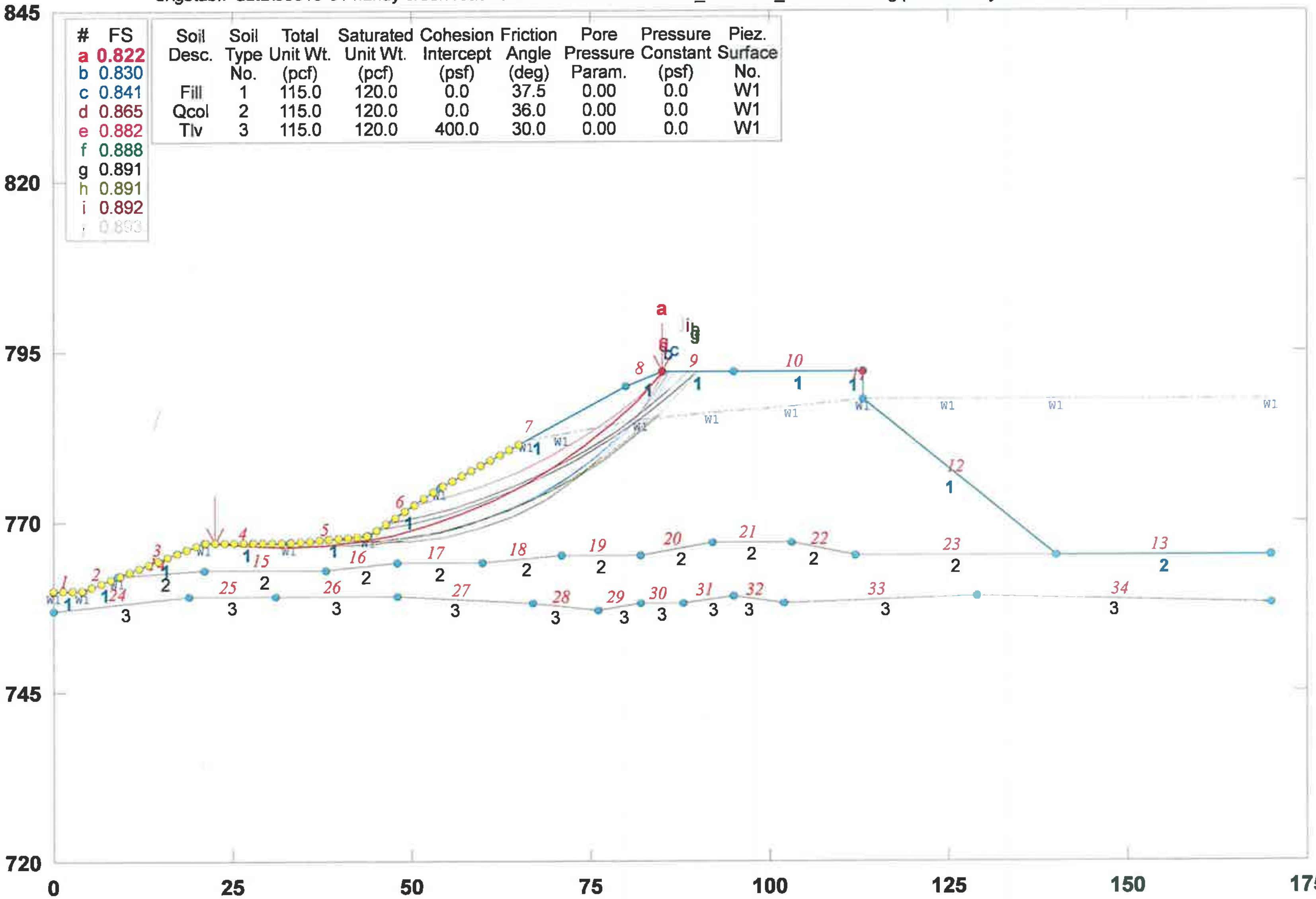
Safety Factors Are Calculated By GLE (Spencer`s) Method (0-1)

33615-01 Handy Creek Rd. Reservoir Section D-D' - Severe Leaking - Static

u:\gstabl7 data\33615-01 handy creek road reservoir\33615-01 eocwd_section d_severe leaking.pl2 Run By: JH 3/11/2014 10:55AM

#	FS
a	0.822
b	0.830
c	0.841
d	0.865
e	0.882
f	0.888
g	0.891
h	0.891
i	0.892
j	0.893

Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
Fill	1	115.0	120.0	0.0	37.5	0.00	0.0	W1
Qcol	2	115.0	120.0	0.0	36.0	0.00	0.0	W1
Tlv	3	115.0	120.0	400.0	30.0	0.00	0.0	W1

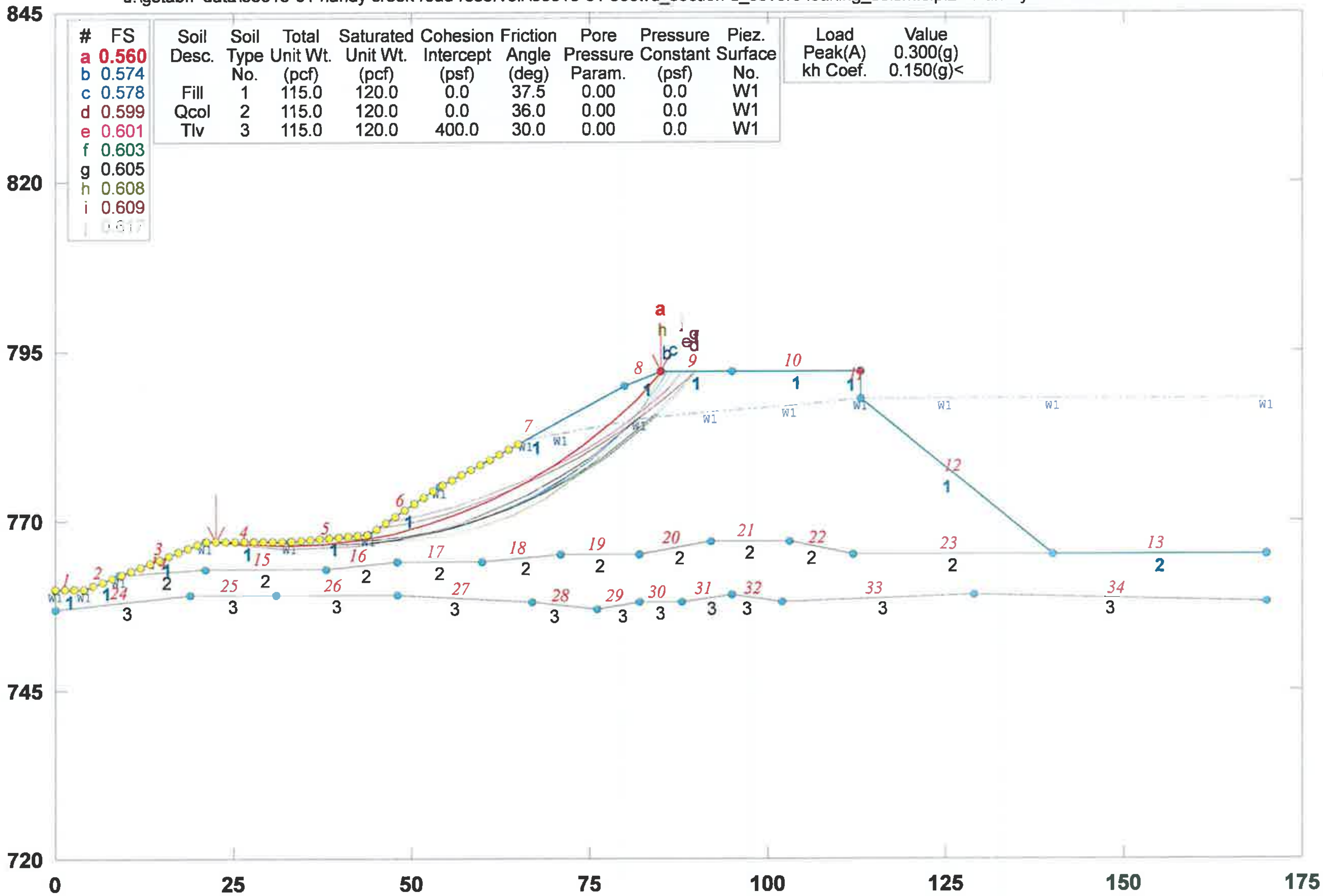


GSTABL7 v.2 FSmin=0.822

Safety Factors Are Calculated By GLE (Spencer`s) Method (0-1)

33615-01 Handy Creek Rd. Reservoir Section D-D' - Severe Leaking - Seismic

u:\gstabl7 data\33615-01 handy creek road reservoir\33615-01 eocwd_section d_severe leaking_seismic.pl2 Run By: JH 3/11/2014 10:56AM



GSTABL7 v.2 FSmin=0.560

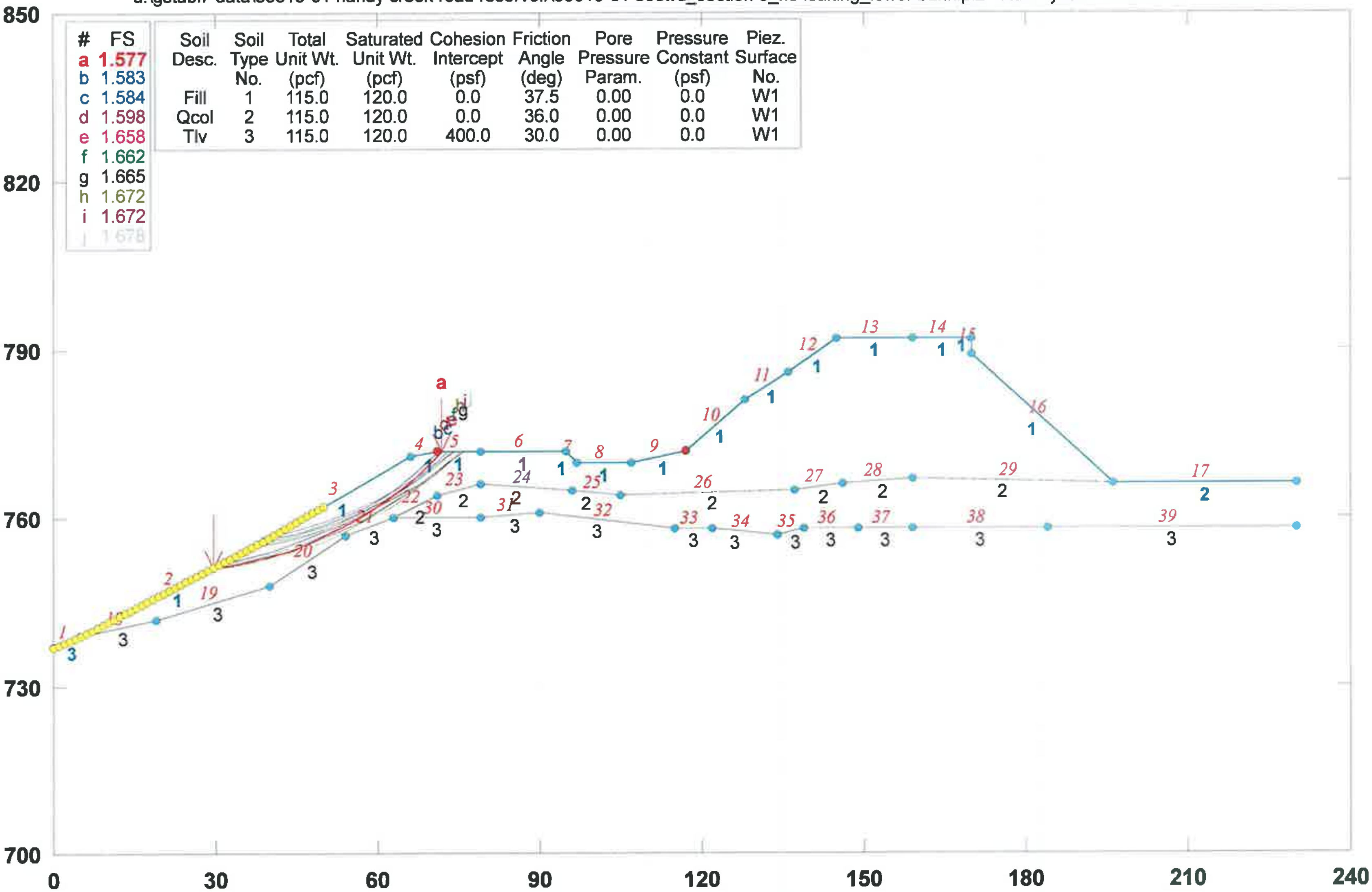
Safety Factors Are Calculated By GLE (Spencer`s) Method (0-1)

33615-01 Handy Creek Rd. Reservoir Section E-E'-No Leak_Lower_Static

u:\gstabl7 data\33615-01 handy creek road reservoir\33615-01 eocwd_section e_no leaking_lower bank.pl2 Run By: JH 3/11/2014 11:03AM

#	FS
a	1.577
b	1.583
c	1.584
d	1.598
e	1.658
f	1.662
g	1.665
h	1.672
i	1.672
j	1.678

Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
Fill	1	115.0	120.0	0.0	37.5	0.00	0.0	W1
Qcol	2	115.0	120.0	0.0	36.0	0.00	0.0	W1
Tlv	3	115.0	120.0	400.0	30.0	0.00	0.0	W1



GSTABL7 v.2 FSmin=1.577

Safety Factors Are Calculated By GLE (Spencer`s) Method (0-1)

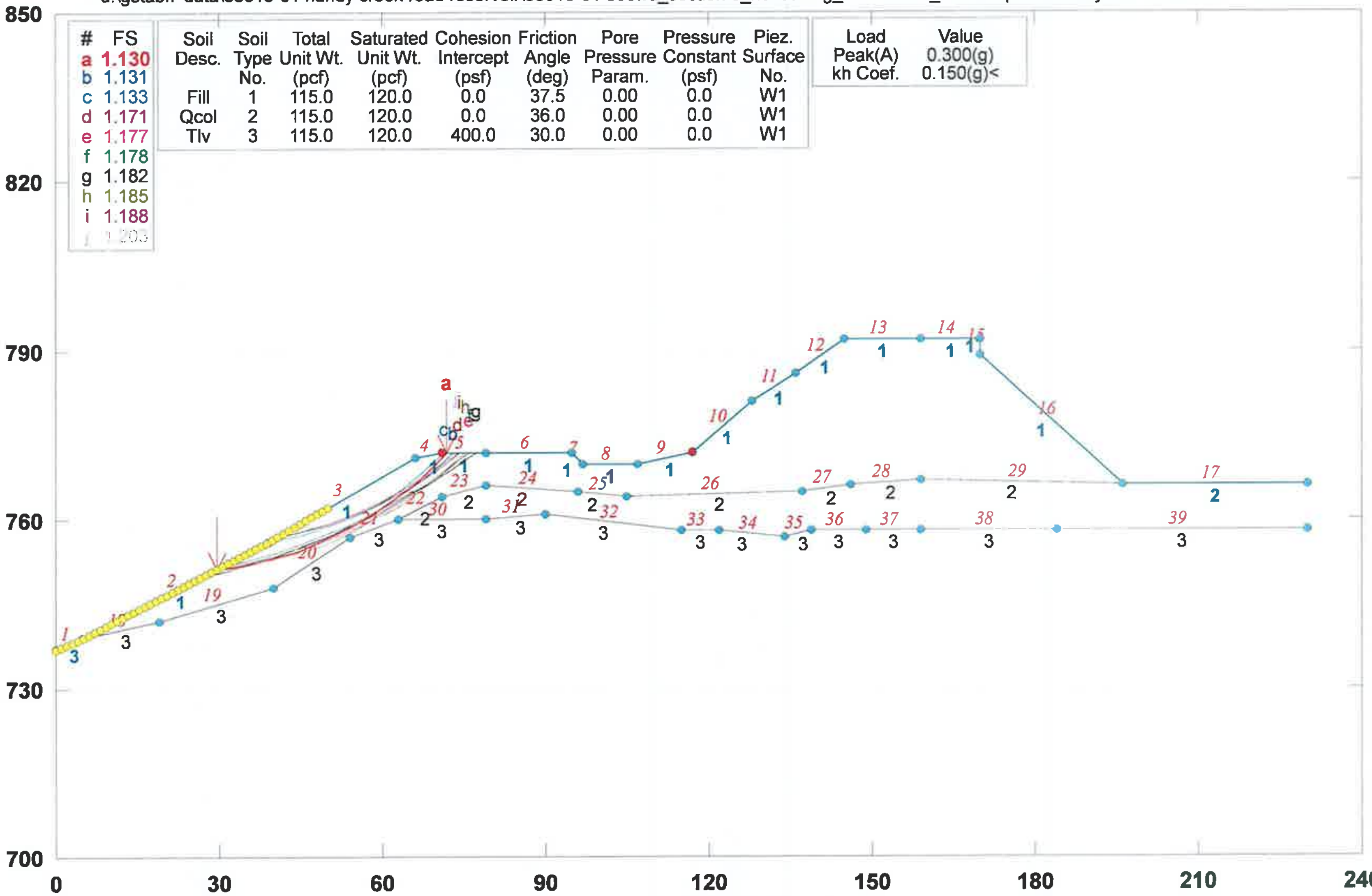
33615-01 Handy Creek Rd. Reservoir Section E-E'-No Leak_Lower_Seismic

u:\gstabl7 data\33615-01 handy creek road reservoir\33615-01 eocwd_section e_no leaking_lower bank_seismic.pl2 Run By: JH 3/11/2014 11:04AM

#	FS
a	1.130
b	1.131
c	1.133
d	1.171
e	1.177
f	1.178
g	1.182
h	1.185
i	1.188
j	1.203

Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
Fill	1	115.0	120.0	0.0	37.5	0.00	0.0	W1
Qcol	2	115.0	120.0	0.0	36.0	0.00	0.0	W1
Tlv	3	115.0	120.0	400.0	30.0	0.00	0.0	W1

Load	Value
Peak(A)	0.300(g)
kh Coef.	0.150(g)<

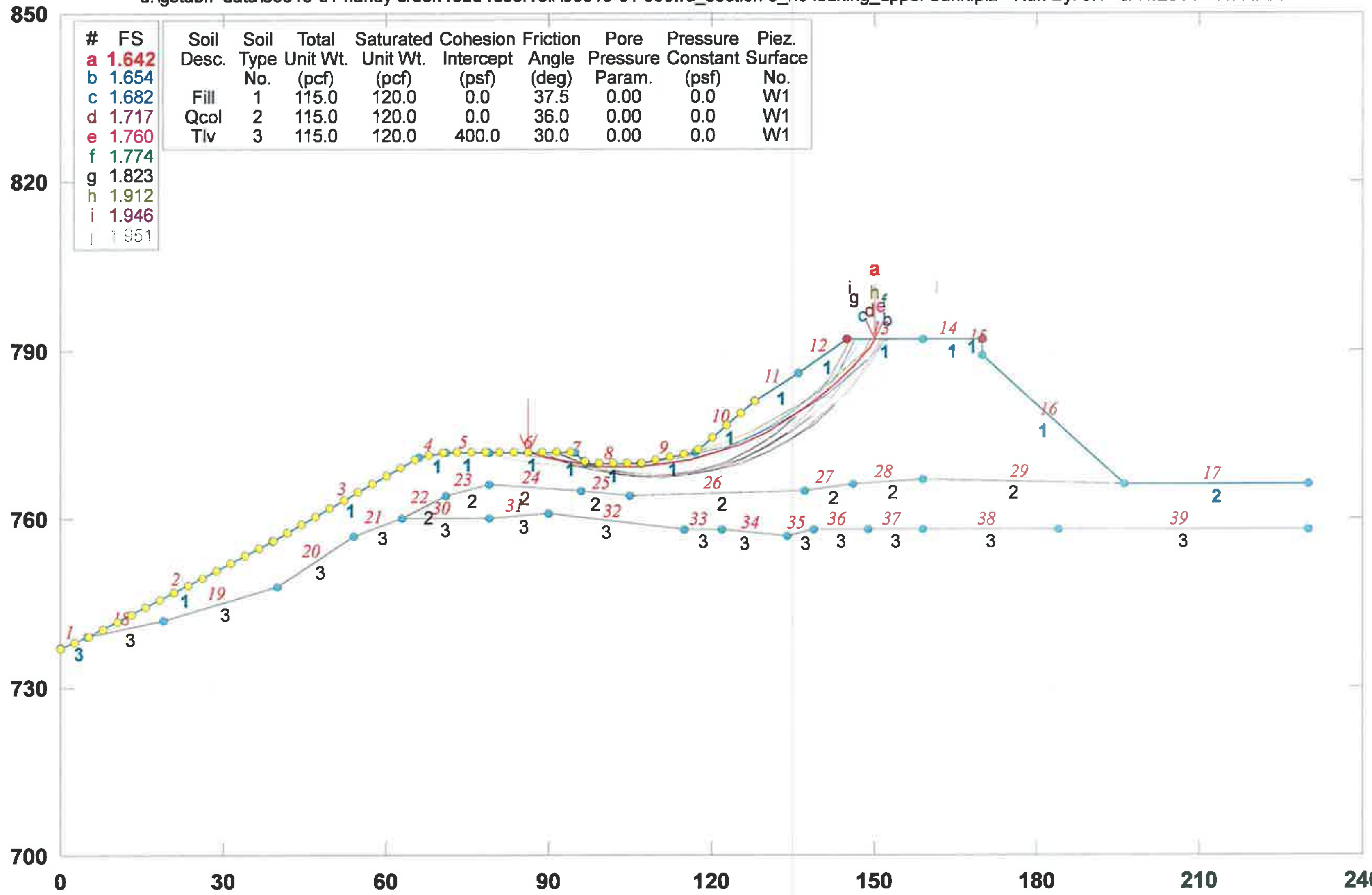


GSTABL7 v.2 FSmin=1.130

Safety Factors Are Calculated By GLE (Spencer`s) Method (0-1)

33615-01 Handy Creek Rd. Reservoir Section E-E' - No Leaking_Upper_Static

u:\gstabl7 data\33615-01 handy creek road reservoir\33615-01 eocwd_section e_no leaking_upper bank.pl2 Run By: JH 3/11/2014 11:44AM



GSTABL7 v.2 FSmin=1.642

Safety Factors Are Calculated By GLE (Spencer`s) Method (0-1)

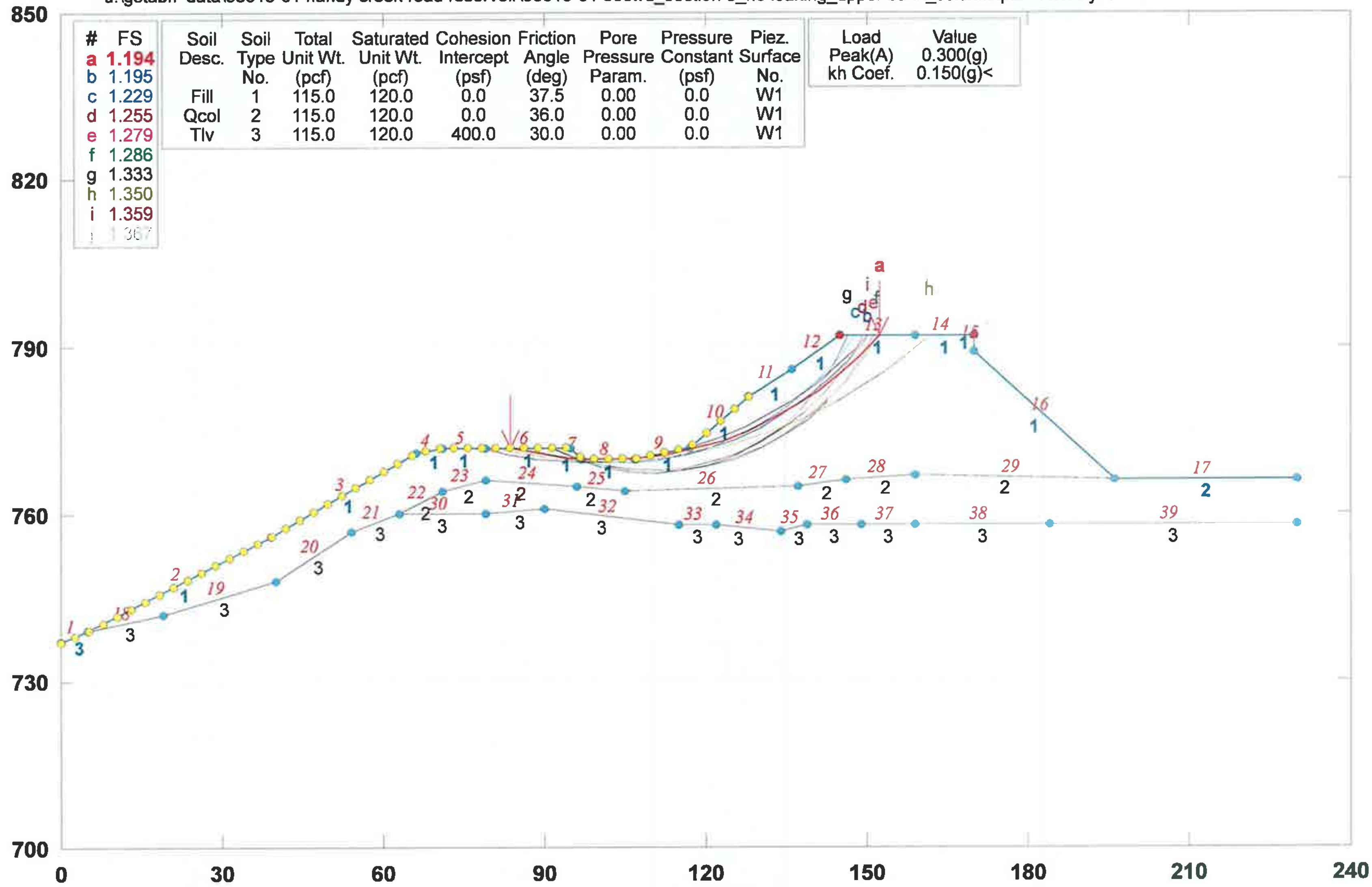
33615-01 Handy Creek Rd. Reservoir Section E-E' - No Leaking_Upper_Seismic

u:\gstabl7 data\33615-01 handy creek road reservoir\33615-01 eocwd_section e_no leaking_upper bank_seismic.pl2 Run By: JH 3/11/2014 11:44AM

#	FS
a	1.194
b	1.195
c	1.229
d	1.255
e	1.279
f	1.286
g	1.333
h	1.350
i	1.359
j	1.367

Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
Fill	1	115.0	120.0	0.0	37.5	0.00	0.0	W1
Qcol	2	115.0	120.0	0.0	36.0	0.00	0.0	W1
Tlv	3	115.0	120.0	400.0	30.0	0.00	0.0	W1

Load	Value
Peak(A)	0.300(g)
kh Coef.	0.150(g)<

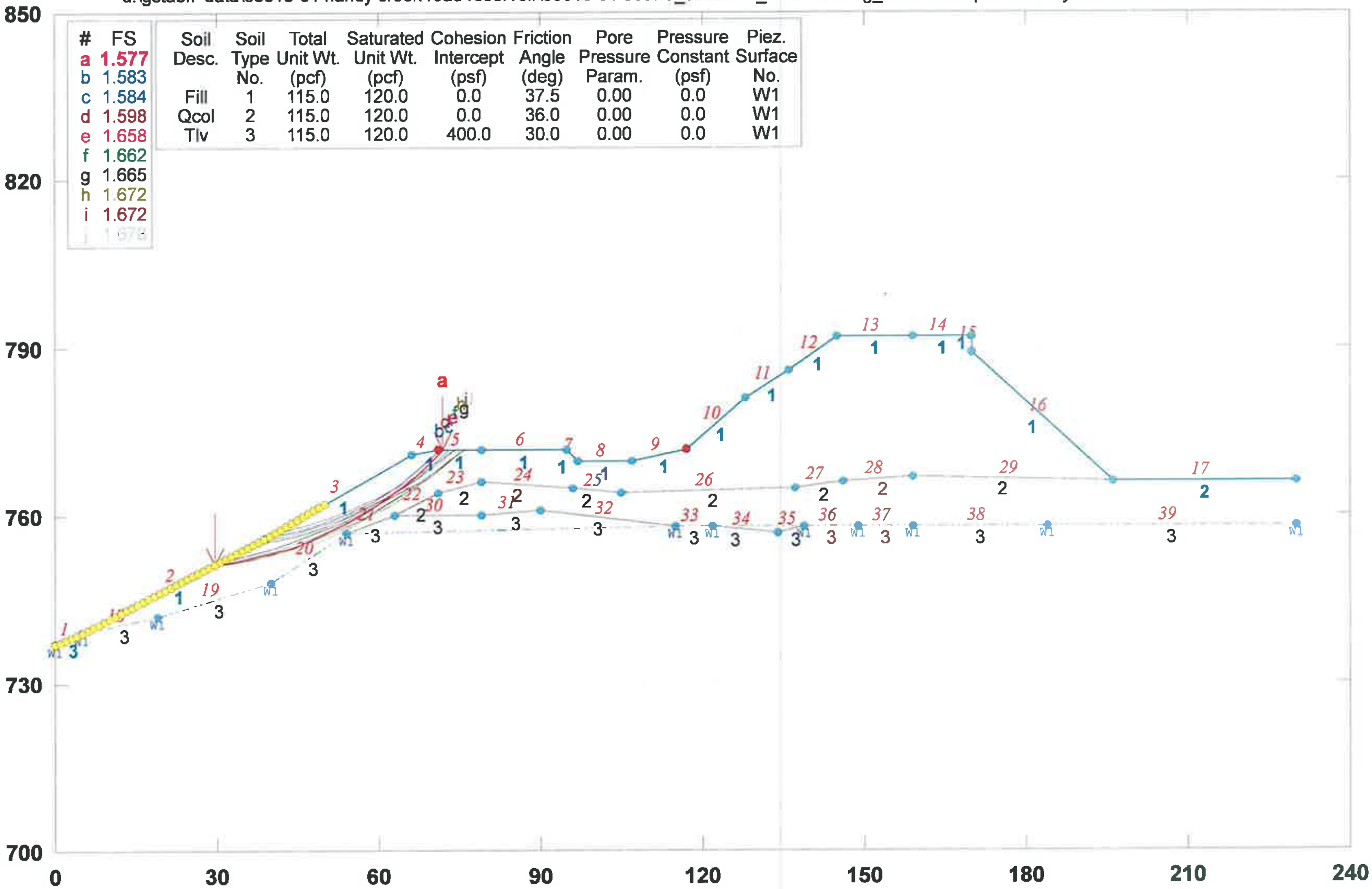


GSTABL7 v.2 FSmin=1.194

Safety Factors Are Calculated By GLE (Spencer`s) Method (0-1)

33615-01 Handy Creek Rd. Reservoir Section E-E'-Minor Leaking_Lower_Static

u:\gstabl7 data\33615-01 handy creek road reservoir\33615-01 eocwd_section e_minor leaking_lower bank.pl2 Run By: JH 3/11/2014 11:19AM



GSTABL7 v.2 FSmin=1.577

Safety Factors Are Calculated By GLE (Spencer`s) Method (0-1)

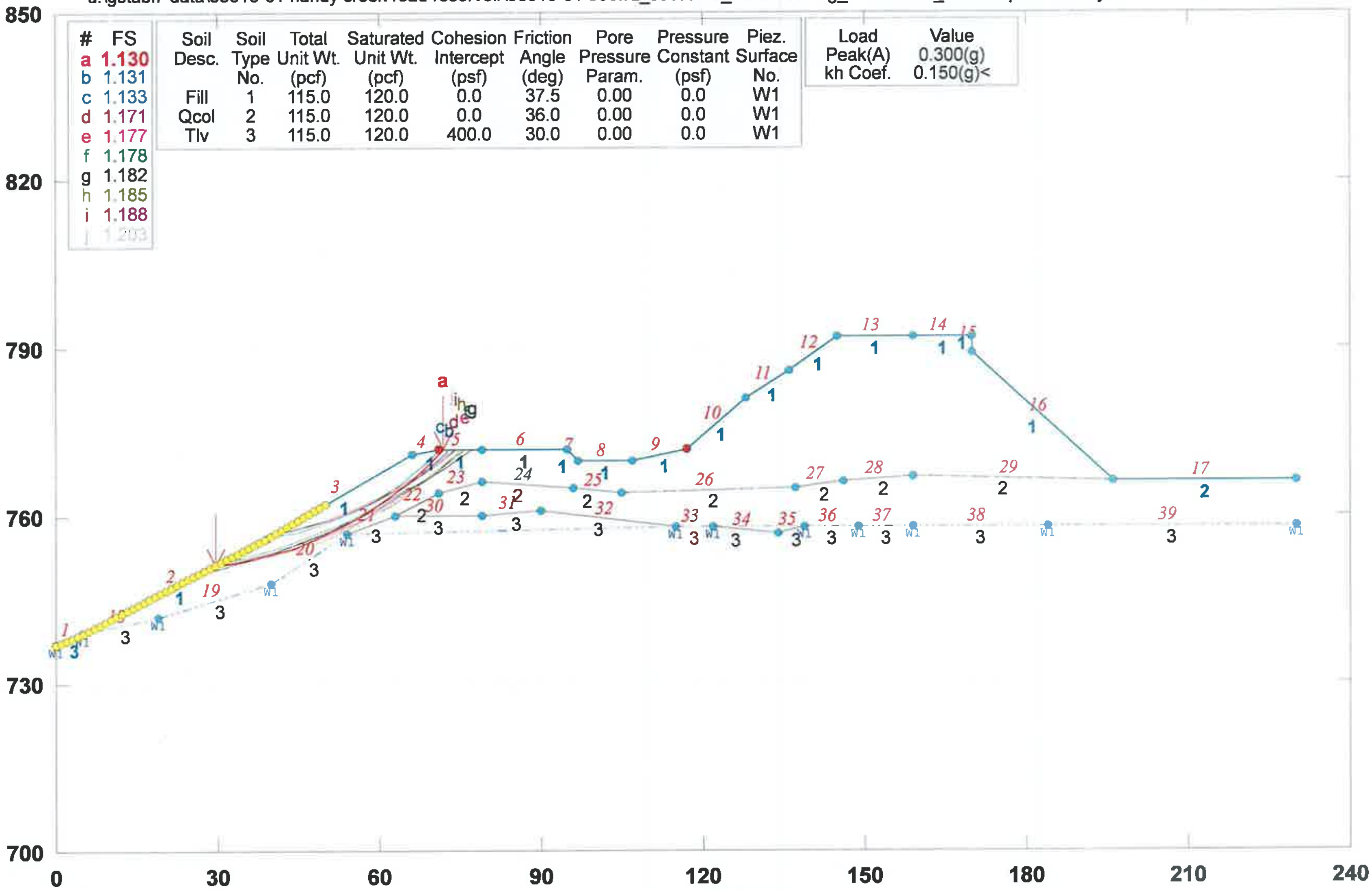
33615-01 Handy Creek Rd. Reservoir Section E-E'-Minor Leaking_Lower_Seismic

u:\gstabl7 data\33615-01 handy creek road reservoir\33615-01 eocwd_section e_minor leaking_lower bank_seismic.pl2 Run By: JH 3/11/2014 11:20AM

#	FS
a	1.130
b	1.131
c	1.133
d	1.171
e	1.177
f	1.178
g	1.182
h	1.185
i	1.188
j	1.203

Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
Fill	1	115.0	120.0	0.0	37.5	0.00	0.0	W1
Qcol	2	115.0	120.0	0.0	36.0	0.00	0.0	W1
Tlv	3	115.0	120.0	400.0	30.0	0.00	0.0	W1

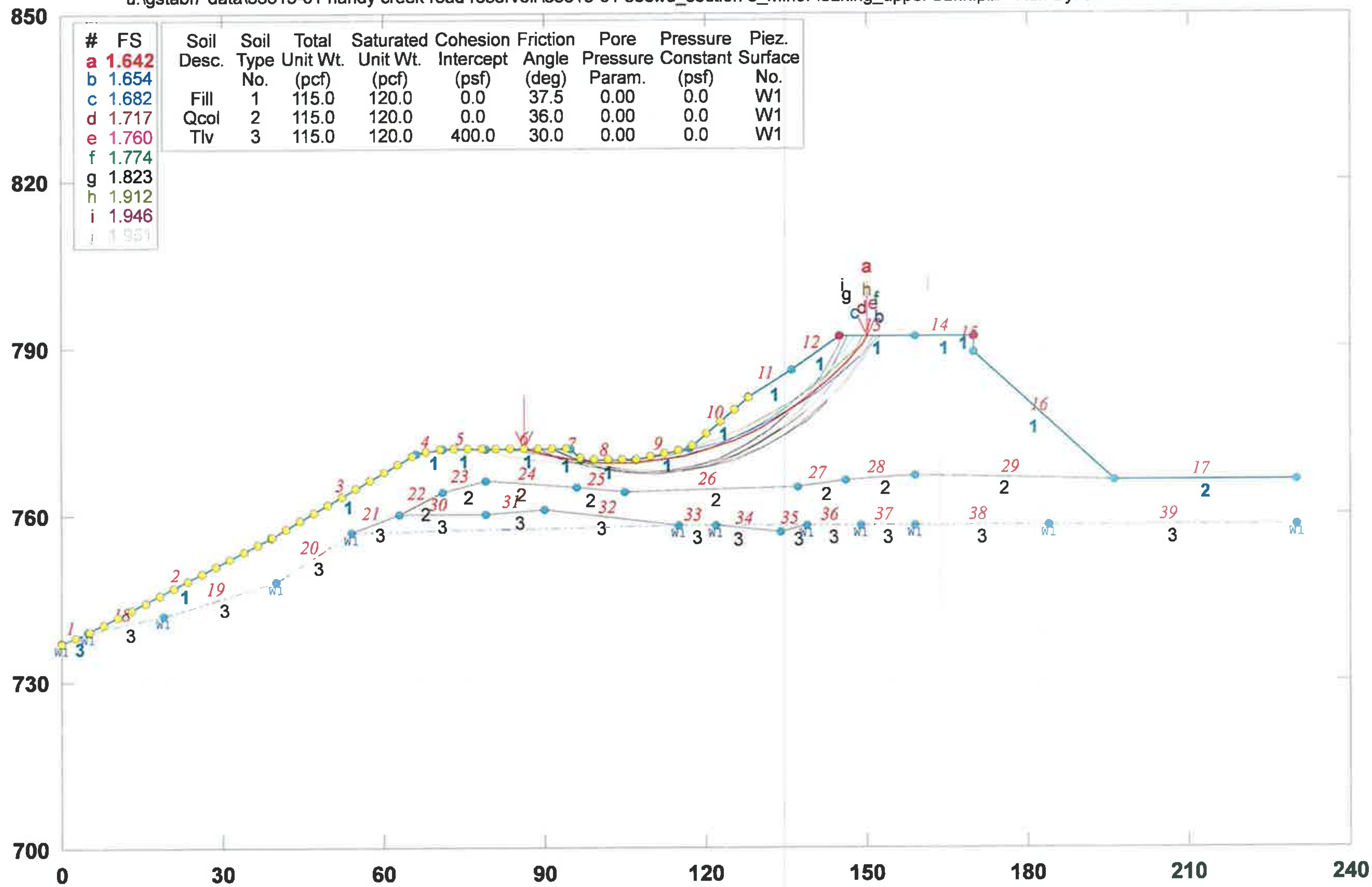
Load	Value
Peak(A)	0.300(g)
kh Coef.	0.150(g)<



GSTABL7 v.2 FSmin=1.130
Safety Factors Are Calculated By GLE (Spencer`s) Method (0-1)

33615-01 Handy Creek Rd. Reservoir Section E-E'-Minor Leaking_Upper_Static

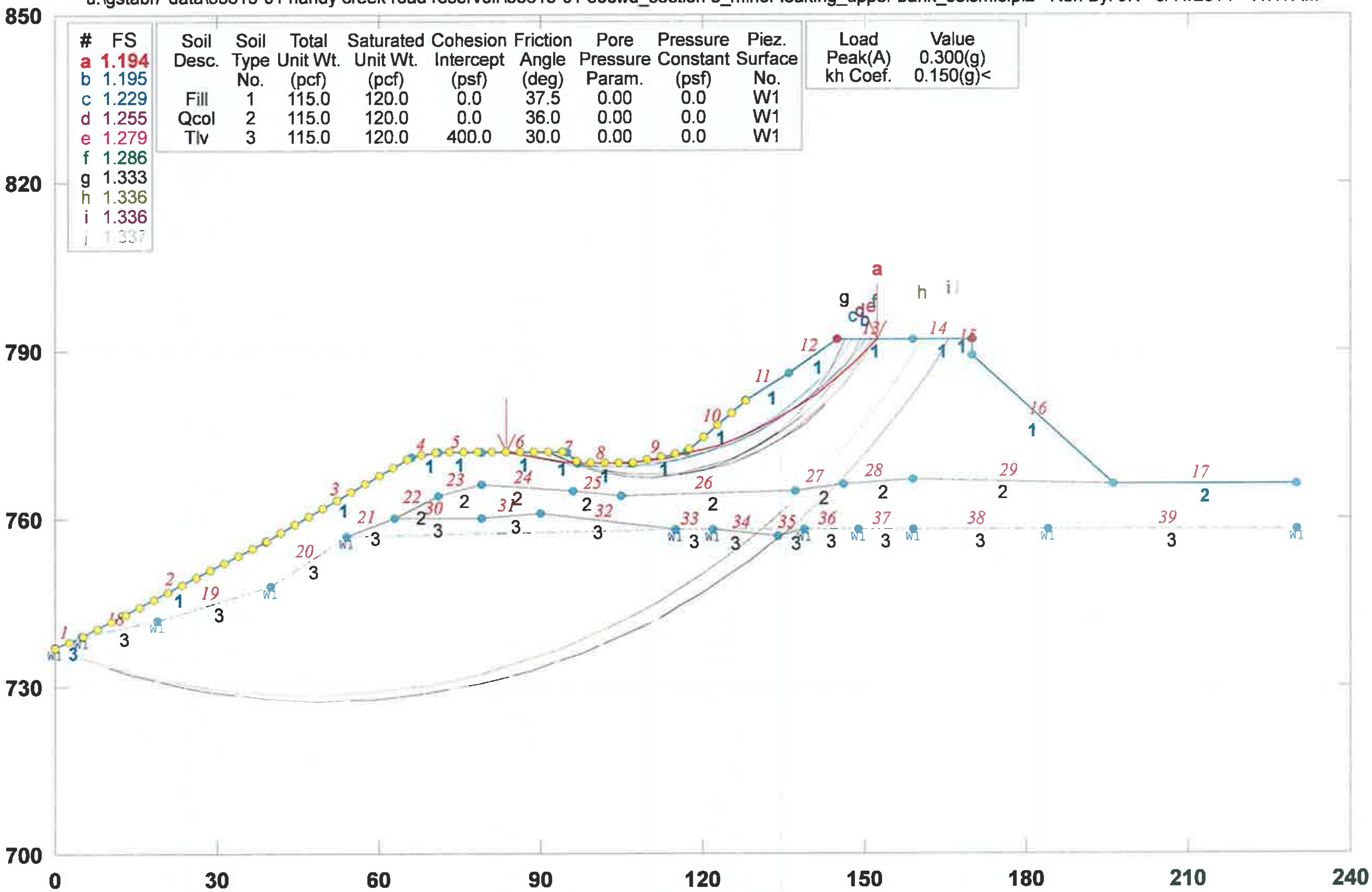
u:\gstabl7 data\33615-01 handy creek road reservoir\33615-01 eocwd_section e_minor leaking_upper bank.pl2 Run By: JH 3/11/2014 11:17AM



GSTABL7 v.2 FSmin=1.642
Safety Factors Are Calculated By GLE (Spencer`s) Method (0-1)

33615-01 Handy Creek Rd. Reservoir Section E-E'-Minor Leaking_Upper_Seismic

u:\gstabl7 data\33615-01 handy creek road reservoir\33615-01 eocwd_section e_minor leaking_upper bank_seismic.pl2 Run By: JH 3/11/2014 11:17AM

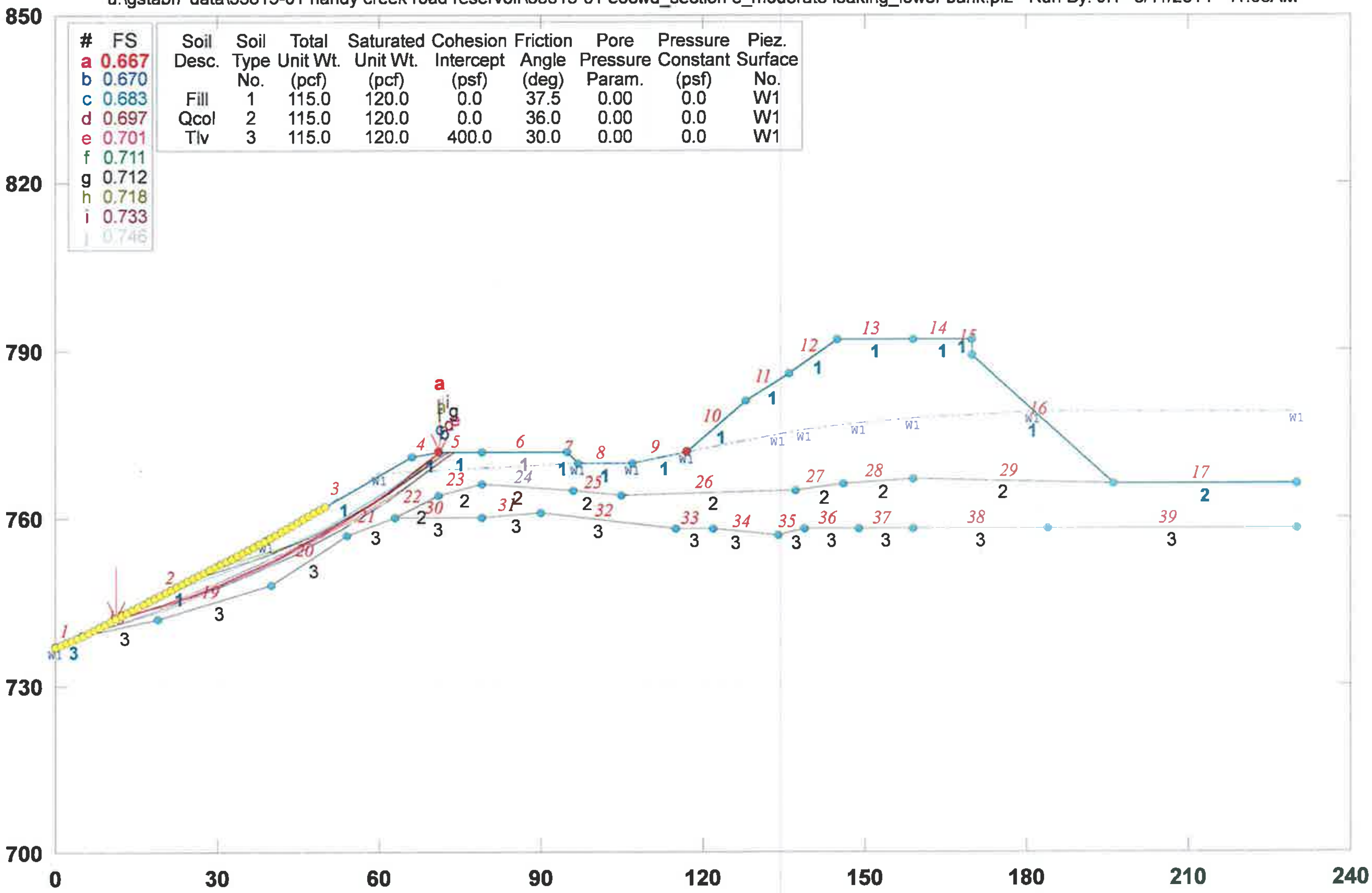


GSTABL7 v.2 FSmin=1.194

Safety Factors Are Calculated By GLE (Spencer`s) Method (0-1)

33615-01 Handy Creek Rd. Reservoir Section E-E'-Moderate Leak_Low_Static

u:\gstabl7 data\33615-01 handy creek road reservoir\33615-01 eocwd_section e_moderate leaking_lower bank.pl2 Run By: JH 3/11/2014 11:06AM

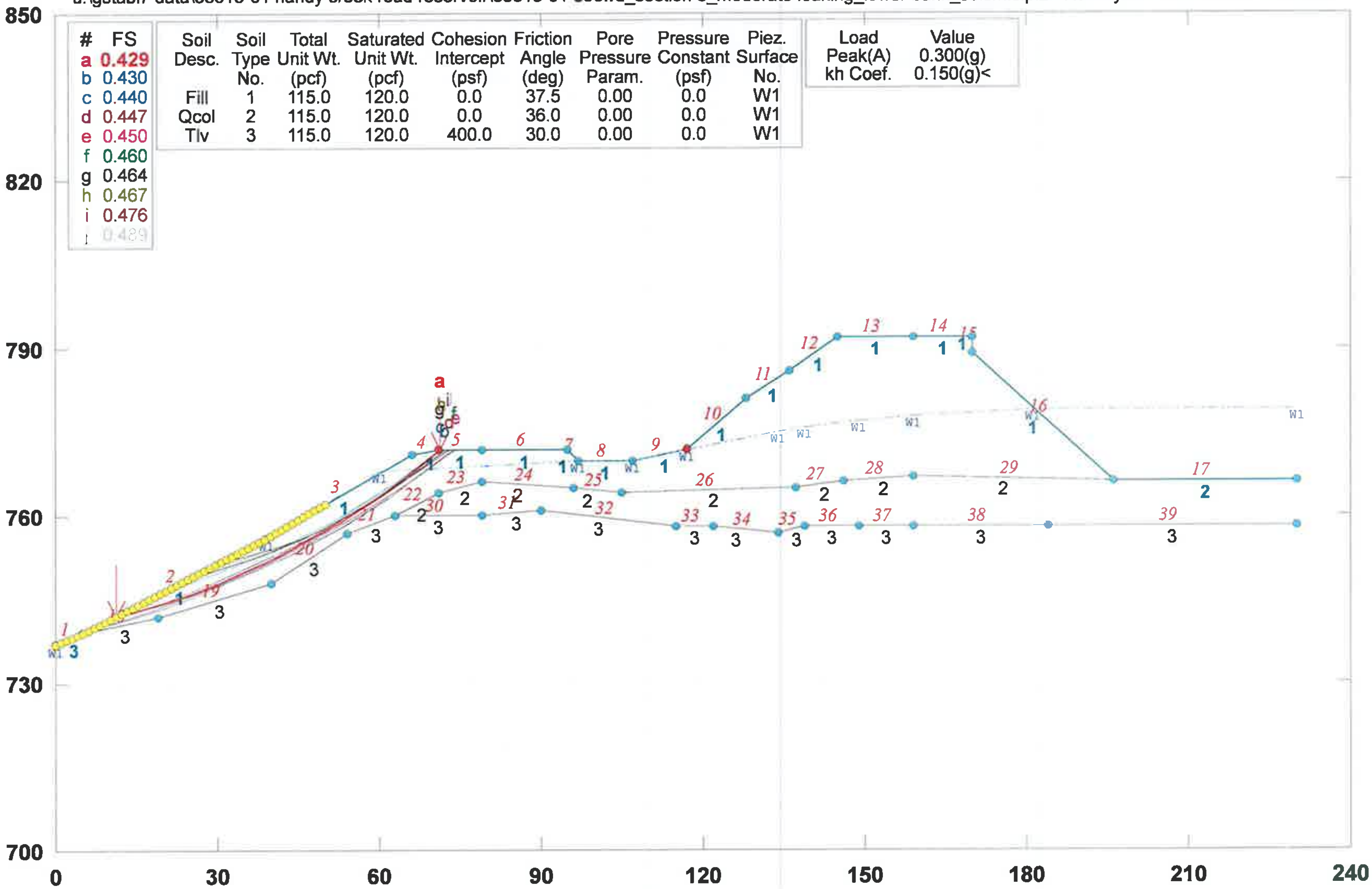


GSTABL7 v.2 FSmin=0.667

Safety Factors Are Calculated By GLE (Spencer`s) Method (0-1)

33615-01 Handy Creek Rd. Reservoir Section E-E'-Moderate Leak_Low_Seismic

u:\gstabl7 data\33615-01 handy creek road reservoir\33615-01 eocwd_section e_moderate leaking_lower bank_seismic.pl2 Run By: JH 3/11/2014 11:07AM

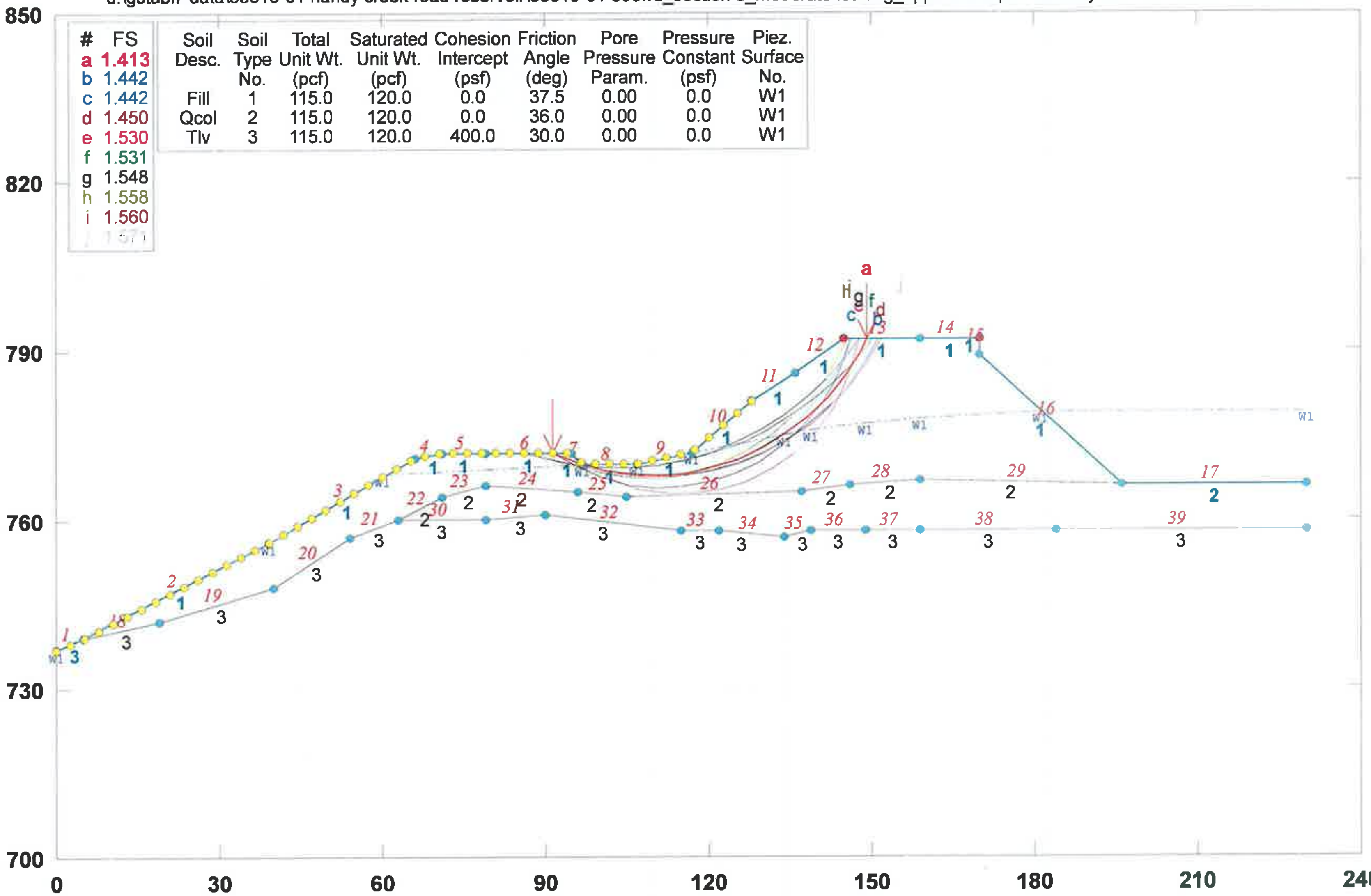


GSTABL7 v.2 FSmin=0.429

Safety Factors Are Calculated By GLE (Spencer`s) Method (0-1)

33615-01 Handy Creek Rd. Reservoir Section E-E'-Moderate Leak_Upper_Static

u:\gstabl7 data\33615-01 handy creek road reservoir\33615-01 eocwd_section e_moderate leaking_upper bank.pl2 Run By: JH 3/11/2014 11:24AM

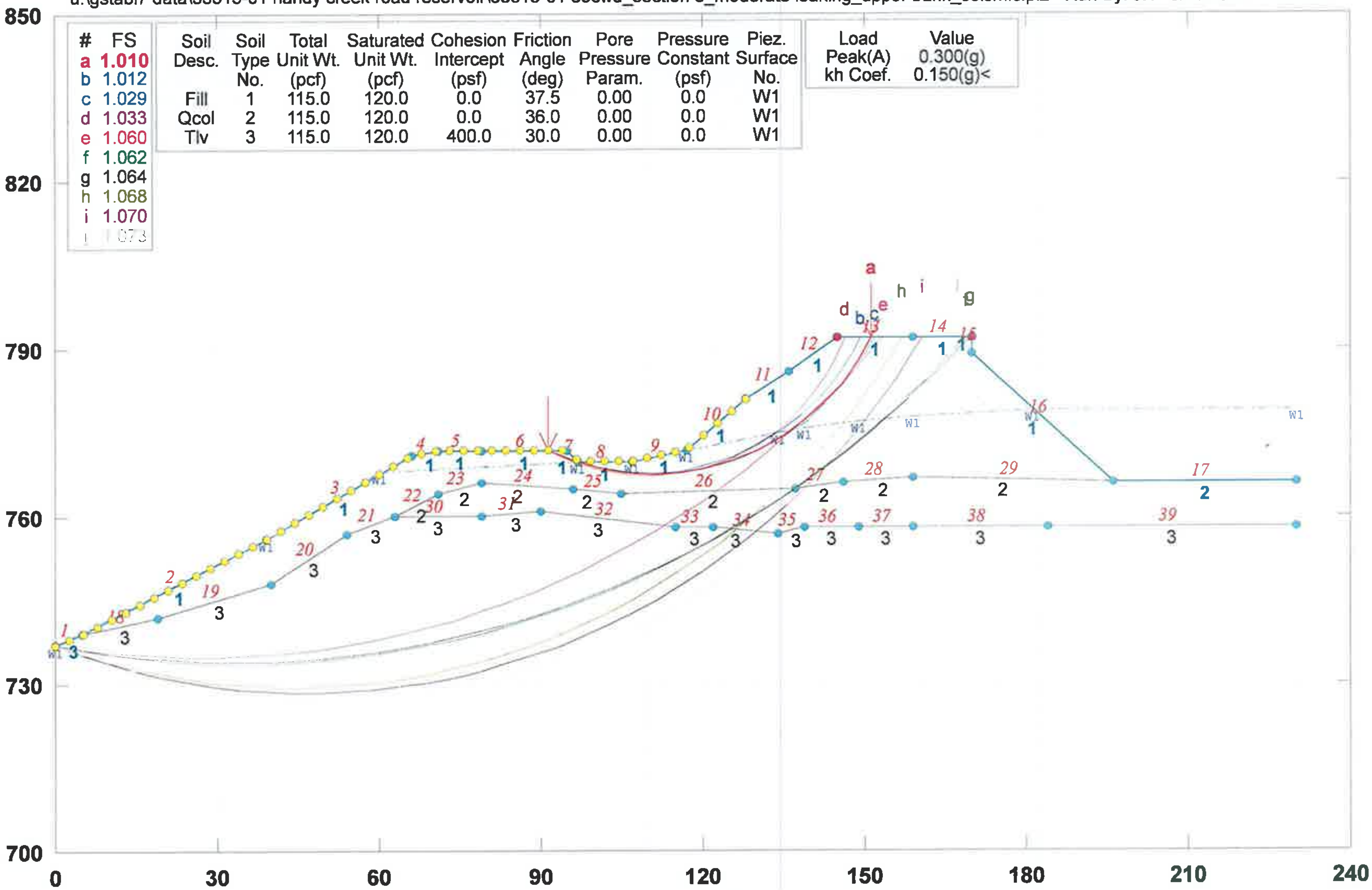


GSTABL7 v.2 FSmin=1.413

Safety Factors Are Calculated By GLE (Spencer`s) Method (0-1)

33615-01 Handy Creek Rd. Reservoir Section E-E'-Moderate Leak_Upper_Seismic

u:\gstabl7 data\33615-01 handy creek road reservoir\33615-01 eocwd_section e_moderate leaking_upper bank_seismic.pl2 Run By: JH 3/11/2014 11:25AM

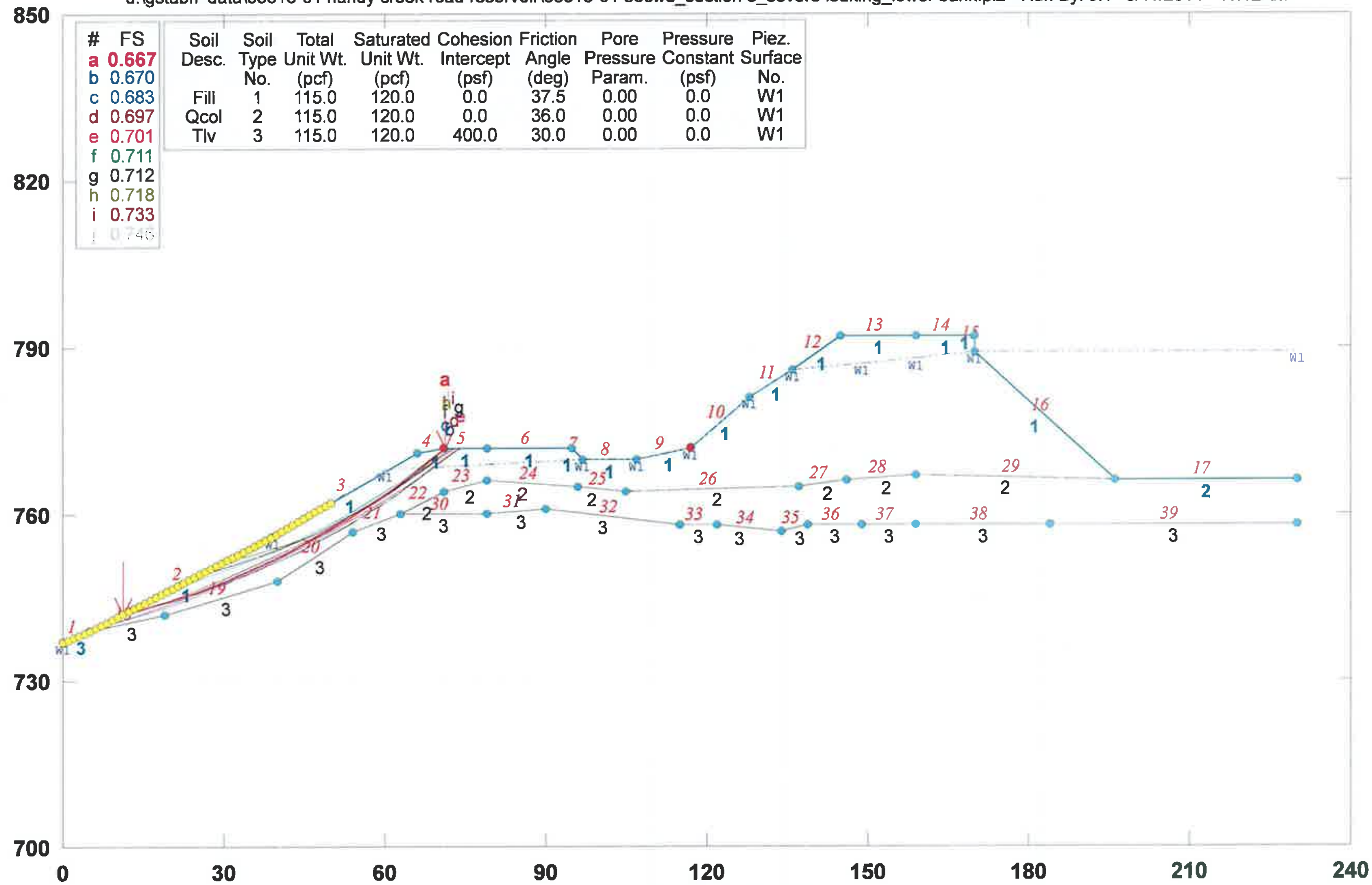


GSTABL7 v.2 FSmin=1.010

Safety Factors Are Calculated By GLE (Spencer`s) Method (0-1)

33615-01 Handy Creek Rd. Reservoir Section E-E' - Severe Leaking - Static

u:\gstabl7 data\33615-01 handy creek road reservoir\33615-01 eocwd_section e_severe leaking_lower bank.pl2 Run By: JH 3/11/2014 11:12AM

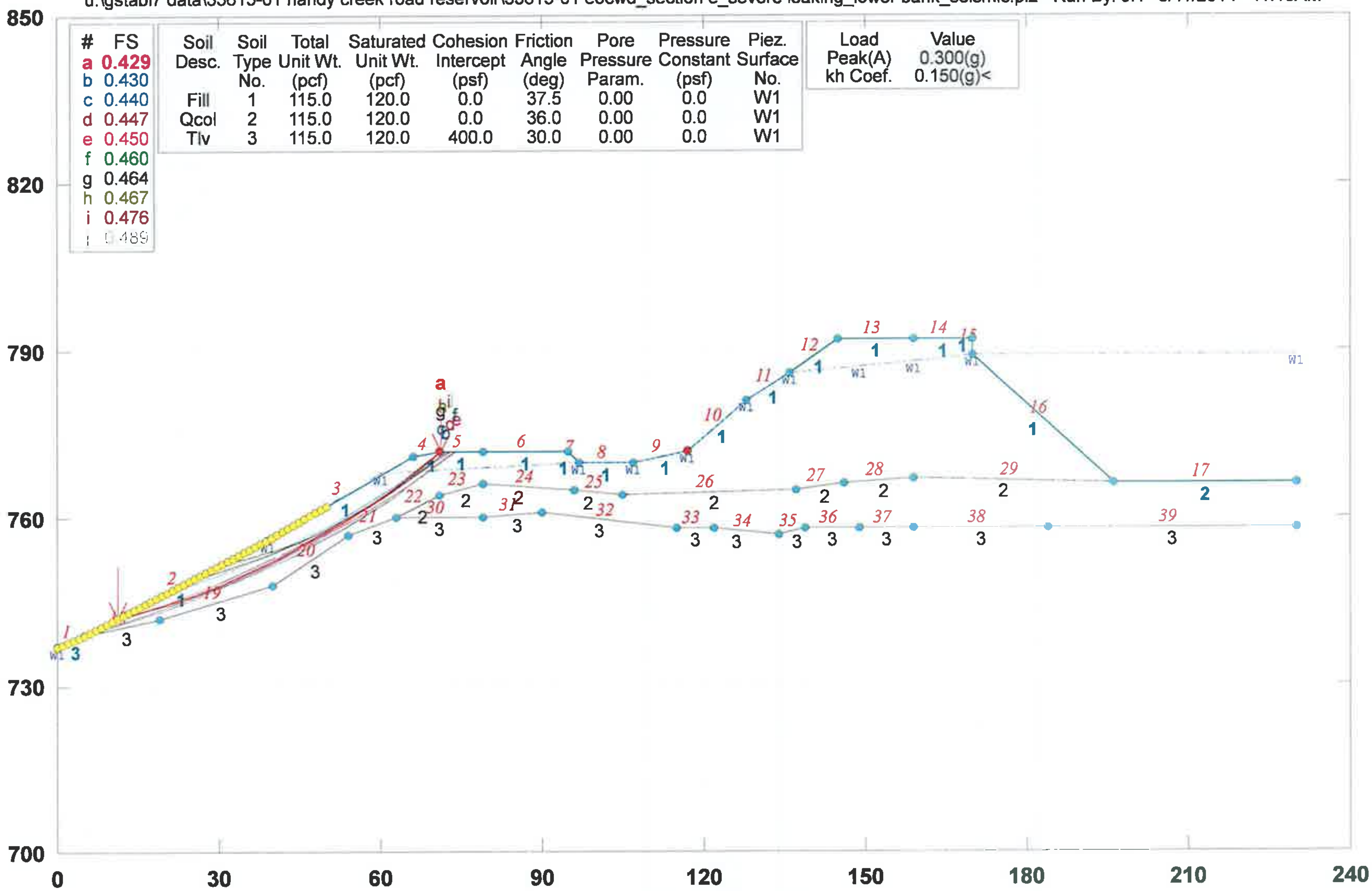


GSTABL7 v.2 FSmin=0.667

Safety Factors Are Calculated By GLE (Spencer`s) Method (0-1)

33615-01 Handy Creek Rd. Reservoir Section E-E' - Severe Leaking - Seismic

u:\gstabl7 data\33615-01 handy creek road reservoir\33615-01 eocwd_section e_severe leaking_lower bank_seismic.pl2 Run By: JH 3/11/2014 11:13AM

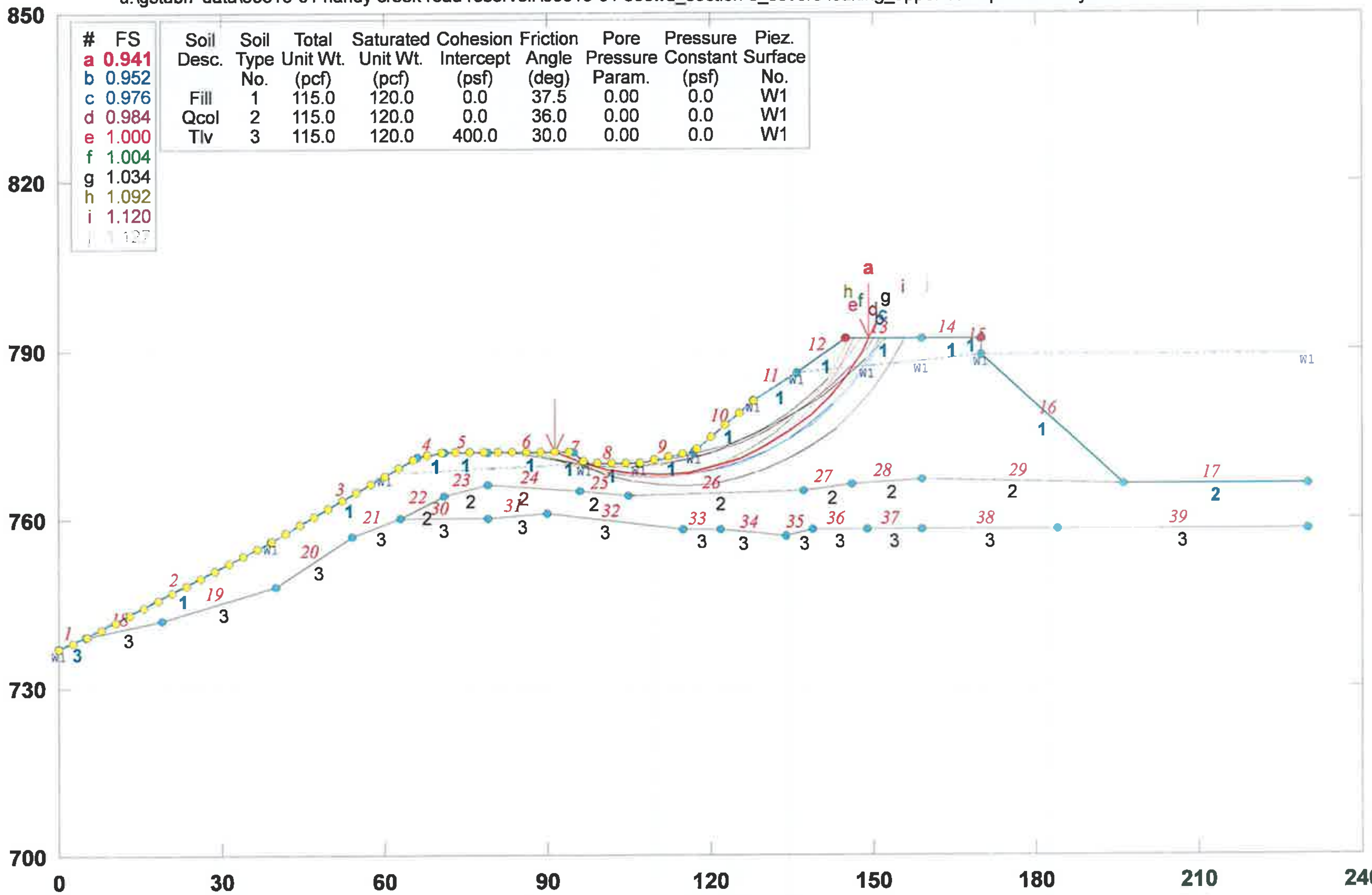


GSTABL7 v.2 FSmin=0.429

Safety Factors Are Calculated By GLE (Spencer`s) Method (0-1)

33615-01 Handy Creek Rd. Reservoir Section E-E' - Severe Leak_Upper_Static

u:\gstabl7 data\33615-01 handy creek road reservoir\33615-01 eocwd_section e_severe leaking_upper bank.pl2 Run By: JH 3/11/2014 11:28AM



GSTABL7 v.2 FSmin=0.941

Safety Factors Are Calculated By GLE (Spencer`s) Method (0-1)

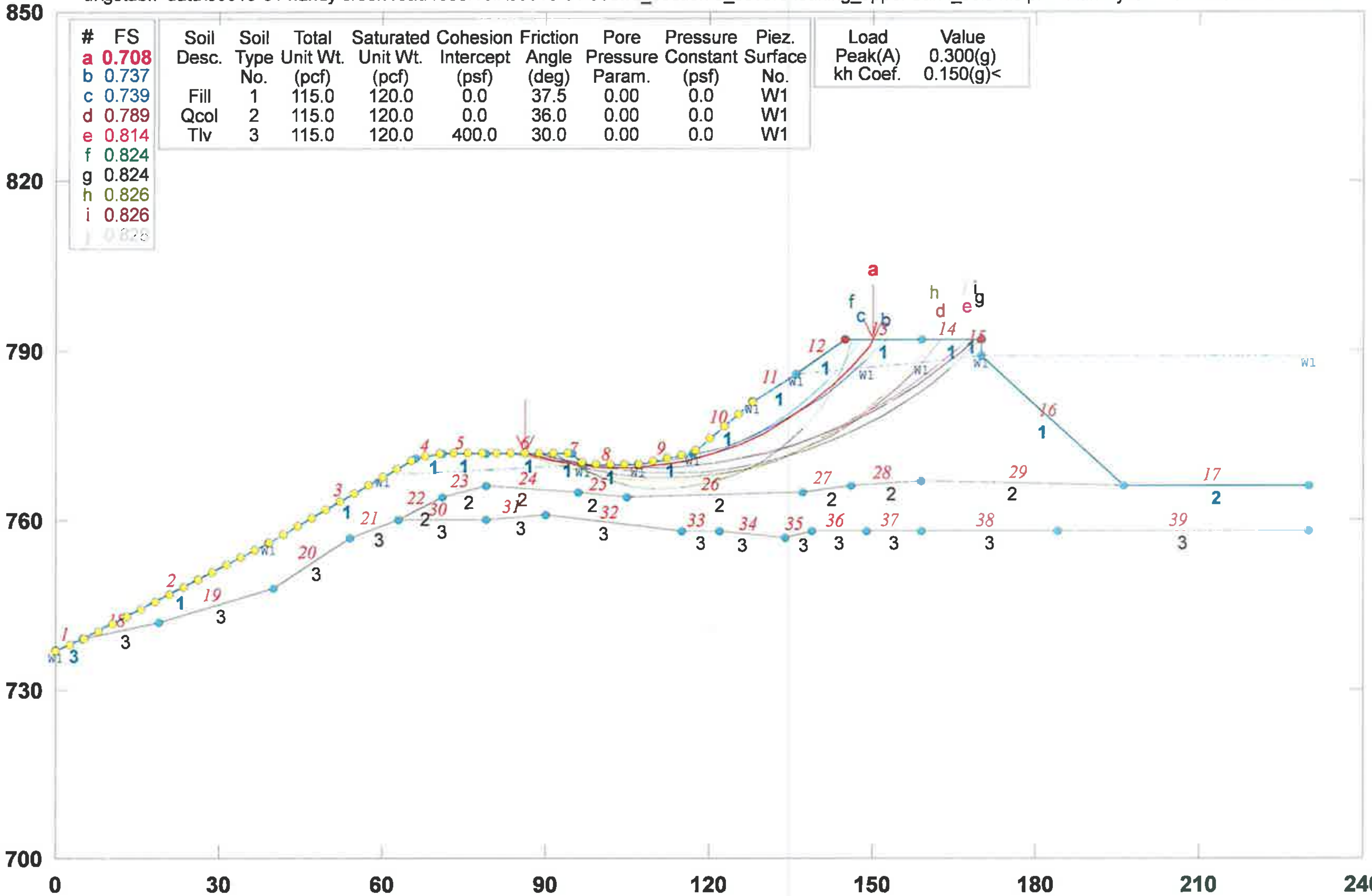
33615-01 Handy Creek Rd. Reservoir Section E-E' - Severe Leak_Upper_Seismic

u:\gstabl7 data\33615-01 handy creek road reservoir\33615-01 eocwd_section e_severe leaking_upper bank_seismic.pl2 Run By: JH 3/11/2014 11:29AM

#	FS
a	0.708
b	0.737
c	0.739
d	0.789
e	0.814
f	0.824
g	0.824
h	0.826
i	0.826

Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
Fill	1	115.0	120.0	0.0	37.5	0.00	0.0	W1
Qcol	2	115.0	120.0	0.0	36.0	0.00	0.0	W1
Tlv	3	115.0	120.0	400.0	30.0	0.00	0.0	W1

Load	Value
Peak(A)	0.300(g)
kh Coef.	0.150(g)<



GSTABL7 v.2 FSmin=0.708

Safety Factors Are Calculated By GLE (Spencer`s) Method (0-1)

To: **Municipal Water District of Orange County**
P.O.Box 20895
Fountain Valley, CA 92728

Attention: **MR. RICHARD B.BELL**
Principal Engineer
& **MR. LEE A. JACOBI**
Senior Engineer

Subject: **Five Earthquake Scenario Ground Motion Maps for Northern Orange County**

Introduction and Purpose:

At your request, and per your authorization, Earth Consultants International (ECI) has prepared this report summarizing five earthquake scenarios within the Municipal Water District of Orange County's (MWDOC) service area in the northern part of Orange County. The five earthquakes that we modeled were selected in consultation with you, and include: the Peralta Hills fault, the Whittier fault, the Puente Hills fault, the San Joaquin Hills fault, and the Newport-Inglewood fault. The The purpose of our study was to calculate and map the strong ground motions that the five earthquakes would generate during a geologically determined plausible event. This report presents the results of our study.

Scope of Work:

Specific tasks that we completed for this study are listed below:

- We identified the known active faults with highest probability of movement in Orange County.
- We reviewed published papers describing the five faults in the vicinity. These faults include the Peralta Hills Thrust, Puente Hills Thrust, Whittier, San Joaquin Hills thrust, and Newport-Inglewood faults.
- We developed a GIS-based ground motion modeling program based on a methodology, similar to that used by the U.S. Geological Survey (USGS), to calculate the level of shaking caused by a defined earthquake on each fault. These are deterministically generated computer maps of the Peak Ground Acceleration (PGA) and intensity of ground shaking expected in Orange County area from five different potential earthquakes that this area could experience.
- We prepared this report summarizing our results.

Earthquake Scenarios:

Earthquake scenarios describe the expected ground motions and effects of specific hypothetical large earthquakes. To make the calculations, we rely on consensus-based information about the potential behavior of the faults to assume that a particular fault or fault segment will rupture over a certain length. Once the size and location of the hypothetical earthquake are chosen, the ground motions at all locations in the region are estimated. In the five cases used here, both larger and smaller earthquakes are possible, but we have chosen magnitudes that seem to best represent the fault's average behavior.

Please note that these earthquake scenarios are not earthquake predictions. That is, no one knows in advance when a future earthquake will occur, or how large it will be. However, if we make assumptions about the size and location of hypothetical future earthquake, we can make a reasonable prediction of the effects of the assumed earthquake when it occurs.

We calculated the five earthquake scenarios that we consider as the most significant cases for the MWDOC's Orange County service area. The scenarios that we chose are as follows:

1) A magnitude 7.5 earthquake on the Puente Hills thrust;
2) A magnitude 6.6 earthquake on the San Joaquin Hills thrust;
3) A magnitude 6.8 earthquake on the Whittier fault;
4) A magnitude 6.9 earthquake on the Newport-Inglewood fault;
5) A magnitude 6.8 earthquake on the Peralta Hills thrust.

Figure 1 shows the simplified fault map for Orange County. The Whittier and Newport Inglewood faults are thought to be near the end of their earthquake cycles and both faults extend through the study area, with the potential to cause significant damage in the area. The Puente Hills blind thrust is also important, because recent seismologic and geologic studies have revealed the danger of this system which directly beneath Los Angeles (Shaw and Shearer 1999, Dolan et. al 2003). Parameters used for calculating the scenarios are summarized in Table 1.

Fault Name	Fault Type per CGS	Length (km)	Slip Rate (mm/yr)	Maximum Magnitude Earthquake	Approximate Recurrence Interval (yrs)
Puente Hills Blind Thrust	B	44 +/- 4	0.7 +/- 0.4	7.5	2,750
Newport-Inglewood (onshore)	B	75	1 +/- 0.5	6.9	2,200-3,900
Whittier	A	38 +/- 4	2.5 +/- 1	6.8	1,100
Peralta Hills	B	10 to 30	unknown, < 1 mm	6.8	unknown
San Joaquin Hills	B	28 +/- 3	0.5 +/- 0.2	6.6	1,600 - 3,100

Estimating Ground Motions for Scenario Earthquake:

To analyze ground shaking accelerations at these sites due to the selected scenario earthquakes, we employed deterministic analyses, using industry-standard software (EZ-FRISK by Risk Eng. Inc.). Deterministic analyses estimate the Horizontal Peak ground accelerations (PGA) that can be expected at a site due to earthquake rupture of the selected fault, attenuated by distance from the fault and the geologic conditions of the site. Because of the large area, we performed our analysis in 2.5 km grid nodes, then used a contouring program to generate the final maps. The parameters selected for display in the maps are PGA and instrumental intensity, which correlate well with damage and is also a convention that users are familiar with. This deterministic PGA analysis accounts for the effects of earthquake magnitude and distance, and the physical properties of the sediment underlying the each grid location. Our method is similar to that used by the USGS where ground motions are estimated using an empirical attenuation relationship.EZ-FRISK incorporates fault parameters provided by the California Geological Survey (CGS). For creating the scenario maps we used the attenuation relationship of Boore et al. (1997) for calculating peak ground acceleration for bedrock. Local soil characteristics are coming from the WRMS documentation (2000). We then correct the amplitude at each location with the amplitude and frequency-dependent factors determined by Borcherdt (1994). The amplification correction used is based on the Quaternary, Tertiary, Mesozoic (“QTM”) geological classification of Park and Ellrick (1998). These categories can be considered to represent soil, soft rock, and hard rock, respectively, and hence they provide a very simple but effective way to assign amplification factors on a large scale. To obtain site amplification factors based on these QTM categories, we used the mean shear-wave velocities assigned to each unit, and then applied the frequency and amplitude-dependent amplification factors determined by Borcherdt (1994) based on these velocities.

For each scenario earthquakes we have prepared two maps, one showing the peak ground acceleration and one showing the shaking intensity away from the fault. On the right hand side in each set of figures, the ocation of the fault is also represented. Calculated ground acceleration results from these scenario earthquakes are shown on Figures 2 through 6. Figures 2a, 3a, etc. show the anticipated seismic intensities as a result of the earthquake scenarios, whereas Figures 2b, 3b, etc. show the peak ground accelerations expected in the area.

The approach used in this study is only approximate in that it shows the average ground motion effect for producing the scenario shake maps. Fault location is accounted for in the present method, but the direction of rupture was not taken into account. The methodology gives average peak ground motion values so it does not account for all the expected variability in motions other than the site amplification variations. Following the USGS earthquake scenario methodology, the way of including the site amplification in the current study is conservative. However, these simple geological classifications are available for the whole Orange County area, and considering the 2.5 km grid size used, are probably accurate enough for the purpose of the analysis. A compilation of more localized (and better constrained) site corrections based on either shallow soil velocity profiles or mainshock / aftershock studies may improve the results. However, such data are not uniformly available.

Actual strong ground motions depend largely on the local site effects, show significant variability for a given distance, magnitude, and site condition and, hence, the scenario ground motions are more uniform than would be expected for an actual earthquake. The true variations are partially attributable to three-dimensional (3D) wave propagation, path effects (such as basin edge amplification and focusing), differences in motions among earthquakes of the same magnitude, and complex site effects not accounted for by the present method. A complete modeling of a scenario earthquake to incorporate all of these factors is a very labor and data intensive effort, and well beyond the stated needs of this project.

We appreciate the opportunity to work with Municipal Water District of Orange County, and we trust that the information provided herein provides you with the information you need at this time. Should you have any questions regarding this report, please do not hesitate to contact either of us.

Respectfully submitted on behalf of
EARTH CONSULTANTS INTERNATIONAL,
Registered Geologists and Certified Engineering Geologists in the State of California

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References:

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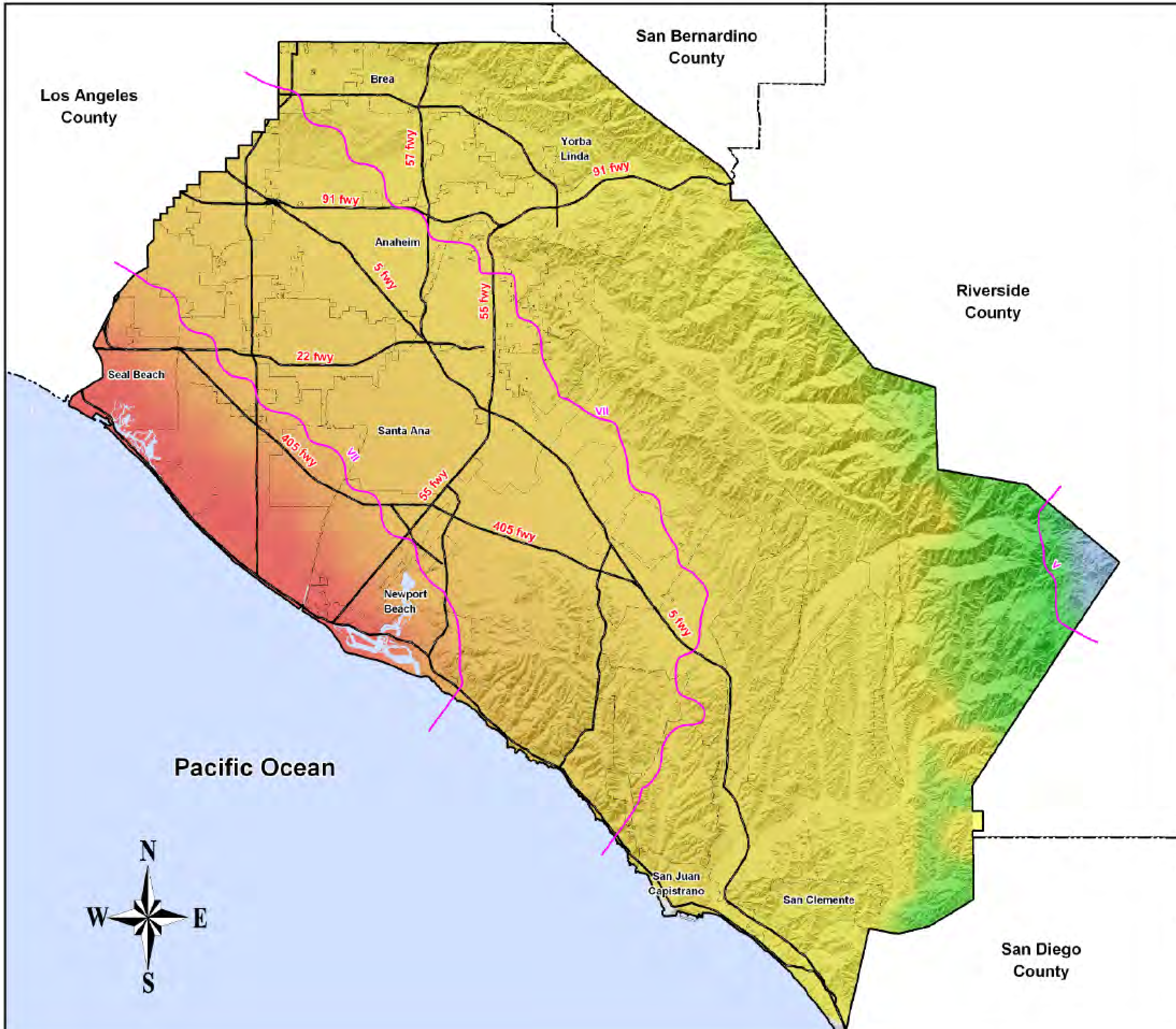
Intensity Map for M6.9 Newport-Inglewood Fault Scenario Orange County, California



Intensity Contour Line

PERCEIVED SHAKING	Not Felt	Weak	Light	Mod	Strong	Very Strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Mod	Mod/Heavy	Heavy	Very Heavy
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

5 0 5 10 15 Kilometers

3 0 3 6 9 Miles

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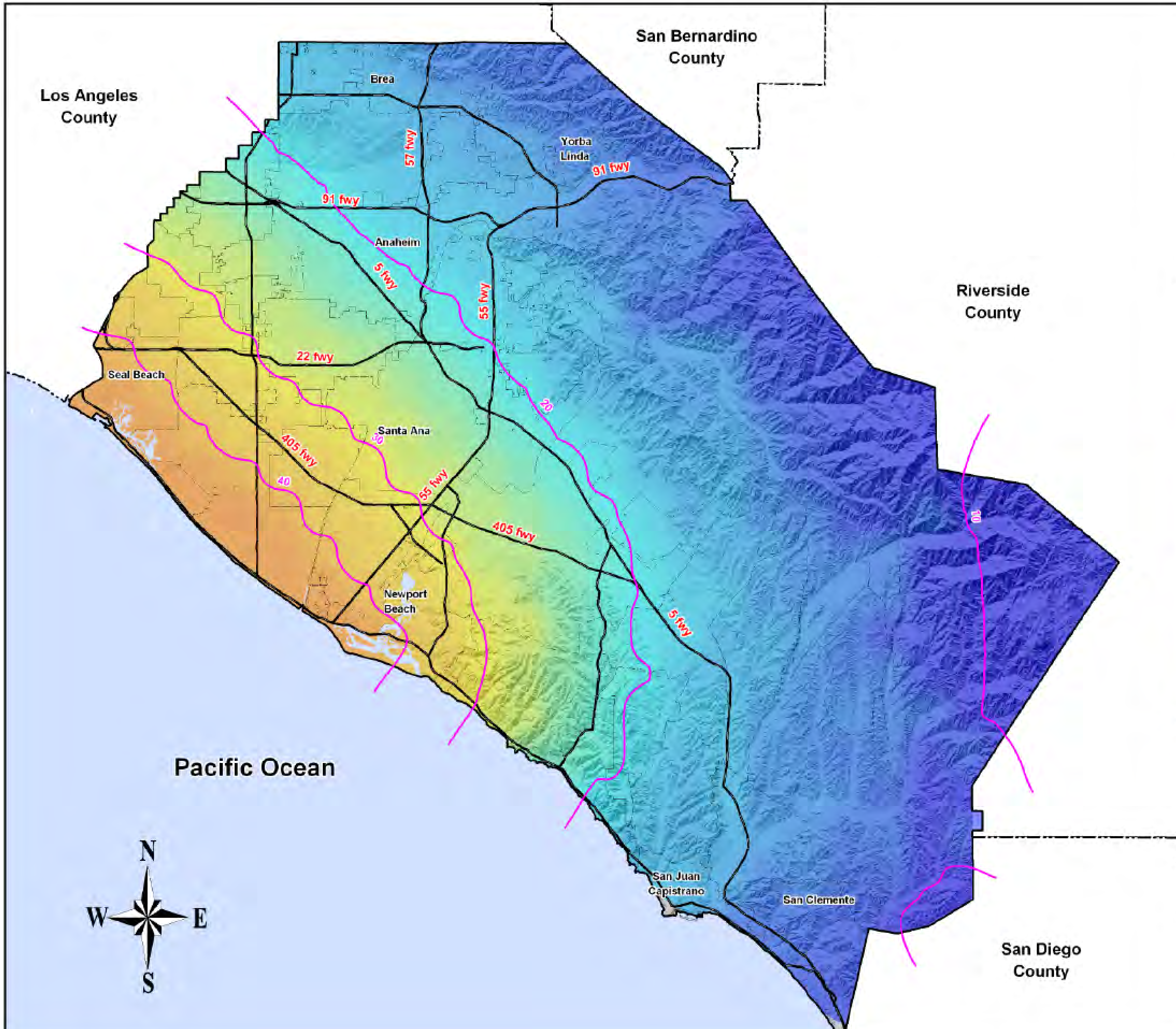
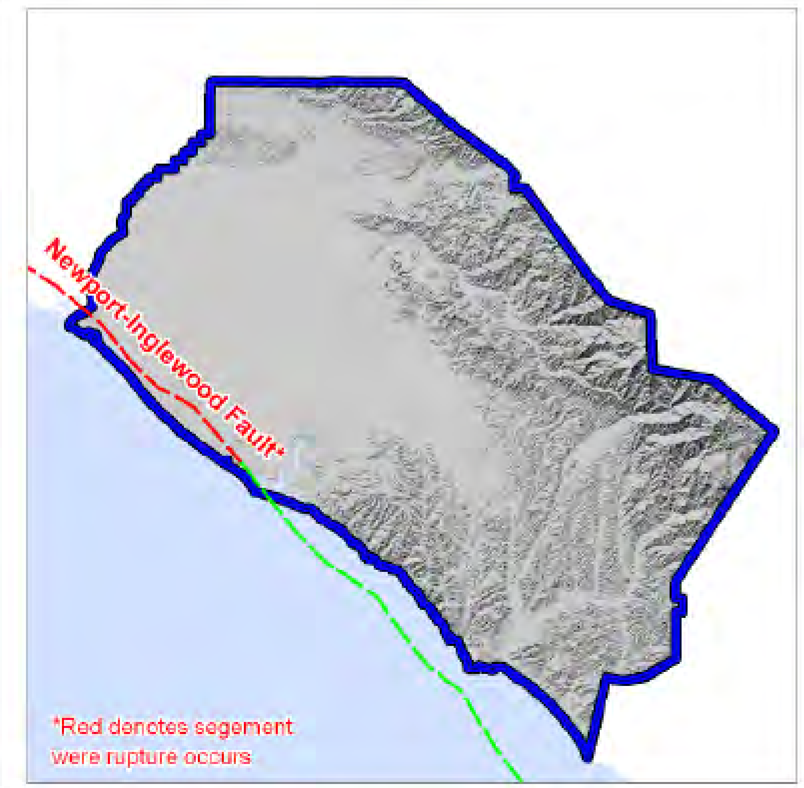
Date: June 2005

Figure 2a

Peak Ground Acceleration (in %g) for M6.9 Newport-Inglewood Fault Scenario Orange County, California





%g Contour Line

10 20 30 40 50 60

Z-units:%g

5 0 5 10 15 Kilometers

3 0 3 6 9 Miles

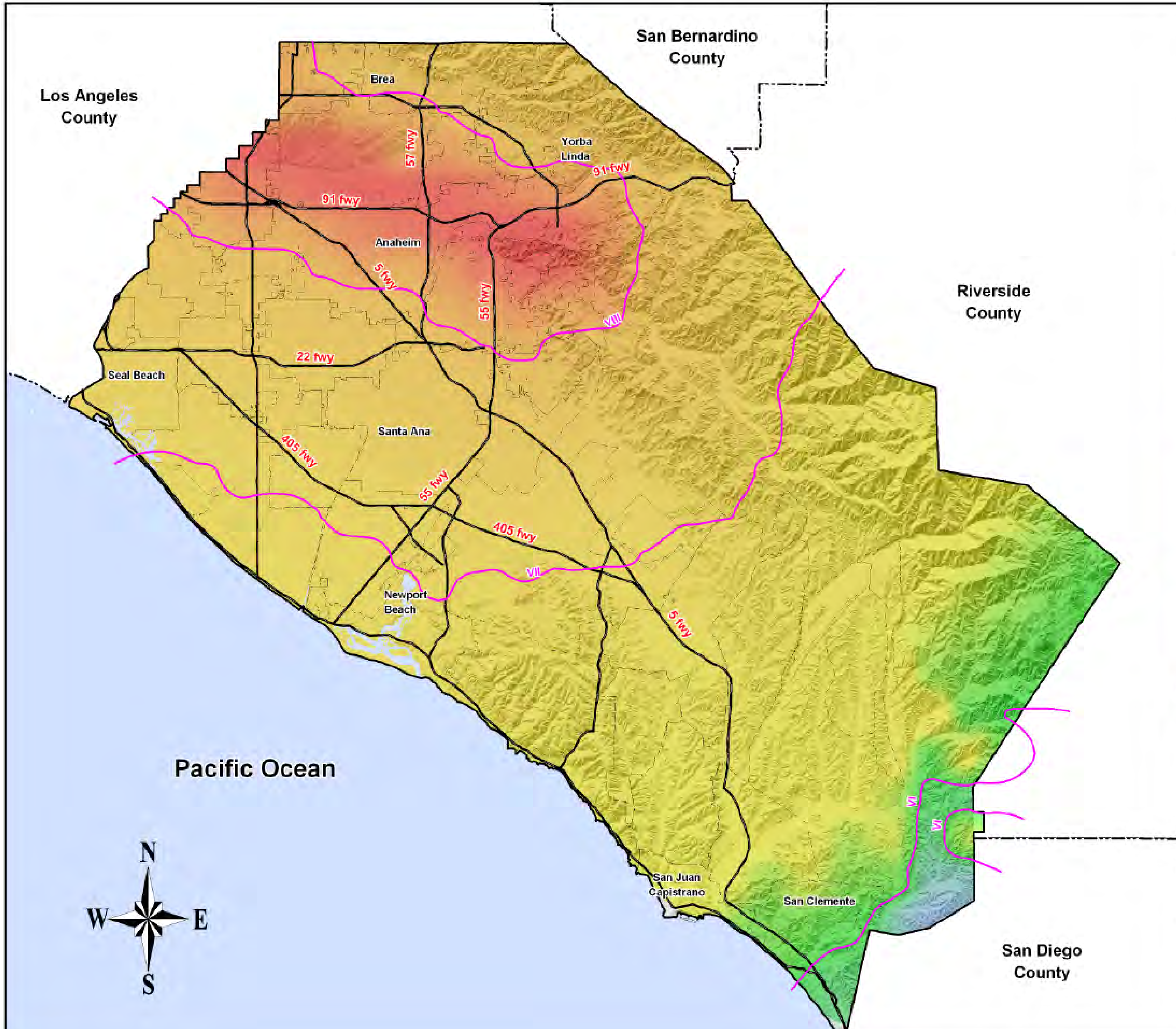
Earth Consultants International

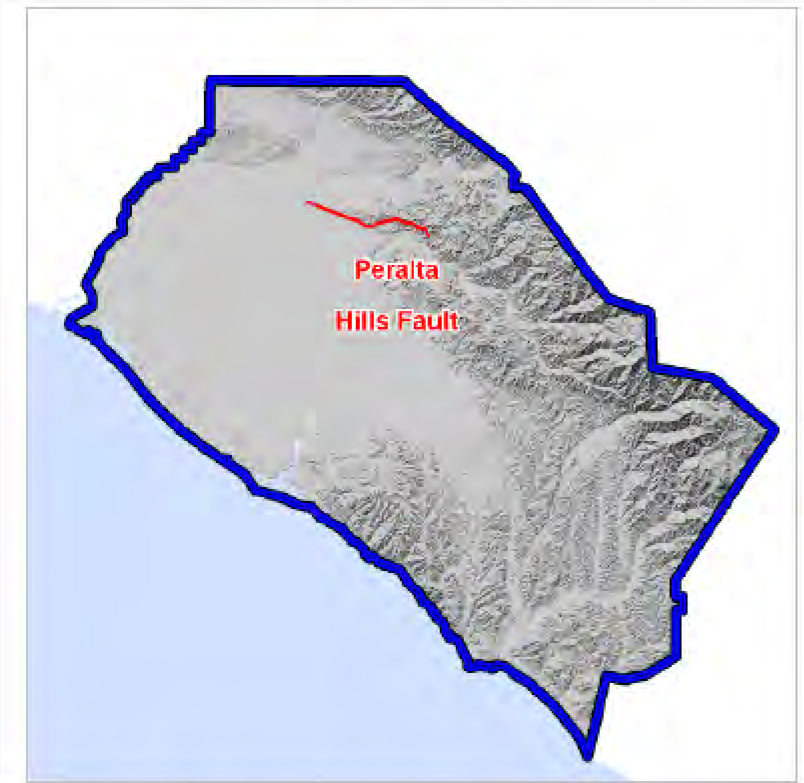
Project Number: 2509
Date: June 2005

Figure 2b

Intensity Map for M6.8 Peralta Hills Fault Scenario

Orange County, California





Intensity Contour Line

PERCEIVED SHAKING	Not Felt	Weak	Light	Mod	Strong	Very Strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Mod	Mod/ Heavy	Heavy	Very Heavy
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

5 0 5 10 15 Kilometers

3 0 3 6 9 Miles

Earth Consultants International

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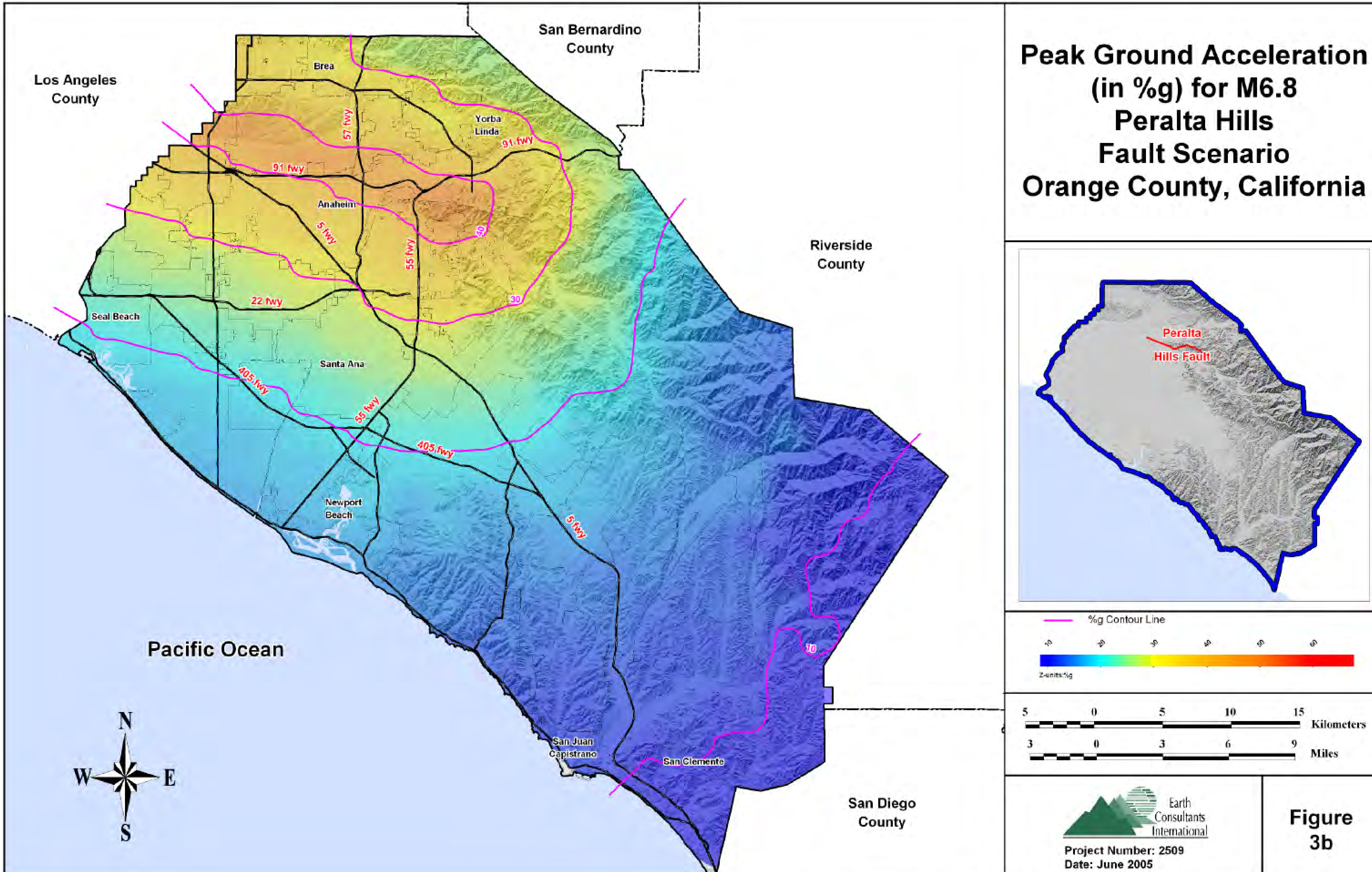
Figure 3a


Peak Ground Acceleration (in %g) for M6.8 Peralta Hills Fault Scenario Orange County, California
San Bernardino County
Los Angeles County
Riverside County
San Diego County
Pacific Ocean
Brea
Yorba Linda
Anaheim
Seal Beach
Santa Ana
Newport Beach
San Juan Capistrano
San Clemente
57 fwy
91 fwy
5 fwy
55 fwy
22 fwy
405 fwy
40
30
10
Peralta Hills Fault
%g Contour Line
Z-units:%g
Kilometers
Miles
N
S
W
E
Earth Consultants International
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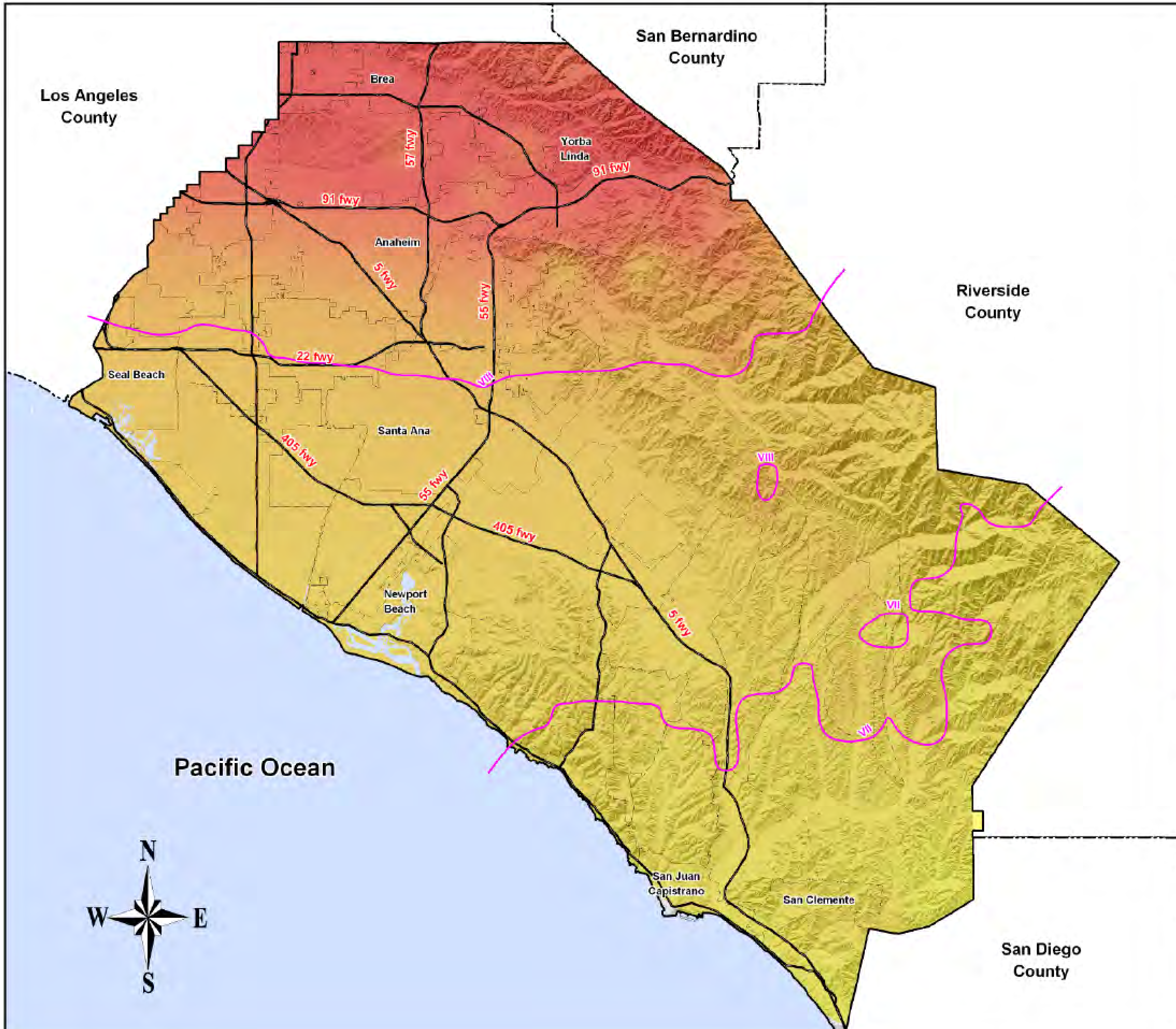
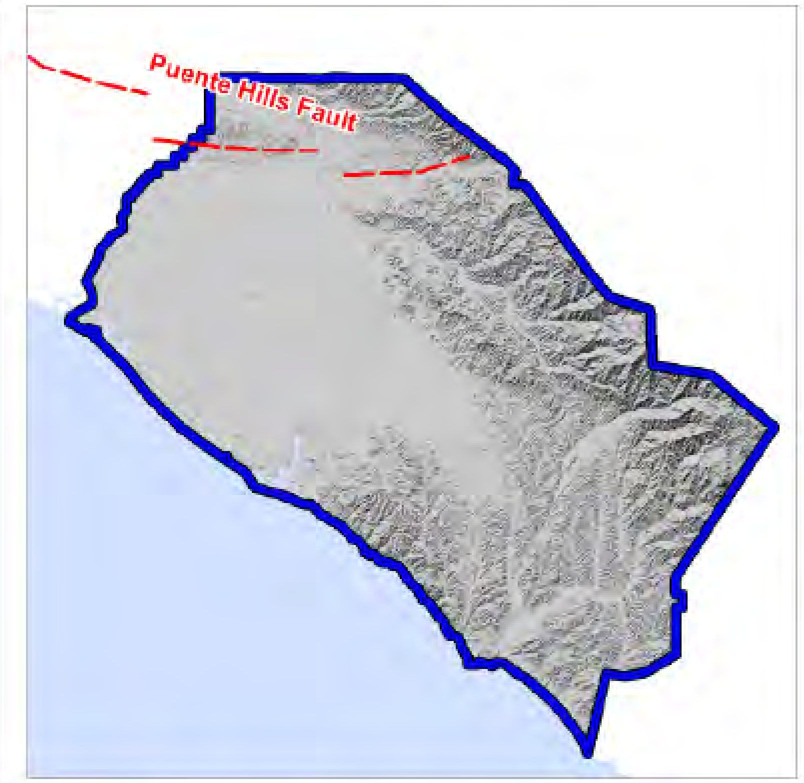
Date: June 2005
Figure 3b

Intensity Map for M7.2 Puente Hills Fault Scenario

Orange County, California





Intensity Contour Line

PERCEIVED SHAKING	Not Felt	Weak	Light	Mod	Strong	Very Strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Mod	Mod/ Heavy	Heavy	Very Heavy
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

5 0 5 10 15 Kilometers

3 0 3 6 9 Miles

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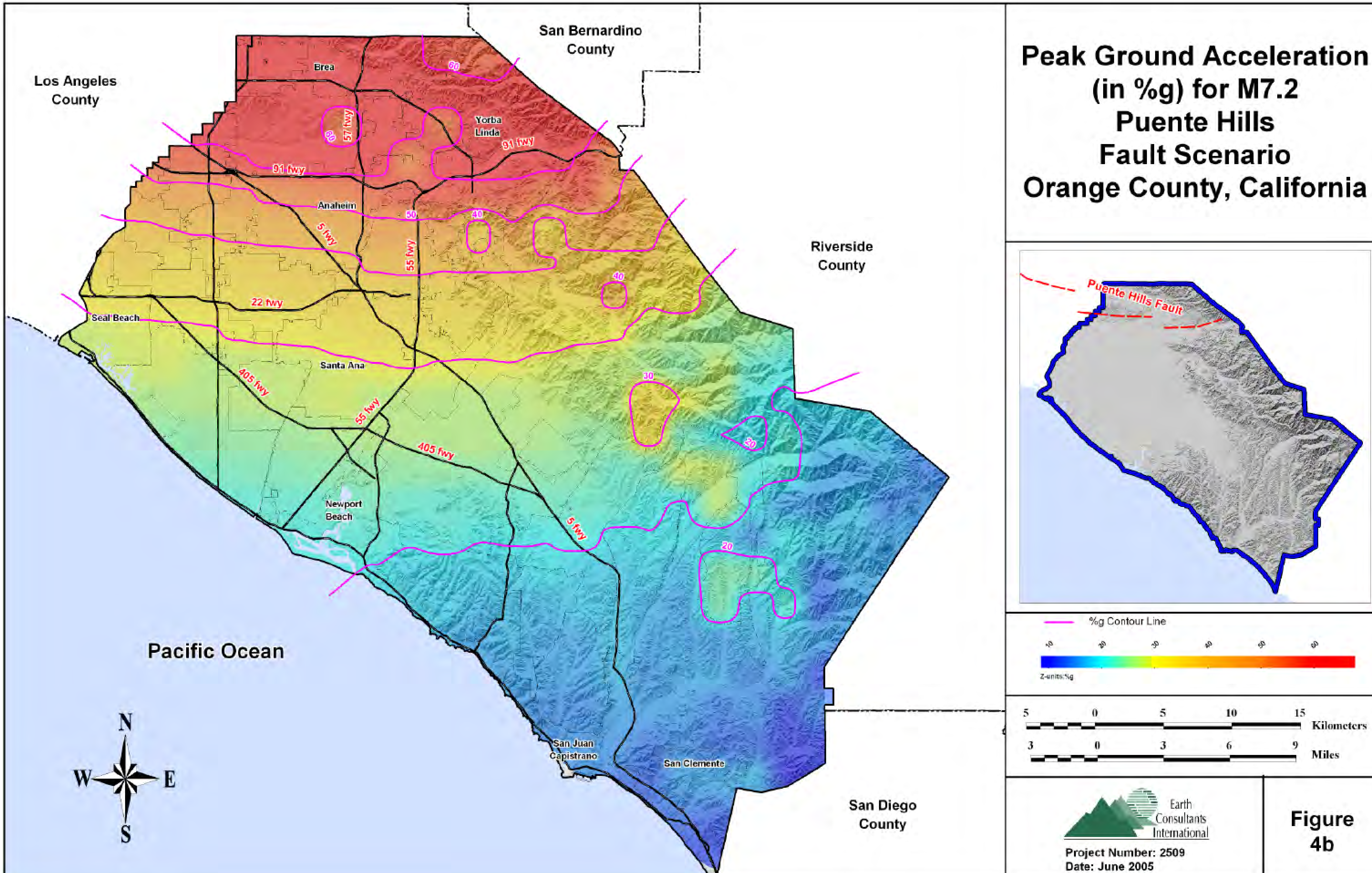
Figure 4a


Peak Ground Acceleration (in %g) for M7.2 Puente Hills Fault Scenario Orange County, California
San Bernardino County
Los Angeles County
Riverside County
San Diego County
Pacific Ocean
Brea
Yorba Linda
Anaheim
Seal Beach
Santa Ana
Newport Beach
San Juan Capistrano
San Clemente
91 fwy
57 fwy
5 fwy
55 fwy
22 fwy
405 fwy
60
50
40
30
20
Puente Hills Fault
%g Contour Line
10
20
30
40
50
60
Z-units:%g
5 0 5 10 15 Kilometers
3 0 3 6 9 Miles
N
S
E
W
Earth Consultants International
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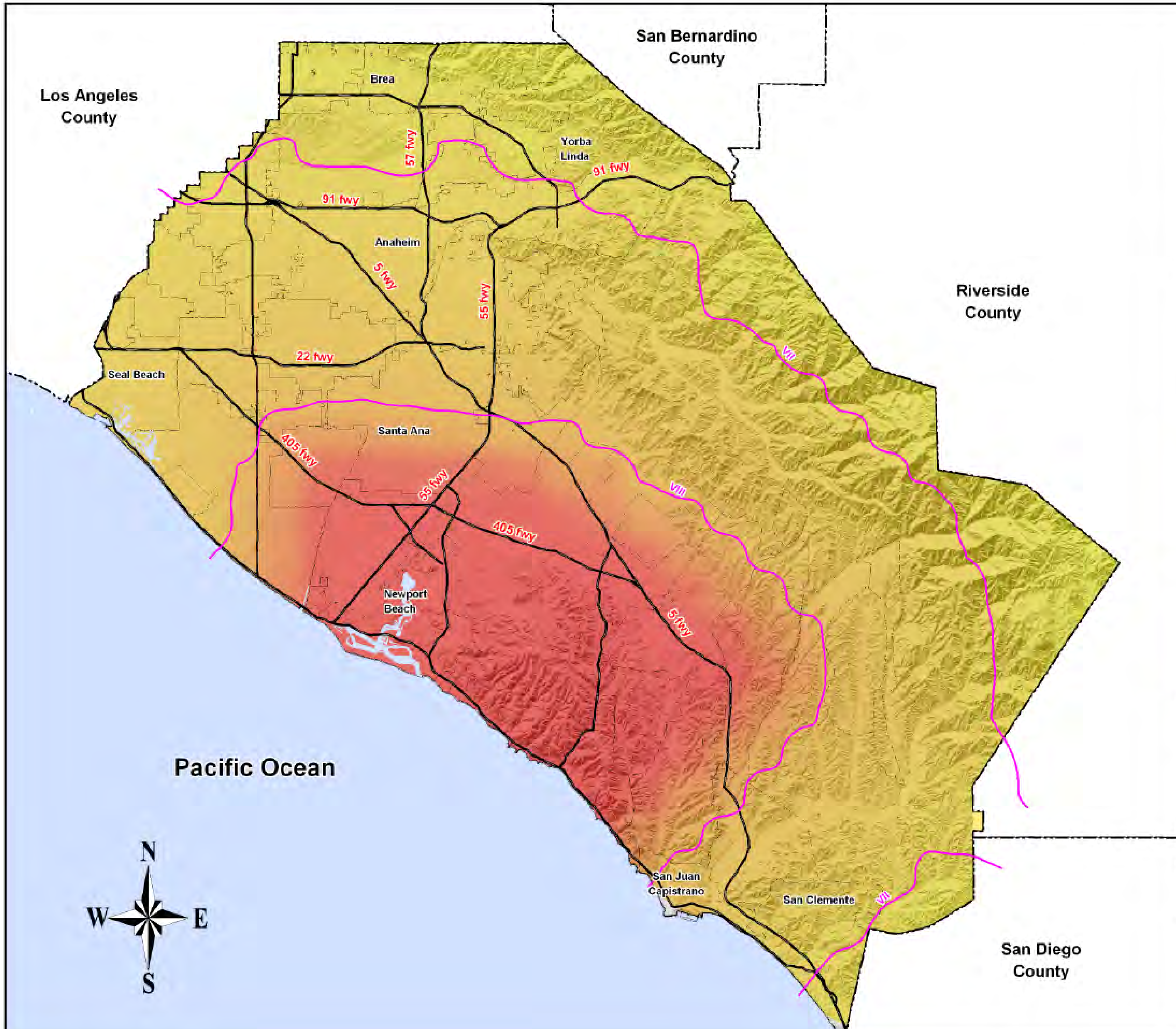
Date: June 2005
Figure 4b



Intensity Map for M6.6 San Joaquin Hills Fault Scenario

Orange County, California

Intensity Contour Line

PERCEIVED SHAKING	Not Felt	Weak	Light	Mod	Strong	Very Strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Mod	Mod/Heavy	Heavy	Very Heavy
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

5 0 5 10 15 Kilometers

3 0 3 6 9 Miles

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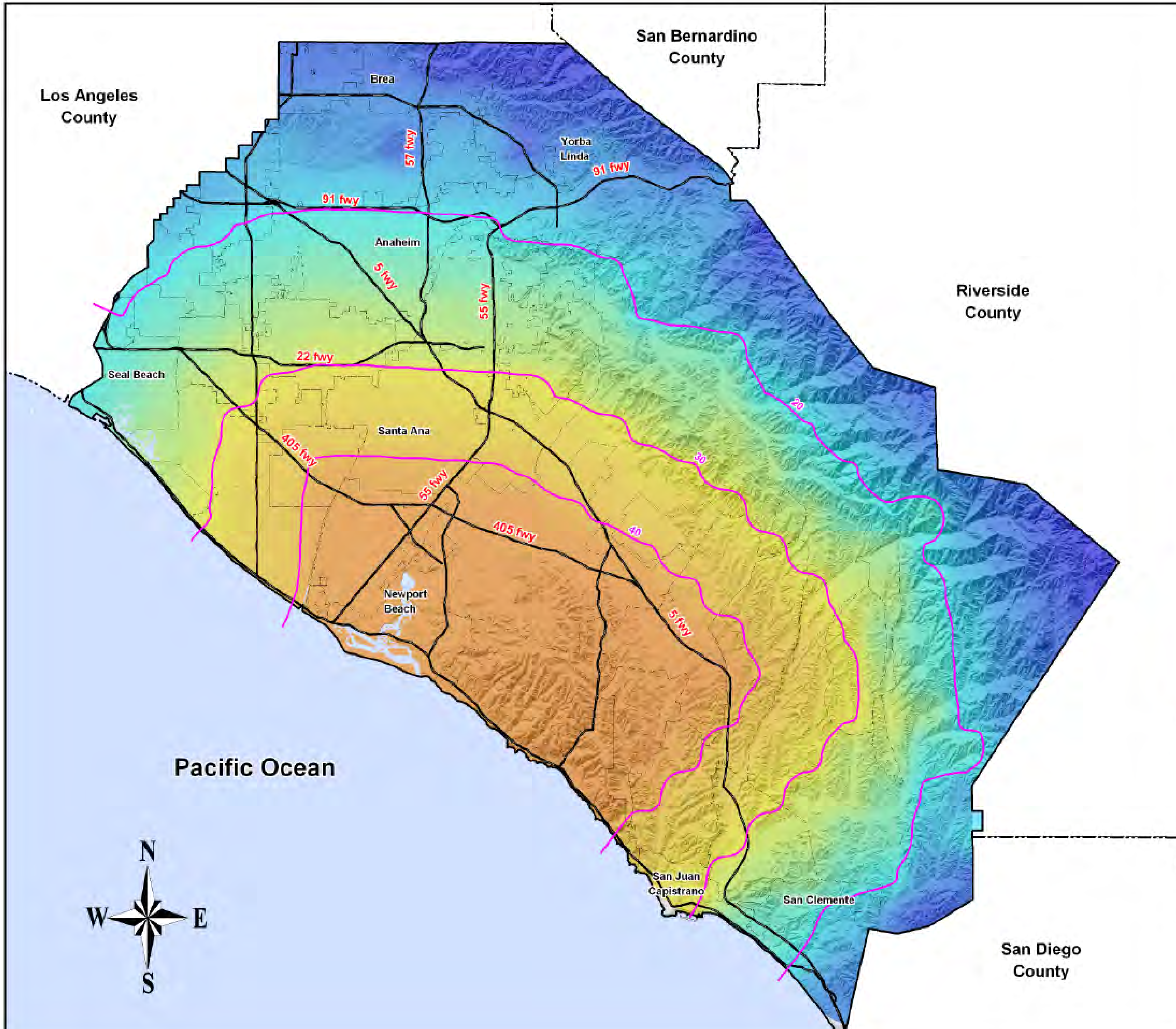
Figure 5a



Peak Ground Acceleration (in %g) for M6.6 San Joaquin Hills Fault Scenario Orange County, California

%g Contour Line

10 20 30 40 50 60

Z-units:%g

5 0 5 10 15 Kilometers

3 0 3 6 9 Miles

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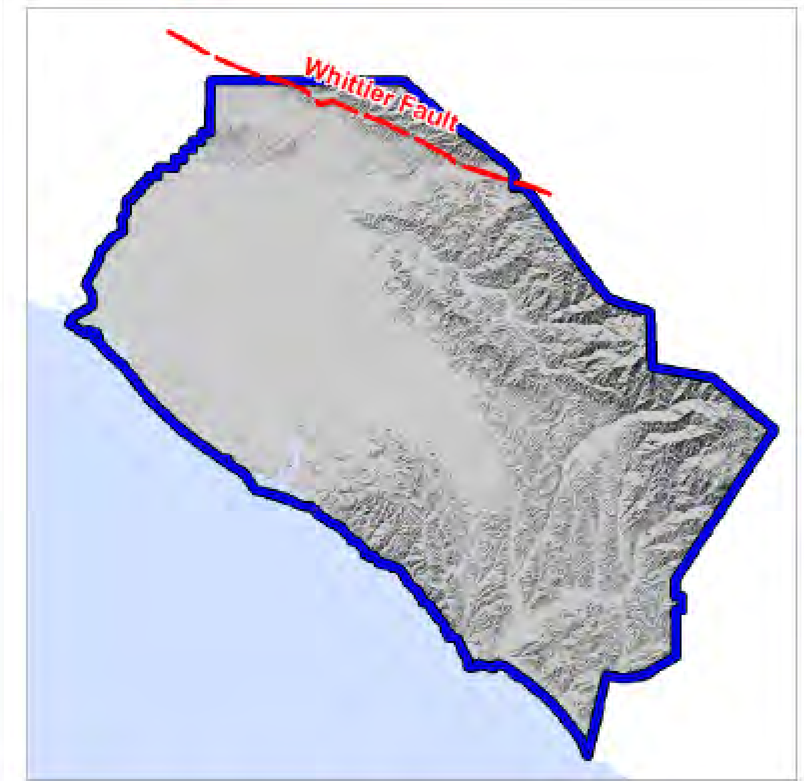
Date: June 2005

Figure 5b

Intensity Map for M6.8 Whittier Fault Scenario

Orange County, California



Intensity Contour Line

PERCEIVED SHAKING	Not Felt	Weak	Light	Mod	Strong	Very Strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Mod	Mod/ Heavy	Heavy	Very Heavy
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

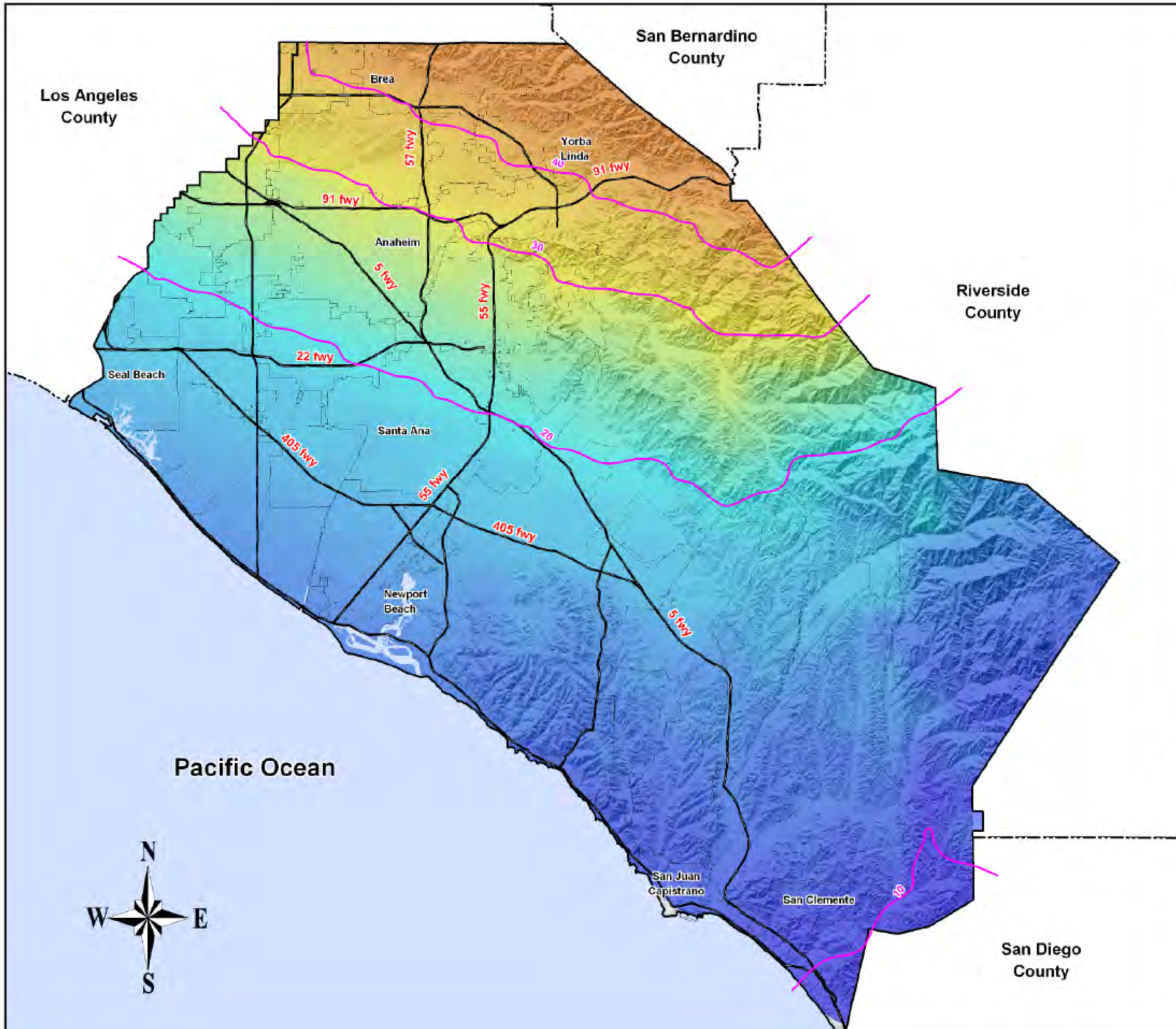
5 0 5 10 15 Kilometers

3 0 3 6 9 Miles

Earth Consultants International

Project Number: 2509
Date: June 2005

Figure 6a



Peak Ground Acceleration (in %g) for M6.8 Whittier Fault Scenario Orange County, California

%g Contour Line

10 20 30 40 50 60

Z-units:%g

5 0 5 10 15 Kilometers

3 0 3 6 9 Miles

Earth Consultants International

Project Number: 2509
Date: June 2005

Figure 6b

The Peralta Hills Fault, a Transverse Ranges Structure in the Northern Peninsular Ranges, Southern California

GEOLOGY AND MINERAL WEALTH OF THE CALIFORNIA TRANSVERSE RANGES © South Coast Geological Society 1982

Mark E. Bryant and Donald L. Fife, Converse Consultants, Inc., P.O. Box 6288, Anaheim, California 92806

ABSTRACT

The dominant structural feature of the Peralta Hills, within the transition between the Transverse and the Peninsular Ranges, is the north-dipping reverse left(?)-oblique Peralta Hills fault. Youthfulness of this fault is well demonstrated at several localities along its approximate 5-mile (8km) sinuous trace across the southern Peralta Hills. For the most part, the fault plane is concordant with bedding planes, while certain anomalous near-surface features are similar to conditions reported for other reverse faults throughout the Transverse Ranges. Considering the structural setting of the area, the Peralta Hills fault may be related to flexural slip and not deep-seated movement. There is uncertainty as to whether or not the Peralta Hills fault is capable of producing a large-magnitude earthquake. However, a great deal of evidence suggests that this fault should be considered a potential geologic hazard from both a ground rupture and a ground-shaking viewpoint. For the present, it must be assumed that a potentially destructive earthquake, similar to past seismic activity associated with other reverse faults in the Transverse Ranges, may be possible in the future. Before the Peralta Hills fault is more clearly understood and its implications evaluated, additional research and subsurface exploration are needed in this intensely urbanized area.

INTRODUCTION

Only recently has a significant fault been recognized along the southern edge of the Peralta Hills. This fault, locally known as the Peralta Hills fault, attains a total known length of about 5 miles (8 km) and is conspicuously similar to reverse faults within the Transverse Ranges. The trace of the Peralta Hills fault generally parallels the east-west trend of the Santa Ana River and coincides with the northern topographic termination of crystalline rocks of the Peninsular Ranges along the southern margin of the Los Angeles sedimentary basin. At several localities, youthfulness of the Peralta Hills fault is well demonstrated.

This paper reviews and discusses the fault characteristics, geologic conditions of the area, previous interpretations, recorded seismicity, and analogies to the other active reverse faults. Also, a significant question arises as to whether the Peralta Hills fault is a major tectonic feature capable of producing large-magnitude earthquakes, or simply related to flexural folding within the sedimentary interval and not capable of such potentially damaging earthquakes.

GEOLOGIC SETTING

The Transverse Ranges Province is typically characterized as an east-west trending geomorphic unit, somewhat anomalous to the prominent northwest-southeast structural alignment of California. In contrast to the generally right-lateral strike-slip motion of major faults in other provinces, the Transverse Ranges Province is dominated by folding and reverse faulting as a result of north-south crustal shortening. The Peralta Hills fault, considered here within a transition zone between the northern Peninsular Ranges and the central Transverse Ranges, exemplifies this north-dipping reverse to thrust faulting found throughout the Transverse Ranges Province. Principal faults of the central Transverse Ranges and northern Peninsular Ranges, as well as the Peralta Hills fault, are shown in Figure 1.

The Peralta Hills consist of a north-dipping homoclinal structure with subordinate folds and faults. The exposed Cenozoic sedimentary interval includes the Pliocene Fernando Formation, Upper Miocene Puente Formation, Middle Miocene Topanga Formation, and Upper Eocene to Lower Miocene Vaqueros-Sespe Formation. The combined stratigraphic thickness of these formations is on the order of 7,000 feet (2,100m) in the vicinity of Peralta Hills (Schoellhamer and others, 1981). Quaternary terrace and alluvial deposits surround this elevated bedrock nose on three sides. The dominant structural feature is the Peralta Hills fault which generally trends along the southern edge of the hills (Figure 2).

PERALTA HILLS FAULT

Previous investigations of the Peralta Hills by Richmond (1953), Yerkes (1957), Morton and others (1973), Schoellhamer and others (1954, 1981), and Morton and Miller (1981) revealed a thrust fault approximately one mile (1.6km) in length, on the southern side of the hills. The Middle Miocene Topanga Formation or the Upper Miocene Puente Formation were shown in juxtaposition with Pleistocene terrace deposits. Fife and others (1980), and various geotechnical reports, including unpublished data by Converse Consultants, have disclosed similar fault segments at other nearby localities. Based on this compilation of data, the fault is considered to be a single sinuous trace across the hills, or possibly, several closely-spaced en echelon faults, with a documented total length of more than 5 miles (8km).

The Peralta Hills fault ascends from about elevation 300 feet (90m) at the west end to about elevation 900 feet (275m) at the eastern terminus. The westerly half of the fault generally bounds the southern edge of the hills, where it traverses through urbanized land. The easterly half is within natural terrain. For much of its length, bedrock has been thrust southward over terrace deposits. Typically, the fault plane ranges between a 30° and 70° dip to the north, and is locally concordant with the shale, siltstone and sandstone beds. However, it is apparent that the fault does cut across the structural grain of the sedimentary bedrock units on a more regional scale. At one location, the fault was studied in detail by Converse Consultants by way of deep exploratory borings and trenches. Here, the fault was distinguished by nearly

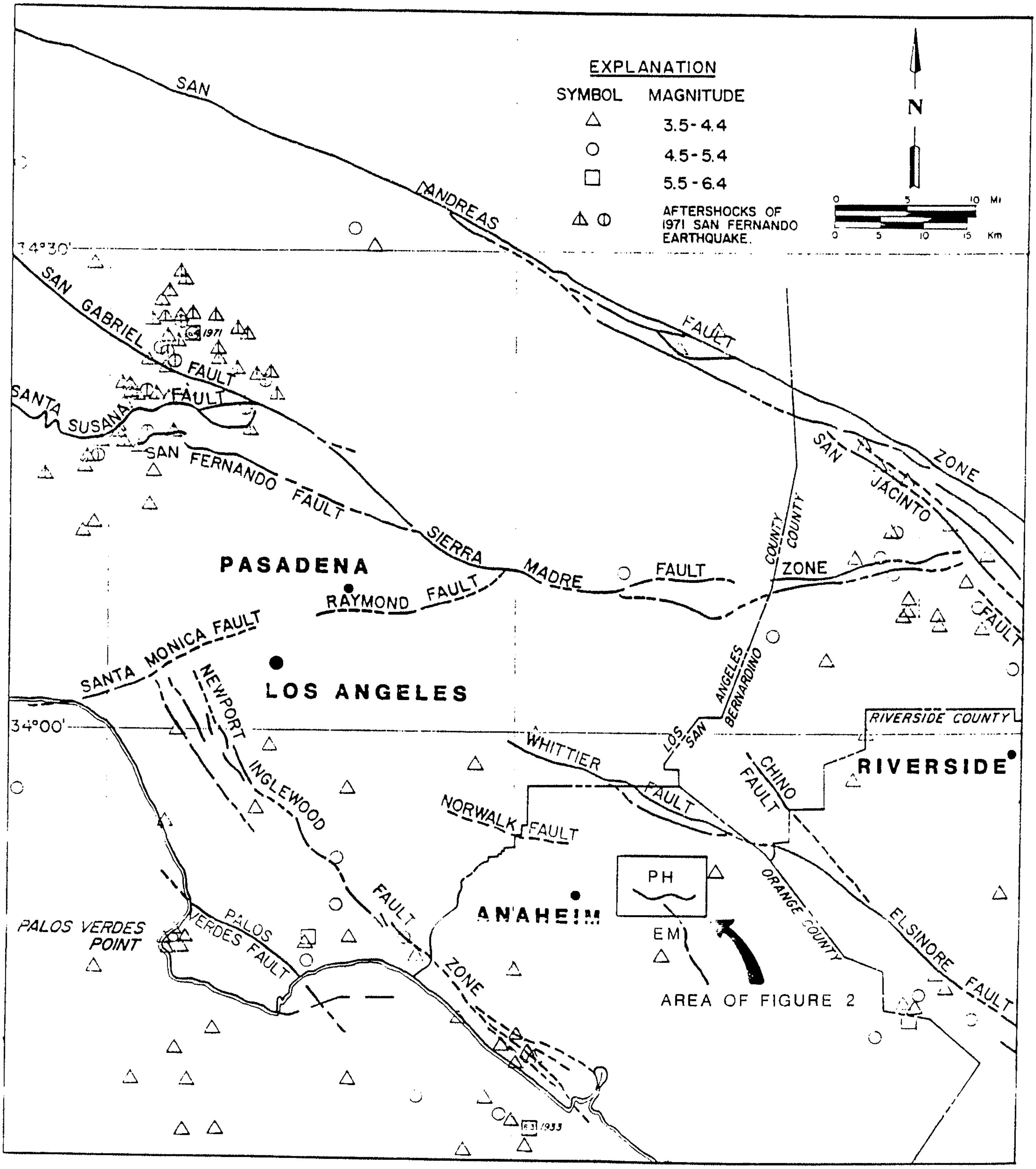


Figure 1. Regional fault map of the central Transverse Ranges and northern Peninsular Ranges. Principal Quaternary-age faults shown and Peralta Hills fault located in southern area. PH = Peralta Hills fault. EM = El Modeno fault.

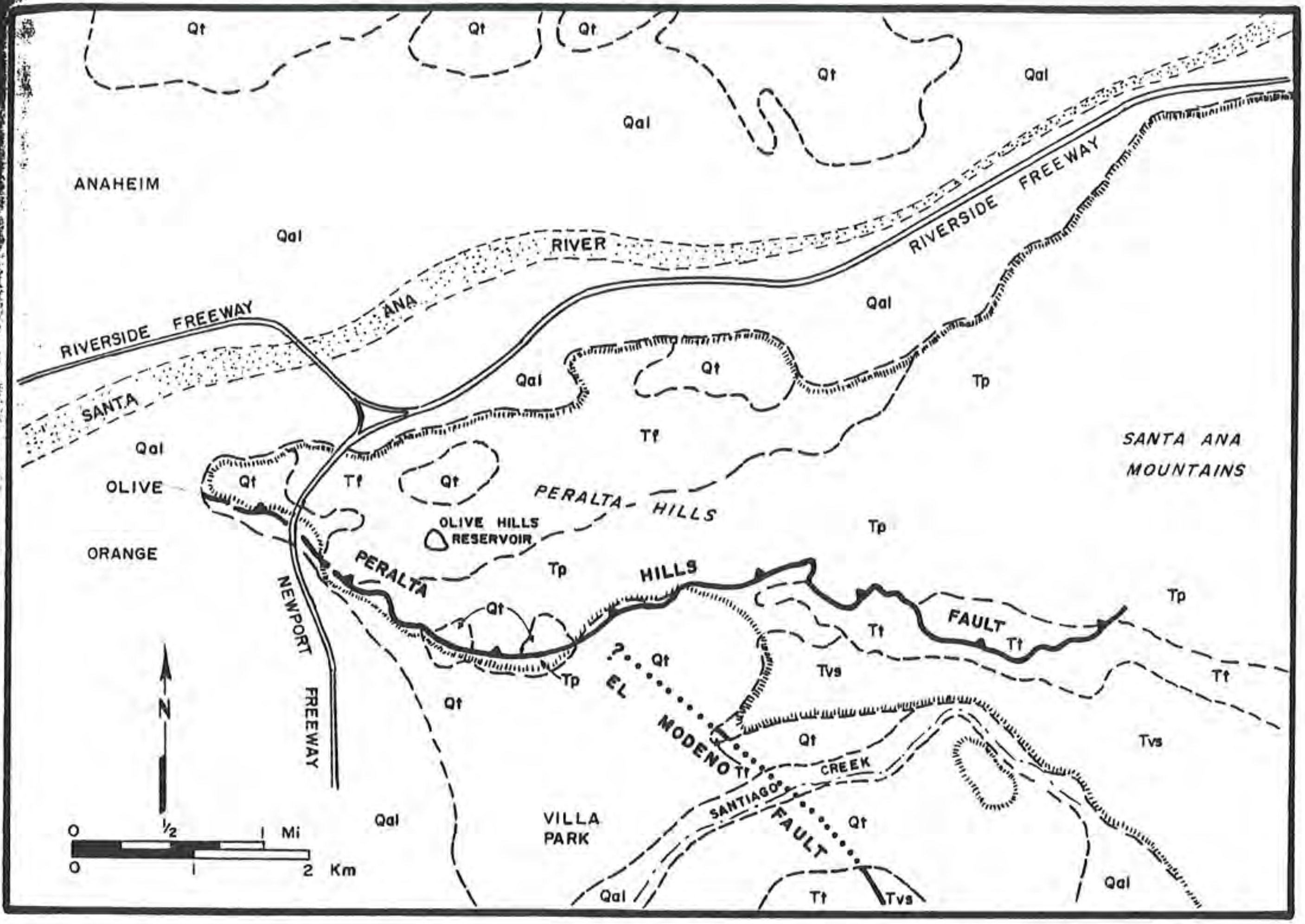


Figure 2. Generalized geologic map of Peralta Hills modified from Morton and Miller)1981). Qal = alluvium, Qt = terrace deposits, Tf = Fernando Formation, Tp = Puente Formation, Tt = Topanga Formation, Tvs = Vaqueros-Sespe Formation, ▲ = reverse fault, ▬•• = normal fault (dotted where burried), — — — = contact, ⁐⁐⁐ = edge of hills.

parallel-to-bedding displacement at depth and a marked change to a south-dipping (gravity slide) plane near the surface as a continuous arcing shear surface (Photographs 1 and 2). Measured offset was indicated to be at least 250 feet (75m). Similar faulting conditions have been revealed at other localities. At a second location, Pleistocene terrace deposits have been substantially deformed on the downthrown (south) side. The stratification within these Pleistocene river gravels and overlying (Holocene?) colluvial deposits now dips to the south and away from the fault at 40° to 60°. At this same location, the resisting force along a stratum has been overcome by this tilting and (block) failure has resulted in the southerly direction.

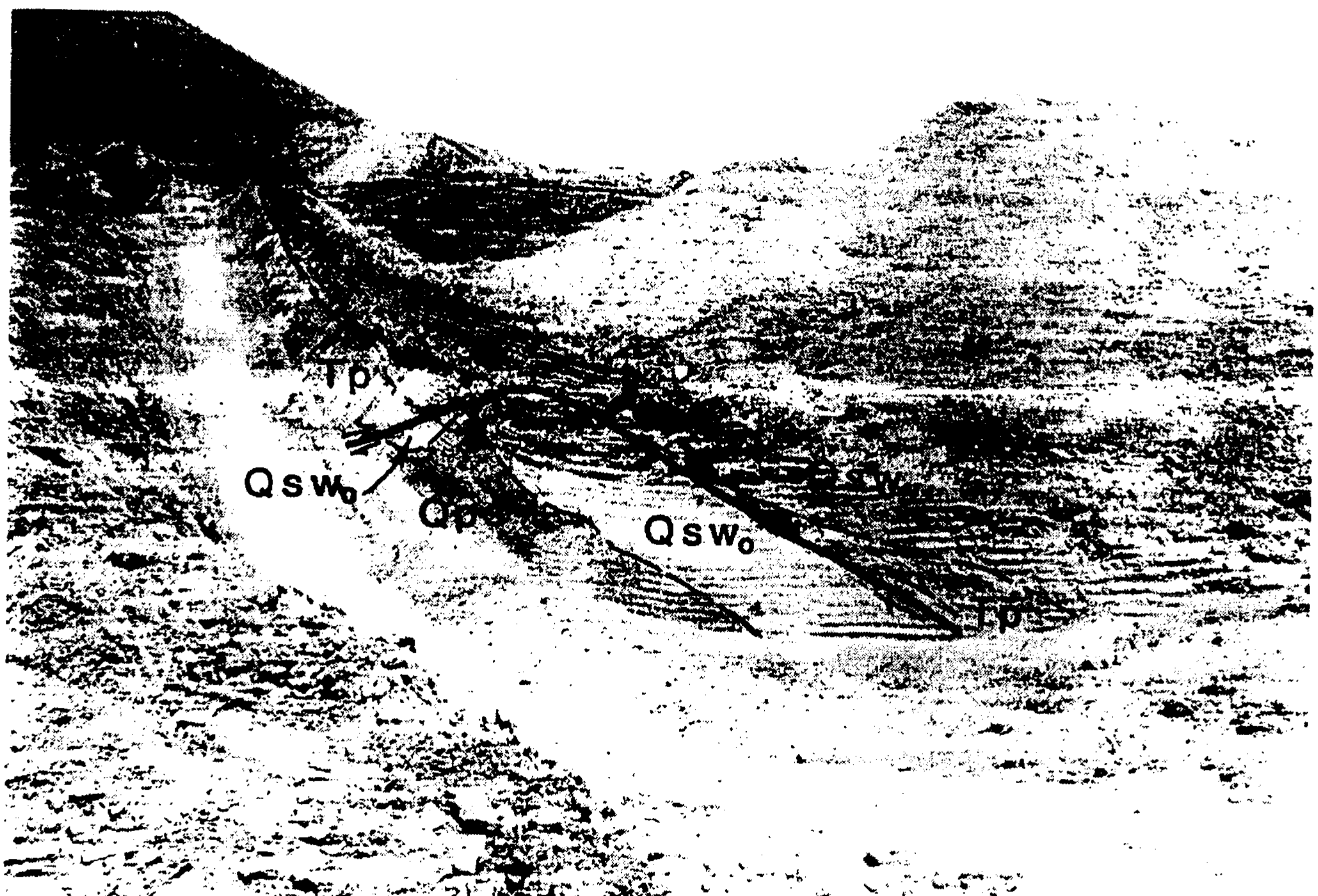
In general, the Peralta Hills fault, as depicted by us, has been unrecognized by previous workers. Erosion and mass wasting have tended to obliterate geomorphic features, while man-made changes to pre-existing surface conditions have further contributed to its obscurity. More recently, roadcuts and large excavations combined with exploratory work along the fault trace have aided us in acquiring valuable near-surface and subsurface data. Youthfulness of the fault was demonstrated at several localities by offsets extending into Pleistocene terrace deposits, and Holocene alluvial and colluvial deposits. Limited C-14 dating of the latter deposits in the vicinity of the aforementioned gravity slide suggested Holocene displacement.

About 10 miles (16km) to the south is another interesting east-west trending feature within the Miocene section consisting mostly of incompetent La Vida Member of the Puente Formation (Tan and others, 1982). This structure trends westward in upper Borrego Canyon for 4 miles (6km) along the north corner of the El Toro quadrangle, just west of the Cristianitos fault. It begins as an asymetrical fold becoming progressively overturned, then to a north-dipping reverse "sheared fold," then apparently into a more conventional north-dipping reverse fault. This feature appears to be an incipient "Peralta Hills fault," although the precise age of deformation has not been determined.

SEISMICITY

Recorded seismic activity for the period 1932-1981 has been rather sparse in the Peralta Hills area as evidenced by the earthquake epicenter plot obtained from the seismological laboratory of the California Institute of Technology earthquake data base. Approximately 60 seismic events occurred in this area, including three significant earthquakes with magnitudes of M3.5, M3.5 and M4.1. The others were less than M3.5 and considered microseismic. Most of the determined focal depths were greater than

Photograph 1. View looking south at east wall of bulldozer trench. Peralta Hills fault at south end. Wall height is about 15 feet (4.6m). Qswy = younger slopewash, Qswo = older slopewash, Qps = older paleosol, Tp = Puente Formation.



16,500 feet (5km), although several were as shallow as 6,500 feet (2km). A cluster of 10 microseismic epicenters were located 1.5 to 2.1 miles (2.4-3.4km) north of the western end of the known Peralta Hills fault. The associated hypocenters are generally consistent with a 60° dip projected from the surface trace, and range between 16,500 and 20,000 feet (5-6km). This focal depth is well within the more competent sedimentary beds, and may be deep enough to be in basement rocks. Of particular interest, the M4.1 earthquake hypocenter can be located on the aforementioned projected fault plane at its determined depth of 14,000 feet (4.3 km). It is possible, however, that the earthquake data may be fortuitous due to the lack of a well established seismicity pattern. Numerous shallow microseismic events may be related to the release of elastic strain energy in the near-surface zone. This is analogous to what takes place in some large landslides within sedimentary bedrock terrane; namely, continuous "slip-stick" movement which occurs along incompetent bedding planes, accompanied by localized shallow ground shaking.

While there is no direct evidence that the Peralta Hills fault generated any major (significant) historic earthquake, it is interesting to note a "short" westward projection would place the fault under the generally accepted location of the 1769 encampment of the Gaspar de Portola expedition (Figure 2). Portola reported the first major California earthquake on July 28, 1769, while camped on the banks of the Santa Ana River near the present site of Olive (Ritcher, 1958). We are not concluding that the Peralta Hills fault ruptured during or generated that earthquake nor are we ruling out that possibility.

DISCUSSION

We propose that the Peralta Hills fault be considered a potential geologic hazard from both a ground rupture and a ground shaking viewpoint. The fault has a known length of about 5 miles (8km), and it may extend for some distance to the east, and especially to the west. Definitive geologic evidence related to depth of faulting and the probability of relatively large-magnitude seismic activity are not known at this time. Future activity may be restricted to only aseismic (creep) movement and associated shallow microseismicity. However, it is conceivable that fault displacement at the surface could accompany a large-magnitude event. Yeats and others (1981), and Yeats (1982) cite examples and provide substantiating evidence for "rootless" reverse faults in the Ventura basin. They differentiate deep-seated faults capable of producing large-magnitude earthquakes from relatively shallow or "low-shake" reverse faults capable of ground rupture, but do not pose a seismic hazard. The latter type consist of either detachment thrusts, flexural-slip faults, or bending-moment faults due to horizontal shortening (Yeats, 1982). Considering these fault models, the Peralta Hills fault most closely resembles a flexural-slip fault.

Characteristic features assigned to Yeats and others' (1981) flexural-slip model include movement exclusively, or nearly, along bedding during folding, and lack of deep microseismicity. Another parameter mentioned is back-tilting of displaced alluvial deposits toward the upthrown block which suggests that the faults flatten with depth, and such faults typically occur as multiple nearly-parallel sets at a synclinal flank. Further, they indicate that surface rupture may result from a large-magnitude earthquake along a nearby "master" fault. The flexural-slip examples described by Yeats and others (1981) are all within approximately 3 miles (5km) of a so-called master fault (i.e. Red Mountain fault, San Cayetano fault, etc.). They point out that flexural-slip faults of Orcutt and Timber Canyons display relative movement opposite to that of the nearby active San Cayetano fault to the north. The interpretation that numerous reverse faults in the Ventura basin are related to flexural slip seems reasonable based on direct geologic evidence.

In the case of the Peralta Hills fault, there are similarities as well as dissimilarities to the prescribed flexural-slip model and associated geologic conditions in the Ventura basin. Among the similarities, the strike of the Peralta Hills fault essentially parallels the bedding planes with both dipping to the north. The Peralta Hills occupy the southern limb of a large broad syncline, where the same formations exposed there crop out 4 to 6 miles (6-10km) to the north, and attain a minimum depth of about 8,000 feet (2500m) beneath the Santa Ana River alluvial valley (Durham and Yerkes, 1965; Schoellhamer and others, 1981; Morton and Miller, 1981). In addition, movement has taken place along bedding, at least near the surface, for much of the Peralta Hills fault; but, displacement has to a limited extent occurred within massive sandstone (Topanga Formation) rather than less competent and stratigraphically higher laminated siltstone and shale beds (Puente Formation). There is no conclusive evidence to relate the recorded microseismicity to either flexural slip or relatively deep crustal displacement based on our cursory review of reported data.

Unlike Yeats and others' (1981) flexural-slip examples, the Quaternary surficial cover has been displaced exclusively along a single fault break although slickensided bedding surfaces were evident within the upthrown block at numerous sites. Vertical offset across the fault plane exceeded 60 feet (18m) at one location. On the Peralta Hills fault, considerable tilting of Quaternary deposits has been recognized at a large excavation. Strata dips southerly as much as 60°, and decreases to 40° for younger material more distant from the north-dipping fault. This sense of deformation is indicative of either drag within the downthrown block, or dominant thrusting effects by the upthrown block. Because of the nearby gravity sliding, we tend to favor the thrusting model. This condition is very similar to the Gould Canyon thrust fault, considered within the Sierra Madre fault zone, and reported by Crook and others (1978). There, the fault dips 30°-65° north into the hillside at depths, and abruptly dips 15°-25° southerly near the surface in one area. Based on mapping and exploration, this "thrust-rooted (gravity) slide" consists locally of 52 feet (16m) of diorite overlying old alluvium (Crook and others, 1978). Another noteworthy example is the Tujunga segment of the San Fernando fault zone where trenches revealed that the north-dipping fault plane was parallel with bedding, but became south-dipping near the surface (Barrows, 1974).

According to Yeats and others (1981), ground rupture along a flexural-slip fault may occur during a large-magnitude earthquake originating on a nearby "master" fault. The closest active fault is the Whittier fault, located approximately 6 miles (9km) to the north. It is a high-angle northeast-dipping reverse fault of probable Late Pleistocene to Holocene age (Morton and others, 1976). The Whittier fault is commonly considered a northern extension of the Elsinore fault; thus, the entire fault zone would have a total length of about 175 miles (280km). The Elsinore fault is a well-documented active fault with right-lateral separation on the order of 6 to 6.5 miles (9-11km), while the Whittier fault has about 2 miles (3km) of vertical separation and nearly one mile (1-2km) of right-lateral displacement (Kennedy, 1977; Weber, 1977; Yerkes, 1972). McGuire (1981) indicates that two types of motion are represented on the Elsinore fault. He points out that 17 to 19 miles (27-30km) of right-lateral offset took place prior to 4 million years ago, but that the fault exhibited reverse and normal separation during the last 4 million years. No doubt, the Whittier fault could qualify as a principal or "master" fault, particularly if the neotectonic setting is contributory to continued reverse (compressional) displacement; however, it might be too far removed from the Peralta Hills fault to have any local tectonic influence. Although the regional structural pattern may be consistent with the flexural-slip model, movement confined to only one fault surface during flexing seems difficult to explain for such a distance.

Still another possibility exists, namely, if the Peralta Hills fault is indeed a reverse fault, it may continue to the west at least in the subsurface, or faulting may have been translated into tighter folding. It is possible to reinterpret Schoellhamer and others' (1981) structure section E-L (Plate 2) by incorporating a north-dipping (40°-60°) reverse fault, projected from the western end of the mapped Peralta Hills fault, between their Richfield Oil Corporation Hamrick-Olive Well No. 1 and Olive Petroleum Company Well No. 1. Such a fault could be shown with 800 feet (245m) or more of stratigraphic separation by a reduction in the syncline-anticline amplitude, and without altering the subsurface structure based on the respective well logs. This would tend to explain the significant difference in depths of the formational contacts at each well location, and be consistent with the known near-surface structure in the immediate area. Additionally, selected microseismicity data are compatible with this projected fault plane, and the 60° dip previously suggested for such a fault.

The El Modeno fault has commonly been projected from its north-northwest trend to an east-west trend to explain the topography of the Peralta Hills (Yerkes, 1957; Morton and others, 1973). The position of the reverse fault suggests that the El Modeno fault continues its north-northwest trend and is truncated by or passes beneath the Peralta Hills fault (Fife and others, 1980; Ryan and others, 1982; Ryan, 1982). This would tend to support the Peralta Hills fault as an active deep-seated structural feature.

CONCLUSIONS

There is considerable uncertainty as to the significance of the Peralta Hills fault. This fault may be capable of producing a large-magnitude earthquake during rupture since certain aspects favor the deep-seated fault model interpretation. The Peralta Hills fault may be somehow related to the Transverse Ranges compressional stresses. Future seismic activity may be similar to other reverse faults within this region (i.e. San Fernando fault). Since the available data are still inconclusive, there is a need for more detailed research, including possibly the installation of a microseismicity network, review of oil and water well data, conducting geophysical surveys, additional trenching, core drilling, etc. If we assume that the currently known fault would undergo surface rupture along its entire length, the associated earthquake would be in the range of M6.0-M6.5 according to Greensfelder (1973). Considering this potentiality and the intense urbanization, more definitive information is required to determine the seismic risk of the area.

ACKNOWLEDGMENTS

The authors wish to thank John Minch, Roy Hoffman and Eldon Gath for review of this paper. Thanks are due to Gerry Simila for obtaining the seismicity data. Karen Faris prepared the figures.

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