April 17, 2015

EMI Project No. 08-103

PARSONS
2201 Dupont Drive, Suite 200
Irvine, California 92612

Attention: Mr. David Speirs

Subject: ***Revised District Preliminary Geotechnical Report***
I-10 Corridor Project, Los Angeles/San Bernardino Counties, California
07-LA-10 PM 44.9/48.3, 08-SBd-10 PM 0.0/R37.0, EA 0C2500

Dear Mr. Speirs:

Attached is the Revised District Preliminary Geotechnical Report (DPGR) for the I-10 Corridor Project. The report is intended to provide preliminary geotechnical information to assist Parsons in preparing the preliminary cost estimate for the project.

Conclusions and recommendations given in this report are based on available as-built subsurface soil information. Conclusions and recommendations are considered preliminary and should be verified in the future by conducting additional site-specific geotechnical field investigations, laboratory soil testing, and analyses during PS&E.

An earlier version of the DPGR dated February 20, 2011 was submitted to Caltrans for review. Caltrans provided their comments on April 9, 2015. EMI developed responses to the Caltrans review comments and incorporated them into this Revised DPGR. All Caltrans review comments and EMI responses are included in Appendix B.

We appreciate the opportunity to provide geotechnical services for the project. If you have any questions please call us.

Sincerely,
EARTH MECHANICS, INC.

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REVISED DISTRICT PRELIMINARY GEOTECHNICAL REPORT
I-10 CORRIDOR PROJECT
LOS ANGELES/SAN BERNARDINO COUNTIES, CALIFORNIA
07-LA-10 PM 44.9/48.3, 08-SBd-10 PM 0.0/R37.0, EA 0C2500

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EMI Project Number: 08-103

April 17, 2015

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1.0 INTRODUCTION

An earlier District Preliminary Geotechnical Report (DPGR), dated January 12, 2009, was prepared for the I-10 High Occupancy Vehicle (HOV) Lane Project, which is mostly the same as the HOV alternative for this current project. A copy of the January 2009 report is included in Appendix A. The 2009 HOV project has now been expanded to include an Express Lane option. Thus, an updated DPGR is required. It should also be noted that this report replaces the 2009 report and the preliminary findings and recommendations presented in this report are applicable for the HOV (Alternative 2) and Express Lane (Alternative 3) options. Also, all of the pertinent Caltrans review comments and our responses included with the January 2009 report in Appendix A have been incorporated into this report.

This DPGR presents findings and conclusions of a geotechnical study conducted by Earth Mechanics, Inc. (EMI) for proposed improvements at the Interstate-10 (I-10) Corridor project located in both Los Angeles and San Bernardino Counties. The project location is shown on the Site Location Map (Figure 1). The purpose of this report is to provide preliminary geotechnical information to assist Parsons in preparing the preliminary engineering plans and cost estimates. Pavement recommendations are addressed separately in a Preliminary Materials Report (EMI, 2015).

2.0 EXISTING FACILITIES AND PROPOSED IMPROVEMENTS

2.1 General

The California Department of Transportation (Caltrans), in cooperation with the San Bernardino Associated Governments (SANBAG), proposes to add freeway lanes through all or a portion of the 33-mile segment of I-10 in San Bernardino County from the Los Angeles/San Bernardino (LA/SB) County Line to Ford Street in Redlands. The project limits including transition areas extending from approximately 0.4 miles west of White Avenue in Pomona at Post Mile (PM) 44.9/48.3 (Los Angeles County) to Live Oak Canyon Road in Yucaipa at PM 0.0/R37.0 (San Bernardino County). The I-10 Corridor in the project area trends in an east-west direction and carries traffic from Los Angeles County, through San Bernardino and Riverside Counties and towards the California/Arizona border.

The project is currently in the Project Approval/Environmental Document (PA/ED) phase. Three alternatives are being considered for the I-10 Corridor project, as described below:

- Alternative 1 (No Build) would maintain the existing lane configuration of the I-10 corridor with no additional mainline lanes or associated improvements to be provided.

- Alternative 2 (High Occupancy Vehicle Lane Alternative) proposes to extend the existing High Occupancy Vehicle (HOV) lane in each direction of I-10 from the current HOV terminus near Haven Avenue in Ontario to Ford Street in Redlands, a distance of approximately 25 miles. Alternative 2 traverses seven cities (Ontario, Fontana, Rialto, Colton, San Bernardino, Loma Linda, and Redlands) and unincorporated areas of San Bernardino County including Etiwanda, Bloomington, and Bryn Mawr.

- Alternative 3 (Express Lanes Alternative) proposes to provide two Express Lanes in each direction of I-10 from the LA/SB County Line to California Street in Redlands and one Express Lane in each direction from California Street to Ford Street in Redlands, a total of 33 miles. Between the LA/SB County Line and Haven Avenue, the existing HOV lane in each direction of I-10 would be combined with an additional lane to provide two express lanes in each direction. Alternative 3 traverses ten cities (Claremont, Pomona, Montclair, Ontario, Fontana, Rialto, Colton, San Bernardino, Loma Linda, and Redlands) and unincorporated areas of San Bernardino County including Etiwanda, Bloomington, and Bryn Mawr.

The proposed improvements are generally within San Bernardino County with some improvements in Los Angeles County to facilitate transitioning between the existing HOV cross section in Los Angeles and the proposed Express Lane cross section in San Bernardino in Alternative 3. Additional details of the project components are described later in Sections 2.4 and 2.5 for Alternatives 2 and 3, respectively.

2.2 Purpose of Project

The purpose of this project is to improve traffic operations on the I-10 freeway in San Bernardino County in order to reduce congestion, increase throughput, and enhance trip reliability for the planning design year of 2045.

The objectives of the project are to:

- Reduce volume-to-capacity ratios along the corridor;
- Improve travel times within the corridor;
- Provide a facility that is compatible with transit and other modal options;
- Provide consistency with the SCAG Regional Transportation Plan;
- Provide a cost effective project solution; and
- Minimize environmental impacts and right of way acquisition.

2.3 Need for Project

Deficiencies of I-10 within the project limits are summarized below:

- Substantial portions of the I-10 mainline GP lanes peak-period traffic demand currently exceeds capacity;
- Nearly all of the I-10 mainline GP lanes are projected to exceed capacity in future years; and
- The I-10 existing mainline HOV lanes operation is degraded during peak-periods.

2.4 Description of Alternative 2 (HOV Lanes) Improvements

Alternative 2 would extend the existing HOV lane in each direction of I-10 from the current HOV terminus near Haven Avenue to Ford Street, a distance of approximately 25 miles. The proposed improvements would involve construction work from post miles 4.7 to R37.0 in San Bernardino County. Proposed engineering features in Alternative 2 are summarized as follows:

Mainline Improvements: Mainline improvements include the following:

- Add one HOV Lane in each direction from Haven Avenue to Ford Street
- Reestablish existing auxiliary lanes along the corridor
- Construct new WB auxiliary lane between Rancho Avenue and La Cadena Drive

Interchange Ramp Improvements: Alternative 2 encompasses 3 system interchanges (I-10/I-15 Interchange, I-10/I-215 Interchange, and I-10/SR-210 Interchange) and 21 local street interchanges from Haven Avenue to Ford Street. Alternative 2 would also require reconstruction of several interchange ramps to accommodate the I-10 widening.

Local Street Improvements: Richardson Street and its structure over I-10 would need to be replaced with a longer-span structure to accommodate the widened freeway.

Railroad Involvement: Five railroad crossings over or under I-10 would be impacted by the proposed freeway widening:

1. UPRR Kaiser Spur OH (widen)
2. UPRR Slover Mountain UP (replace)
3. UPRR Colton Crossing OH (widen)
4. UPRR Pavillion Spur OH (abandon)
5. BNSF West Redlands OH (widen)

Structure Improvements: Alternative 2 would necessitate replacement of 2 structures, widening of 31 structures, partial reconstruction of 4 structures, and construction of tie-back walls at 2 overcrossing structures. Four structures are also planned to be abandoned in place.

2.5 Description of Alternative 3 (Express Lanes) Improvements

Alternative 3 would provide two Express Lanes in each direction of I-10 from the LA/SB County Line to California Street in Redlands and one Express Lane from California Street to Ford Street in Redlands. Between the LA/SB County Line and Haven Avenue, the existing HOV lane in each direction of I-10 would be combined with an additional lane to provide two express lanes in each direction. The proposed improvements under Alternative 3 would involve construction work within the following routes and post miles:

- 07-LA-10 PM 44.9/48.3
- 08-SBd-10 PM 0.0/R37.0
- 08-SBd-15 PM 0.7/4.0
- 08-SBd-38 PM 0.0/0.3
- 08-SBd-83 PM 10.7/11.5
- 08-SBd-210 PM R33.0/R31.5

- 08-SBd-215 PM 2.1/5.7

Proposed engineering features in Alternative 3 are summarized as follows:

Mainline Improvements: Mainline improvements include the following:

- Add one Express Lane in each direction from the LA/SB County Line to Haven Avenue to operate jointly with existing HOV lanes as two Express Lanes in each direction
- Add two Express Lanes in each direction from Haven Avenue to California Street
- Add one Express Lane in each direction from California Street to Ford Street
- Reestablish existing auxiliary lanes along the corridor
- Construct new EB auxiliary lane between Mountain Avenue and Euclid Avenue
- Modify existing WB auxiliary lane at Haven Avenue WB on-ramp to begin at Haven Avenue WB loop on-ramp
- Modify existing EB auxiliary lane at Haven Avenue EB on-ramp to begin at Haven Avenue EB loop on-ramp
- Extend WB auxiliary lane preceding the Riverside Avenue off-ramp to Pepper Avenue
- Construct new WB auxiliary lane between Rancho Avenue and La Cadena Drive
- Provide ten ingress/egress access points, nine with additional weave lane and one as weave zone

Interchange Ramp Improvements: Alternative 3 encompasses 3 system interchanges (I-10/I-15 Interchange, I-10/I-215 Interchange, and I-10/SR-210 Interchange) and 30 local street interchanges including one interchange (Indian Hill Boulevard) in Los Angeles County. Alternative 3 would also require reconstruction of several connectors and interchange ramps to accommodate the I-10 widening.

Local Street Improvements: Eight arterial streets crossing over I-10 would be reconstructed to accommodate the I-10 improvements, as listed below:

1. San Antonio Ave
2. Euclid Avenue
3. Sultana Avenue
4. Campus Avenue
5. 6th St Avenue
6. Vineyard Avenue
7. Richardson Street
8. Tennessee Street

Three arterials parallel to I-10 would be modified as part of the proposed project improvements:

1. Palo Verde Street between Mills Avenue and Monte Vista Avenue
2. 7th Street between Euclid Avenue and Euclid Avenue WB hook ramps intersection
3. J Street between 3rd Street and Pennsylvania Avenue (near Rancho & Colton OH)

Railroad Involvement: Similar to Alternative 2, five railroad crossings over or under I-10 would be impacted by the proposed freeway widening.

Structure Improvements: Alternative 3 would necessitate replacement of 12 structures, widening of 43 structures, partial reconstruction of 4 structures, and construction of tie-back walls at 6 structures. Four structures are also planned to be abandoned in place.

3.0 PHYSICAL SETTING

3.1 Climate

The climate of the site region is semi-arid. The hottest months are July and August when high temperatures average about 98°F and low temperatures average about 60°F. The coolest temperatures are in the winter months of December and January when average highs are in the 65°F range and average low is 36°F.

The extreme high temperatures range from the 80s in the winter months to more than 110°F in July, August, and September. The extreme low temperatures range from about 20°F in December and January to the low 50s in the summer months. Although freezing occurs occasionally on the winter nights, the freezing is generally of short duration (a couple hours) and does not commonly result in a "hard" freeze. Snowfall is rare and has occurred in the winter months, but the snow generally melts the same day it falls.

Annual precipitation is about 11 inches with most of the rain falling between November and March. Monsoon-type thunder showers occasionally occur in the summer and can cause local flash flooding.

3.2 Topography

The I-10 Corridor project area traverses the central part of the Upper Santa Ana River plain (USAR) (Figure 2). The native ground surface along the corridor is flat to very gently undulating. The freeway roadway across this terrain is a mixture of shallow excavated cuts and low embankment fills constructed to form a relatively flat roadway. Elevations in the western end of the corridor are about 1,000 feet and these elevations are maintained from the west end to about Riverside Avenue, where a series of rounded, linear, north- south-trending ridges and swales cross the corridor. These ridges are present to about the Warm Creek bridge. Warm Creek and the adjacent Santa Ana River pass under the freeway in channels that are about 20 to 30 feet below the general level of the plain. East of the Santa Ana River, in the Colton area, elevations rise gently to the Redlands area where elevations culminate at about 1,400 feet. As the I-10 corridor turns southeast through Redlands, elevations raise more abruptly and at Ford Avenue, the eastern end of the project, elevations are about 1,700 feet.

3.3 Regional and Local Geology

3.3.1 Physiography

The project corridor traverses the USAR Valley from the Ontario area to the Redlands area. The USAR Valley is a relatively flat plain that slopes gently southerly from the San Gabriel Mountains within the Western Transverse Ranges physiographic province in the north, to the Perris Highlands (Perris Block) and the Crafton Hills of the Peninsular Ranges physiographic province on the south (Figure 2). The USAR Valley is bounded by the Puente/Chino Hills and San Jose Hills on the west, and by the San Bernardino Mountains on the east. There are a few hills scattered across the USAR plain; these include Red Hill in the northwest, the Norco Hills in the southwest, and the Jurupa Hills in the south-central area. The nearest hill to the project is Slover Mountain, just south of the corridor between Pepper and Rancho Streets. The natural height of Slover Mountain has been reduced substantially due to mining.

The major river in the province is the Santa Ana River, which flows westerly from the San Bernardino Mountains along the southern margin of the USAR Valley. Major tributaries to the Santa Ana River are Lytle Creek and Cajon Wash, which flow from the north; Warm Creek which flows from the San Bernardino Mountains in the east; San Antonio Creek which flows south from the San Gabriel Mountains; and San Timoteo Creek which flows from the south. Other smaller intermittent creeks flow into the USAR from all the surrounding hills and mountains. Most of the natural stream and river channels have been modified to confine flow within concrete and rip-lined aqueducts.

3.3.2 Stratigraphy

The surficial materials along the I-10 corridor project consist of Quaternary alluvial sediments. In the west, the sediments consist of predominantly alluvial fan deposits of sand and gravel with some areas of wind-blown sands that form a veneer over alluvial deposits. Just east of the I-15 interchange, the sediments comprise alluvial fan deposits with local patches of older alluvium that form a series of north-south trending linear ridges. The deposits in the channels of Warm Creek and the Santa Ana River are generally loose sands and gravels deposited on a broad flood plain. East of Santa Ana River, the surficial deposits are young stream-channel and fan alluvium. At Redlands, the surficial materials are generally dense, old alluvium that has been strongly oxidized to reddish-brown colors, hence the name Redlands.

In general, the alluvial deposits along the project corridor consist of loose to compact sand and gravel except for the old alluvium in the Redlands area, which comprises dense to slightly indurated, clay-rich sands with gravel stringers.

The alluvium is underlain by crystalline igneous and metamorphic rocks generally assumed to be Mesozoic age. Based on the data of Dutcher and Garrett (1963) and Fife et al., (1976), the alluvium is about 1,100 feet thick in the west near Haven Avenue and gradually thins to about 900 feet at Sierra Avenue. Alluvium thins easterly from there to about 200 feet thick between Pepper Avenue and Rancho Avenue near the Slover Mountain in the Colton area. Near the Rancho Avenue overcrossing, the alluvium abruptly becomes thickens to 500-600 feet at a ground-water barrier. The thickness of alluvium increases to more than 800 feet at the I-215 interchange, where it crosses several ground-water barriers and increases to 1,000 feet at Richardson Street. The Quaternary alluvium east of I-215 may be underlain by Pliocene-age deposits of the San Timoteo Formation. The thickness remains about 1,000 feet to California

Street, and then thins gradually to 600 feet at the 210 (SR 30) interchange. The thickness then varies from 600 to 800 feet to the end of the project corridor at Ford Street.

The thickness of alluvium and depth to basement rocks increases considerably east of the I-215 Interchange. In contrast to the basement rocks to the west which are primarily igneous rocks, the basement rock in the area to the east is generally Mesozoic metamorphic rocks of Pelona Schist.

3.3.3 Geologic Structure

The major earthquake fault crossing the project corridor is the San Jacinto fault, which trends northwest-southeast across the corridor near the I-215 interchange (Bortugno and Spittler, 1986; Jennings and Bryant, 2010) (Figure 2). Geophysical data (Stephenson et al., 2002; Catchings et al., 2008) indicate a broad rupture zone extending from west of the Santa Ana River to the Loma Linda area. This faulted zone includes the Rialto-Colton fault, the San Jacinto fault, and the Loma Linda fault, as well as several branches and splays of these faults. The Rialto-Colton fault trends northwesterly away from the San Jacinto fault and crosses the project corridor near Mt Vernon Avenue (Figure 2). Geophysical data (Anderson et al., 2004; Catchings et al., 2008) indicate that it is a major basement fault, but there is little surface evidence for the feature to indicate that it has been highly active in late Quaternary time.

The geophysical investigations indicate that there are other faults in the area, but the data are not adequate to allow reliable correlations between geophysical lines. Schell (2008) discovered lineaments associated with active surface faults to the north near the Shandin Hills that project to the southeast and coincide with the geophysical faults, and has suggested the possibility of a significant fault in the central San Bernardino Valley that would cross the project corridor near Waterman Avenue.

A major zone of east-west trending faults, the Crafton Hills fault zone, occurs at the eastern part of the project area (Figure 2). The Crafton Hills fault zone comprises several normal type faults. These include from north to south, the Redlands fault, Reservoir Canyon fault, Yucaipa fault, and Chicken Hill fault. The Redlands fault crosses the project area near Highland Avenue but the others are south of the project.

3.3.4 Geologic Hazards

The shallow groundwater along with the abundance of young cohesionless alluvium within the Santa Ana River Wash led Matti and Carson (1991) to classify the area as having a high to moderately high susceptibility for liquefaction during a large earthquake. The susceptibility is low along most of the rest of the project corridor except perhaps near the small drainages that cross the corridor (e.g. Day Creek, Etiwanda Creek, San Antonio Creek, etc.).

4.0 SEISMICITY

4.1 Seismicity

The site is in seismically active southern California and the project area is near the boundary between the Pacific and the North American tectonic plates. The principal faults of the plate boundary are the San Andreas and San Jacinto fault zones. Seismicity maps indicate several dense clusters of earthquakes in the USAR Valley region, as well as more widely distributed events throughout the region. The main clusters occur: 1) along the southern margin of the San Gabriel Mountains; 2) along the San Jacinto fault in the southern end of the Upper Santa Ana River Valley; 3) near the Shandin Hills; 4) in the Fontana Plain; and 5) in the Crafton Hills area.

A seismicity map of instrumentally recorded earthquakes within the project region is provided in Figure 3. The approximate locations of pre-instrumentally located events that occurred in the years of 1923 and 1899 are included on this seismicity map. It should be noted that the report erroneously gave the date of the 1899 event as 1918. An instrumentally located event that occurred in 1998 near the junction of the San Jacinto fault and the Crafton Hills fault is also shown on this seismicity map.

The largest historical earthquakes in the region have occurred along the San Jacinto fault. During historical times, the San Jacinto fault system may have produced more earthquakes than any other fault in southern California. Since about 1890, as many as eleven earthquakes in the magnitude 6 to 7 range have occurred on the San Jacinto fault. One of the largest earthquakes appears to have been the 1918 event on the San Bernardino Valley segment that had a magnitude of about M ~ 6.8. An earthquake of similar magnitude (M = 6.3) occurred in 1923 at the southern end of the valley (Dozer 1992).

A small earthquake (M=4.5) occurred near the eastern end of the project area in 1998. Although the event was small, it is notable because it yielded a normal-fault focal mechanism, and it may have been associated with the Crafton Hills fault system where it intersects the San Jacinto fault.

The Fontana seismic zone crosses the project corridor between about Etiwanda Avenue and Citrus Avenue. This zone comprises a dense cluster of earthquakes but they are small events (M < 5). Many of the events are shallow (2-3 miles), but there are many deep events (> 10 miles) suggesting that the seismic zone is related to basement-involved tectonic activity.

4.2 Ground Motions

Based on Merriam (2012), several nearby faults are capable of generating relatively significant ground motions within the project area. These faults are listed in Table 1.

Table 1. Summary of Nearby Faults

Fault Name	Style of Fault [1]	Maximum Magnitude (M)
San Jose	SS	6.6
Redhill-Etiwanda Avenue fault	Rev	6.2
Fontana (Seismicity)	SS	6.5
San Jacinto fault (San Bernardino)	SS	7.7
San Jacinto fault (San Bernardino Valley Section)	SS	7.7
Crafton Hills fault	N	6.4
San Andreas fault (San Bernardino S)	SS	7.9
[1] *XX : Unknown; SS: Strike-Slip; Rev: Reverse; N: Normal (Merriam, 2012)*		

To calculate Peak Ground Acceleration (PGA) for liquefaction evaluation and slope stability analysis, acceleration response spectrum (ARS) curves were developed using Caltrans ARS online (Caltrans 2012a and Shantz, 2012) in accordance with the 2013 Seismic Design Criteria (SDC) (Caltrans, 2013a) and Methodology for Developing Design Response Spectrum for Use in Seismic Design Recommendations (Caltrans, 2012c) procedures. We considered the following response spectra. The design ARS curve is the envelope of the following spectra:

- Deterministic Spectrum based on late-Quaternary faults in the 2012 fault database (Caltrans, 2012b and Merriam, 2012).
- Probabilistic Spectrum based on 5% in 50 years probability of exceedance ground motion.
- Minimum Deterministic Spectrum based on a Mw = 6.5 strike-slip event occurring at a distance of 7.5 miles (12 km) from the site.

Results generated by Caltrans ARS Online were verified using the Caltrans Deterministic Response Spectrum Spreadsheet and Probabilistic Response Spectrum Spreadsheet. We used these spreadsheets following the procedures outlined in Methodology for Developing Design Response Spectrum for Use in Seismic Design Recommendations.

Results obtained from the deterministic spreadsheet and the Caltrans ARS Online were compared and the discrepancy was found to be less than 10%. Therefore, in accordance with Methodology for Developing Design Response Spectrum for Use in Seismic Design Recommendations, the deterministic ARS curve developed using the Caltrans ARS Online is acceptable for design.

Spectral acceleration values for the probabilistic response spectrum were calculated using the USGS Interactive Deaggregation Tool (USGS, 2008) for the periods of 0, 0.3, 1.0 and 3.0 seconds. Results obtained from the Caltrans ARS Online and USGS Interactive Deaggregation Tool were compared in the Caltrans Probabilistic Response Spectrum

Spreadsheet, and the discrepancy was found to be less than 10%. Therefore, in accordance with Methodology for Developing Design Response Spectrum for Use in Seismic Design Recommendations, the probabilistic ARS curve developed using the Caltrans ARS Online is acceptable for design.

Using the subsurface information obtained from the available as-built Log-of-Test-Borings (LOTB) sheets, small-strain shear wave velocities (Vs^{30}) were calculated for each structure listed in Section 5.1 using the SPT correlations (Caltrans, 2012c). Preliminary design ARS curves were developed for the calculated Vs^{30} values. The design PGA is the ground acceleration at a spectral period of zero second. The calculated PGA values for the bridge locations within this project limit are provided in Table 2. The maximum and minimum estimated PGA values are 0.899 and 0.632g. The estimated higher PGA values are for structures located at the eastern part of the project corridor (between Rialto Channel RCB Bridge and Redlands Blvd WB Off-Ramp UC), and they ranged from 0.780 to 0.899g.

Table 2. Summary of PGA Estimates

Post Mile	Structure Name	Bridge No.	Calculated PGA
0	Mills Ave UC	54-0453	0.741
0.32	San Antonio Wash Bridge	54-0451	0.738
0.68	Monte Vista Ave UC	54-0450	0.735
1.23	Central Ave UC	54-1186	0.725
1.75	Benson Ave UC	54-0448	0.719
2.37	Mountain Ave UC	54-1187	0.737
2.92	San Antonio Ave OC	54-0446	0.724
3.47	Euclid Ave OC (Route 83/10 Sep)	54-0445	0.703
3.75	Sultana Ave OC	54-0444	0.699
4.02	Campus Ave OC	54-0443	0.704
4.33	6th St OC	54-0442	0.693
4.7	West Cucamonga Channel	54-1117	0.683
4.88	Grove Ave UC	54-0441	0.680
5.24	4th St UC	54-0440	0.653
6.1	Vineyard Ave OC	54-0439	0.637
6.7	Cucamonga Wash Bridge (L/R)	54-0438L/R	0.644
6.8	Holt Blvd Off-Ramp UC (Lt)	54-0437L	0.641
8.16	Haven Ave OC (L/R)	54-1201L/R	0.649
8.16	Haven Ave OC (Rt)	54-0560R	0.649
9.17	Milliken Ave OC	54-0539	0.632
9.98	W10-S15 Bridge over Day Canyon	54-0914F	0.632
10.12	W10-N15 Bridge over Day Canyon	54-0927F	0.642
10.13	Day Canyon Channel Bridge	54-0351	0.643
10.99	Etiwanda Wash Bridge (L/R)	54-0378L/R	0.649
10.99	Etiwanda Wash Bridge (EB Off-Ramp)	54-0378S	0.649

Post Mile	Structure Name	Bridge No.	Calculated PGA
11.5	Valley Blvd EB Off-Ramp UC (Lt)	54-0030L/R	0.661
11.64	Etiwanda-San Sevaine Channel (L/R)	54-0454L/R	0.661
11.64	Etiwanda-San Sevaine Channel (EB On-Ramp)	54-0454S	0.661
11.74	Kaiser Spur OH	54-0416	0.661
19.9	Rialto Channel RCB Bridge	54-1116	0.780
21.46	Slover Mountain UP	54-0835	0.782
21.96	Rancho Ave OC	54-0817	0.826
22.36	Colton OH (R/L)	54-0464R/L	0.835
22.62	La Cadena Dr UC	54-0462	0.864
22.62	La Cadena Dr EB Off-Ramp UC	54-0462S	0.864
22.71	9th St UC	54-0461	0.866
23.6	Warm Creek Bridge (L/R)	54-0830L/R	0.845
23.82	Santa Ana River Bridge (R/L)	54-0292R/L	0.888
24.76	Hunts Ln UC	54-0601	0.896
25.26	Waterman Ave UC	54-0600	0.852
25.54	San Timoteo Creek	54-0599	0.855
26.27	Tippecanoe Ave UC	54-0598	0.899
26.81	Richardson St OC	54-0597	0.847
27.3	Mountain View Ave UC	54-0596	0.870
27.64	West Redlands OH/Mission Channel	54-0570	0.870
28.3	California St UC	54-0595	0.860
28.8	Nevada St UC	54-0594	0.835
29.82	Tennessee St OC	54-0592	0.860
30.38	Texas St UC	54-0583	0.892
33.13	Ford St UC	54-0588	0.856
33.29	Redlands Blvd WB Off-Ramp UC	54-0589	0.821

4.3 Ground Rupture

There has been no ground ruptures related to faulting in the project area in historical time. Trenching studies in the Santa Ana River wash near Hunts Lane by Wesnouski et al., (1991) found evidence of young (Holocene) faulting along the San Jacinto fault indicating a potential for surface ruptures. Aerial photographs indicate that the latest surface ruptures of the San Jacinto fault extends under the embankment fill of the northbound connector to the I-215 from the west bound I-10. The California Geological Survey has established an Alquist-Priolo Earthquake Fault Zone along the surface trace of the latest rupture of the San Jacinto fault, but this zone does not include much of the deformed area indicated by the geophysical data.

A large, east-west trending, surface escarpment represents the Redlands fault near Highland Avenue in Redlands. The height of the feature (>100 feet) indicates a long history of multiple surface ruptures in Quaternary time, but actual ages of that faulting have never been determined. The fault is believed to be a normal fault with the north side faulted down relative to the south side.

As part of the I-10 HOV (Alternative 2) project (EMI, 2009), a fault rupture investigation including aerial photos interpretation and field verification using geophysical survey and/or trenching was conducted by EMI in 2009. The results of this fault rupture investigation were provided in a separate report prepared by EMI (EMI, 2010), which was reviewed and approved by Caltrans. As indicated in this report (EMI, 2010), fault rupture investigation was originally recommended at the following locations to evaluate the presence of active faulting:

- Rancho Avenue OC (54-0817),
- Warm Creek Bridge (54-830R/L),
- Santa Ana River Bridge (54-0929R/L),
- Santa Ana River (55-0292G),
- Richardson Street OC (54-0597), and
- Highland Avenue UC (54-0587R/L).

Later, Caltrans concluded that only Warm Creek Bridge and Highland Avenue UC require a special study and no further work is warranted for the remaining four structures. Based on the detailed geophysical investigations conducted at the Highland Avenue structure, it was concluded that although there were some possible geophysical anomalies at the Highland Avenue site, these features did not project through the overcrossing or its abutments, so no further investigations were done at the site. Geophysical data and trenching study at the Warm Creek site indicated that the fault projects well south of the Warm Creek bridge, therefore it was concluded that there is little potential for fault rupture at the Warm Creek Bridge.

For the I-10 Express Lane (Alternative 3) project where the western limit of the I-10 HOV project was extended from near Haven Avenue to the LA/SB County Line, the proposed structures located within this western extension portion do not fall within an Alquist-Priolo Earthquake Fault Zone or within 1,000 feet of an unzoned fault that is Holocene or younger in age. As a result, further fault studies are not needed per Caltrans Memo to Designer 20-10 (Caltrans, 2013b).

5.0 SUBSURFACE SOIL AND GROUNDWATER CONDITIONS

5.1 Subsurface Soil Conditions

To assess the subsurface conditions within the project limits, the following as-built LOTB sheets were reviewed:

- Mills Ave Undercrossing (Bridge No. 54-0453)

- San Antonio Wash Bridge (Bridge No. 54-0451)
- Monte Vista Ave Undercrossing (Bridge No. 54-0450)
- Central Ave Undercrossing (Bridge No. 54-1186)
- Benson Ave Undercrossing (Bridge No. 54-0448)
- Mountain Ave Undercrossing (Bridge No. 54-1187)
- San Antonio Ave Overcrossing (Bridge No. 54-0446)
- Euclid Ave Overcrossing (Route 83/10 Sep) (Bridge No. 54-0445)
- Sultana Ave Overcrossing (Bridge No. 54-0444)
- Campus Ave Overcrossing (Bridge No. 54-0443)
- 6th St Overcrossing (Bridge No. 54-0442)
- West Cucamonga Channel (Bridge No. 54-1117)
- Grove Ave Undercrossing (Bridge No. 54-0441)
- 4th St Undercrossing (Bridge No. 54-0440)
- Vineyard Ave Overcrossing (Bridge No. 54-0439)
- Cucamonga Wash Bridge (Lt) (Bridge No. 54-0438L)
- Cucamonga Wash Bridge (Rt) (Bridge No. 54-0438R)
- Holt Blvd Off-Ramp Undercrossing (Lt) (Bridge No. 54-0437L)
- Holt Blvd Off-Ramp Undercrossing (Rt) (Bridge No. 54-0437R)
- Haven Ave Overcrossing (Lt) (Bridge No. 54-1201L)
- Haven Ave Overcrossing (Rt) (Bridge No. 54-0560R)
- Milliken Ave Overcrossing (Bridge No. 54-0539)
- Day Canyon Channel Bridge (Bridge No. 54-0351)
- Etiwanda Wash Bridge (Lt) (Bridge No. 54-0378L)
- Etiwanda Wash Bridge (Rt) (Bridge No. 54-0378R)
- Etiwanda Wash Bridge (EB Off-Ramp) (Bridge No. 54-0378S)
- Valley Blvd EB Off-Ramp Undercrossing (Lt) (Bridge No. 54-0030L)
- Valley Blvd EB Off-Ramp Undercrossing (Rt) (Bridge No. 54-0030R)
- Etiwanda-San Sevaine Channel (Lt) (Bridge No. 54-0454L)
- Etiwanda-San Sevaine Channel (Rt) (Bridge No. 54-0454R)
- Etiwanda-San Sevaine Channel (EB On-Ramp) (Bridge No. 54-0454S)
- Kaiser Spur Overhead (Bridge No. 54-0416)

- Cedar Ave Overcrossing (Bridge No. 54-0035)
- Slover Mountain Underpass (Bridge No. 54-0835)
- Rancho Ave Overcrossing (Bridge No. 54-0817)
- Colton Overhead (Rt) (Bridge No. 54-0464R)
- Colton Overhead (Lt) (Bridge No. 54-0464L)
- La Cadena Dr Undercrossing (Bridge No. 54-0462)
- La Cadena Dr EB Off-Ramp Undercrossing (Bridge No. 54-0462S)
- 9th St Undercrossing (Bridge No. 54-0461)
- Mt. Vernon Ave Overcrossing (Bridge No. 54-0459)
- Warm Creek Bridge (Lt) (Bridge No. 54-0830L)
- Warm Creek Bridge (Rt) (Bridge No. 54-0830R)
- Santa Ana River Bridge (Rt) (Bridge No. 54-0292R)
- Santa Ana River Bridge (Lt) (Bridge No. 54-0292L)
- Hunts Ln Undercrossing (Bridge No. 54-0601)
- Waterman Ave Undercrossing (Bridge No. 54-0600)

Locations of the above structures are shown in Figure 4.

In general, the upper subsurface materials along the project corridor consist of loose to medium dense sand, sand with silt, and silty sand. The consistency usually increases with depth and occasional interbedded silt and clay layers and scattered gravel were also encountered. Materials at deeper depths along the project corridor are generally dense to very dense sand, sand with silt, and silty sand with trace to significant amounts of gravel. In addition, some pebbles and cobbles were also encountered within the depths explored.

The above soil descriptions are general and are intended to describe the subsurface in very broad terms. The soil descriptions above should not be construed to indicate that the subsurface profile is uniform and that soil is homogeneous within the project corridor. Soil type and consistency at locations of proposed improvements should be verified by performing additional site-specific exploratory borings during the PS&E phase of the project.

5.2 Groundwater

Groundwater is generally deep along the project corridor. Regional studies (e.g. Fife et al., 1996; Matti and Carson, 1991) indicate groundwater is about 500 feet deep in the western part of the project area. The groundwater becomes shallower to about 100-200 feet in the Pepper-Rancho area and reaches depths as shallow as about 10 feet at the Santa Ana River wash. During the winter and spring rainy seasons, the river bed may be filled with flowing water. The depth to groundwater remains shallow eastward to about the Waterman Avenue area, and then gradually deepens to 75-100 feet from Richardson Street to the Redlands area. At the eastern end of the project, the water becomes shallower again and is about 50 feet deep at Highland Avenue.

5.3 Soil Corrosivity

Corrosion test results are not available; therefore, corrosion potential of on-site soils is not known. A site-specific corrosion study will be performed later during PS&E and mitigation measures will be recommended if the site soils are found to be corrosive to concrete or steel. Based on EMI's experience, clay soils have a higher tendency to be corrosive, whereas sands and silts tend to be non-corrosive.

According to the Caltrans Corrosion Guidelines (2012d), soils are considered corrosive if the pH is 5.5 or less, or chloride content is 500 parts per million (ppm) or greater, or sulfate content is 2,000 ppm or greater.

For preliminary cost estimating purposes, culvert material recommendations are provided in Table 3 for two assumed conditions under non-abrasive conditions with a flow velocity less than 5 fps: (1) non-corrosive soils having a pH equal to 7.0, soluble chloride content less than 500 ppm, soluble sulfate less than 2,000 ppm, and minimum resistivity of 1,500 ohm-cm; and (2) mildly-corrosive conditions assuming soil has a minimum resistivity of 800 ohm-cm, chloride content of 600 ppm, sulfate content of 1,000 ppm, and pH equal to 7.0.

Table 3. Culvert Material Recommendations

Culvert Material	Non-Corrosive Soils	Mildly-Corrosive Soils
Reinforced Concrete Pipe (RCP)	Standard concrete mix design should be suitable for RCP. Type IP (MS) modified cement or Type II modified cement is recommended.	For chloride resistant RCP, a cement content of 23.7 pcf should be used in the mix design. Concrete cover should be a minimum 2 inches.
Corrugated Steel Pipe (CSP)	Minimum 10-gage pipe or 16-gage pipe with bituminous coating on the soil side of the pipe.	Minimum 8-gage pipe or 14-gage pipe with bituminous coating on the soil side of the pipe.
Aluminum or Aluminized Steel Pipe	Aluminum pipe can be used if abrasive conditions do not exist. Aluminized steel pipe can be used.	Should not be used due to corrosive soil conditions.
Plastic Pipe	Plastic pipe may be used; however, abrasion should be evaluated by the project civil engineer.	Plastic pipe may be used; however, abrasion should be evaluated by the project civil engineer.

Notes:
1. Recommendations are for an estimated service life of 50 years.
2. Culvert materials were determined using the CULVERT4 computer program developed by Caltrans.

The termini of any plastic pipes should be protected from potential physical or fire damage such as by constructing concrete headwalls, or by concrete or metal treatment. The above corrosivity recommendations are only for corrosion and the culvert may require additional thickness for strength, overfill or higher flow velocities.

If corrosive soils are found near foundations of bridges and walls, reinforced concrete (included piles) requires corrosion mitigation in accordance with Bridge Design Specifications, Article 8.22; when steel piles are specified, sacrificial corrosion allowance is required per Caltrans Corrosion Guidelines (2012d).

6.0 MATERIAL SOURCES

Numerous commercial suppliers for sand, gravel, aggregate base, and concrete are located in the San Bernardino and Riverside counties, which will be identified during PS&E phase of the project. Pulverizing existing pavement, during construction, might be performed. Pulverized AC material (or Reclaimed Asphalt Pavement – RAP) can be used as aggregate base (AB) provided the material meets the quality requirements of AB specified in Section 26 “Aggregate Bases” of the Caltrans Standard Specifications (2010). Pulverized AC material may also be used within Aggregated Subbase (AS), if it meets the requirements of Section 25 “Aggregate Subbases” of the Caltrans Standard Specifications (2010). Pulverized AC material may also be used within certain Hot Mix Asphalt (HMA) mixes, such as HMA Type A, if pulverized AC material and its processing complies with Standard Special Provision (SSP) # S1-020H.

7.0 MATERIAL DISPOSAL

According to the civil designer, import material will most likely be required to achieve proposed grades. Therefore, disposal of on-site soils is not anticipated (from a geotechnical standpoint).

8.0 CONCLUSIONS AND RECOMMENDATIONS

8.1 Earthwork

Earthwork should be conducted in accordance with Section 19 of the latest Caltrans Standard Specifications. In areas where compacted fill will be placed, removal of compressible surficial materials including topsoil, loose or soft alluvium or fill soil, dry or saturated soil, and unsuitable fill is required prior to fill placement. A minimum overexcavation of 2 feet is recommended within areas to receive fill; the overexcavation should extend horizontally a minimum distance of 2 feet from edges of new fills or structures. Fill placed on sloping ground should be properly keyed and benched into existing ground and placed as specified in Section 19-6 of the Caltrans Standard Specifications (2010). Overexcavations should be observed by qualified geotechnical personnel to verify that firm and unyielding bottoms are exposed. Overexcavated areas should be cleaned of loose soils and debris and should be observed to be firm and unyielding before receiving fill. These on-site materials can be excavated using conventional heavy-duty earth-moving equipment and the materials are not expected to pose a rippability problem.

8.2 Soil Expansion Potential

On-site soils are expected to have an expansion potential varying from non-expansive to very low. However, there may be localized, discontinuous clayey sand and sandy lean clay soils, which can exhibit expansion potential ranging from low to medium. Soils having high or very high expansion potential are not anticipated within the project area.

8.3 Soil Erosion Potential

In general, the erosion potential of soils is expected to be minor to moderate considering the provisions for site drainage, slope planting and other measures required by Caltrans. In order to minimize potential erosion, all finish slopes should be planted as soon as practical after grading.

8.4 Liquefaction Potential and Seismically-Induced Settlement

Liquefaction is the loss of shear strength in generally cohesionless, saturated soils when the pore-water pressure induced in the soil by a seismic event becomes equal to or exceeds the overburden pressure. Primary factors influencing liquefaction potential include: groundwater elevation, soil type and grain-size distribution, relative density of soil, initial confining pressure, and intensity and duration of ground shaking. Soils most susceptible to liquefaction are saturated low-density sands and silty sands within top 50 feet of the ground surface.

Soil liquefaction assessments were conducted for all the bridge sites listed in Section 5.1. Results of our assessment show that only five bridges (Warm Creek, Santa Ana River, Waterman Avenue UC, San Timoteo Creek, and San Timoteo Creek On-Ramp Bridges) are founded on a potentially liquefiable site. For these five bridges, seismically-induced settlement was calculated and the maximum magnitude was determined to be about 3 inches. The seismically-induced settlement calculations are included in Appendix C.

The liquefaction potential and resulting seismically-induced settlement should be confirmed during the PS&E phase using site-specific subsurface data.

8.5 Embankment Settlement

The project involves constructing new earthen embankments for median lanes and widening existing embankments to create new alignments and configurations. The proposed embankments are anticipated to be up to about 30 feet high.

Because the subsurface soils are predominantly granular, the soils are not expected to undergo large consolidation settlement (settlement over long periods of time). However, the soils can undergo “immediate” elastic settlement, which usually occurs during earthwork activities and shortly thereafter. For new embankments and the proposed widening of existing embankments, total settlement estimates are summarized in Table 4. Linear interpolation can be used for settlements of other embankment heights within the tabulated range.

Table 4. Summary of Total Settlement Estimates

Embankment Height (feet)	Approximate Total Settlement (inches)
3	0.75
5	1.1
10	1.8
15	2.3
20	2.8
25	3.2
30	3.6

8.6 Stability of Embankment Slopes

Per Topic 304 of Caltrans HDM (2012e), 4H:1V side slopes or flatter should be used where possible. These side slopes will be globally and surficially stable. Caltrans design exception and approval process will be required for side slopes with gradients steeper than 4H:1V. However, proper maintenance with erosion protection and drainage control in accordance with Section 21 of Caltrans Standard Specifications (2010) are still recommended for long-term performance.

Assuming the earthen embankments will be constructed using compacted fill having a minimum friction angle of 32 degrees and minimum cohesion of 200 psf, slopes up to 30 feet high and with inclinations of 2H:1V or flatter are expected to be globally stable (i.e., minimum factor-of-safety is 1.5 and 1.1 under static and pseudo-static conditions, respectively).

In addition, using a minimum friction angle of 32 degrees and minimum cohesion of 200 psf, slopes with inclinations of 2H:1V or flatter are expected to be surficially stable based on the infinite slope method. Shear strength parameters or fines content and plasticity of soils that will be used to construct the earthen embankments will need to be verified during construction.

8.7 Earth Retaining Structures

Cantilevered retaining walls are proposed at various locations throughout the project including along the on- and off-ramps. Retaining walls are proposed to be standard Caltrans retaining walls. However, other types will be investigated during the PS&E phase. Based on the subsurface information shown on the available as-built LOTB sheets, spread footings are suitable for supporting standard Caltrans retaining walls with heights equal to or less than 20 feet. Pile foundation might be required to support taller retaining walls. Some amount of remedial earthwork below the proposed spreading footings to remove loose near-surface soils should be anticipated; remedial overexcavations will most likely be less than 3 feet.

8.8 Hazardous Waste Considerations

If for any reason hazardous or toxic materials are believed to exist within the project area, an environmental specialist should be consulted.

8.9 Supplemental Geotechnical Investigations

EMI recommends performing numerous exploratory borings throughout the project area, during the PS&E phase of the project, to investigate site-specific soils and conditions and to collect samples of subsurface soils for laboratory testing. The locations and depths of the borings should be selected once locations of proposed improvements have been finalized.

Soil samples recovered during the supplemental field investigation should be tested to determine soil type, soil shear strength, compressibility characteristics, and corrosion potential.

9.0 LIMITATIONS

This DPGR is intended for use by Parsons, SANBAG and Caltrans for proposed improvements for the I-10 Corridor Project. This report is based on the project as described herein and available as-built subsurface information. Soils and subsurface conditions described in the as-built exploratory borings are presumed to be representative of the project site; however, subsurface conditions and characteristics of soils between exploratory borings can vary.

The data, opinions, and recommendations contained herein are applicable to the project which is the subject of this report. Data, opinions, and recommendations herein have no applicability to any other design elements or to any other locations, and any and all subsequent users accept any and all liability resulting from any use or reuse of the data, opinions, and recommendations without the prior written consent of EMI.

Services performed by EMI were conducted in a manner consistent with that level of care and skill ordinarily exercised by members of the profession currently practicing in the same locality under similar conditions. No other representation, expressed or implied, and no warranty or guarantee is included or intended.

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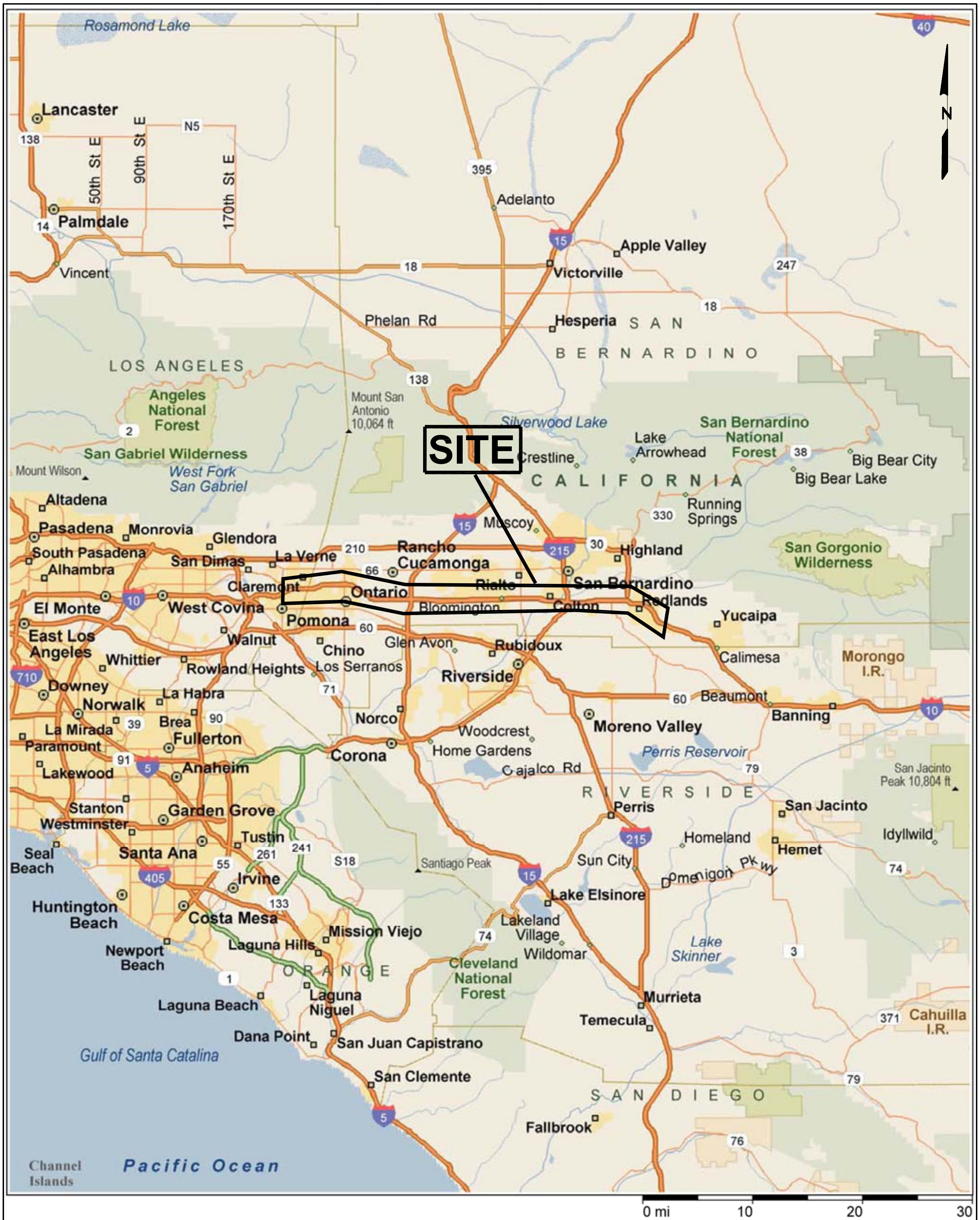


Earth Mechanics, Inc.

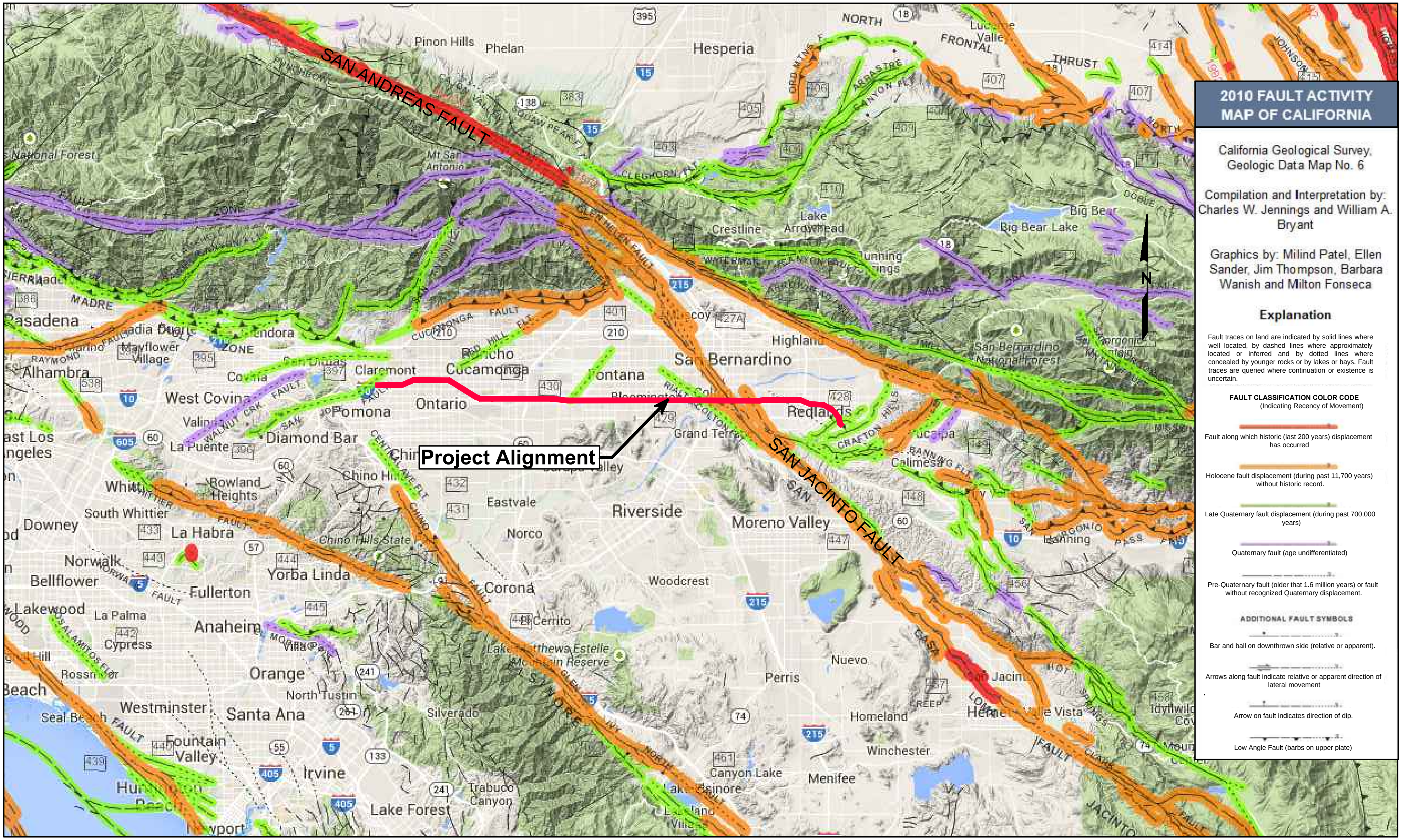
Geotechnical & Earthquake Engineering

SITE LOCATION MAP

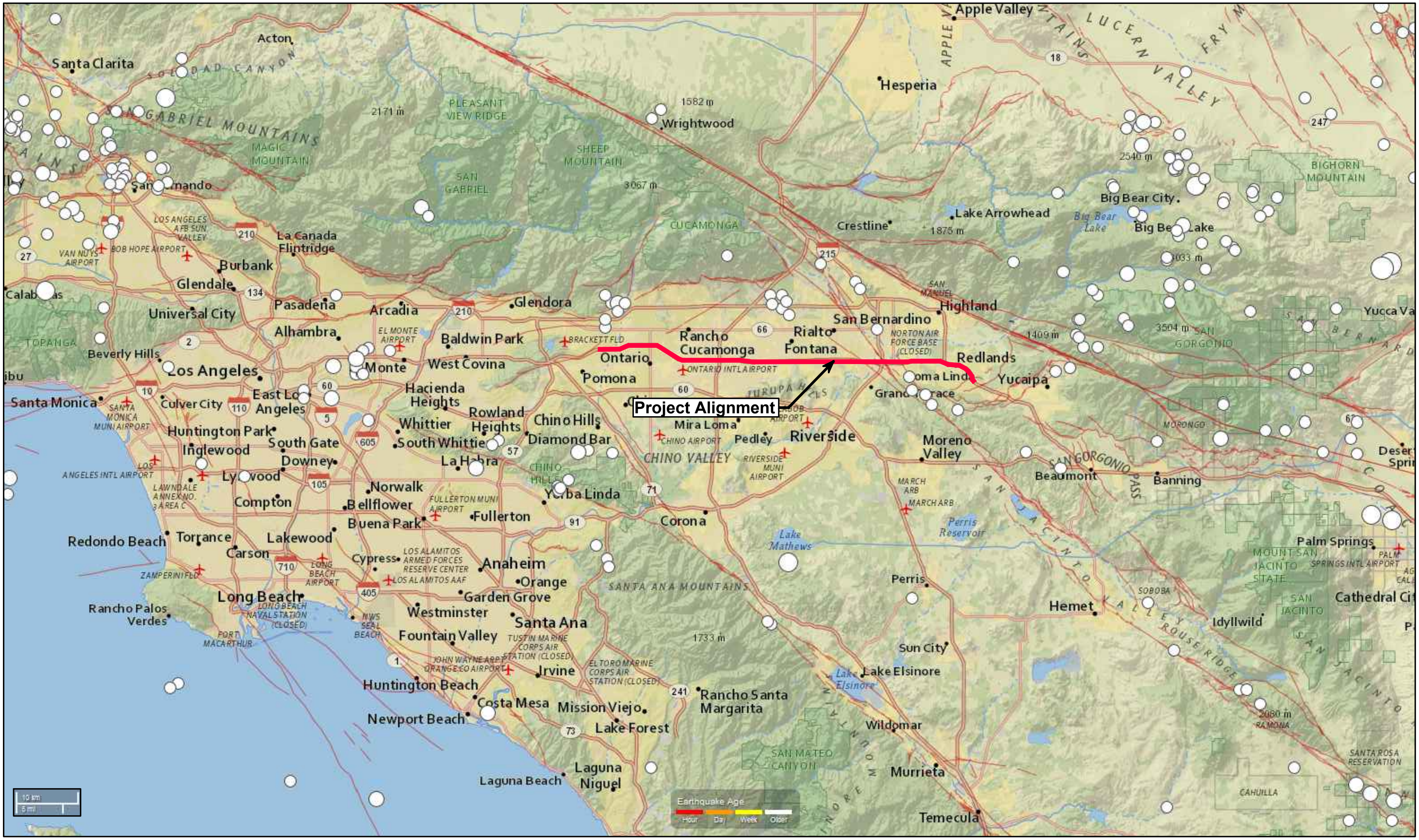
Figure 1

I-10 CORRIDOR PROJECT

Project No. 08-103 **Date:** 01-07-2015



Earth Mechanics, Inc. Geotechnical and Earthquake Engineering	**I-10 Corridor Project**	Regional Physiography and Fault Map
	Project No. 08-103 / Date: 01-07-2015	Figure 2



Earthquake Magnitude
= 6
= 5
= 4

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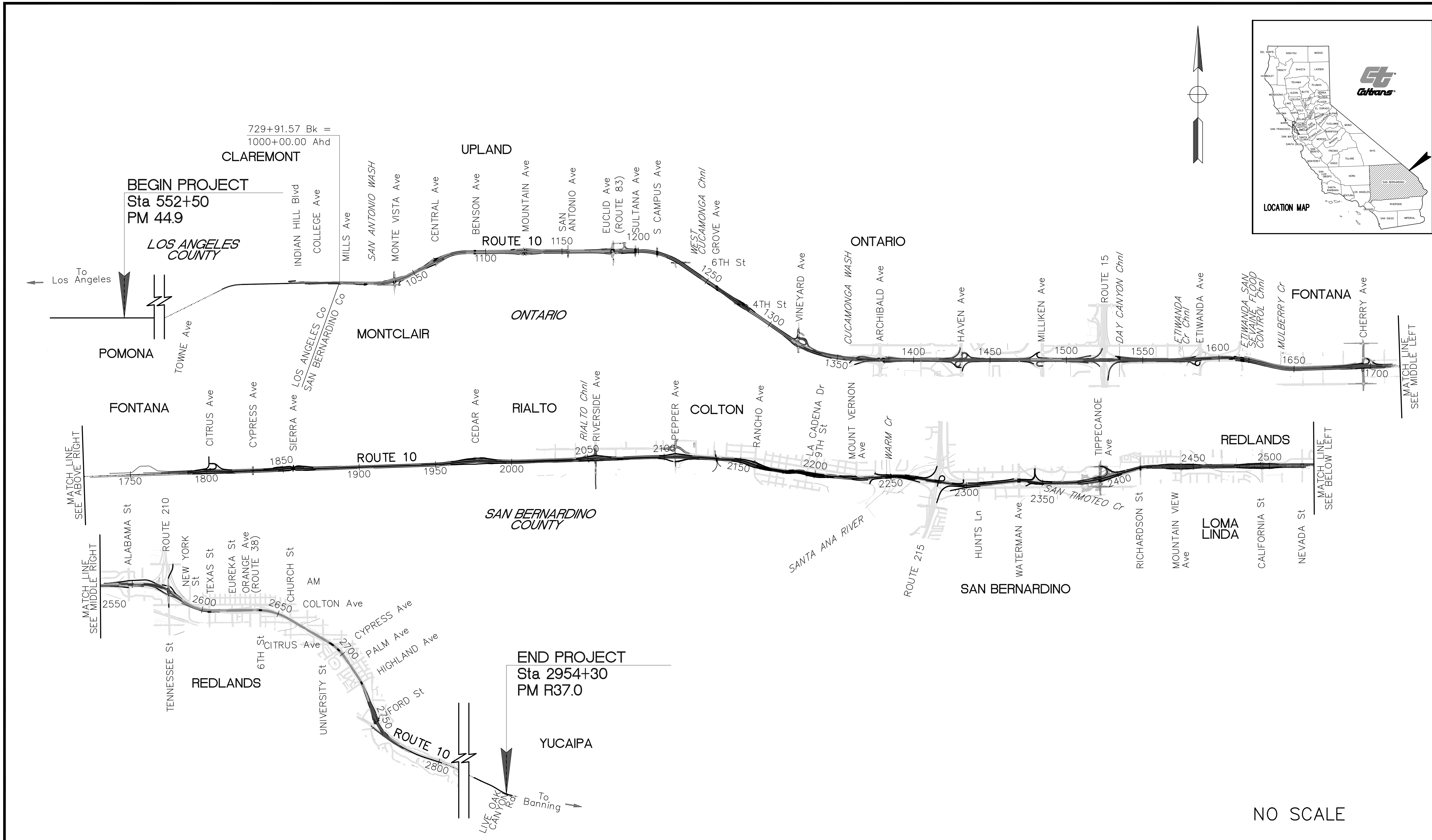
I-10 Corridor Project

Project No. 08-103

Date: 01-07-2015

Recorded Earthquake Map

Figure 3



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I-10 CORRIDOR PROJECT

EMI Project No. 08-103

Date: 01-07-2015

Bridge Location Map

Figure 4

APPENDIX A

DPGR, DATED JANUARY 12, 2009, PREPARED BY EMI FOR I-10 HOV PROJECT

AND CALTRANS APPROVAL LETTER

DEPARTMENT OF TRANSPORTATION
PROGRAM PROJECT MANAGEMENT (MS 1229)
464 W. FOURTH STREET, 6TH FLOOR
SAN BERNARDINO, CA 92401-1400
PHONE (909) 659-7483
FAX (909) 383-6899
TTY (909) 383-6300

Flex your power!
Be energy efficient!

March 12, 2009

Ms. Marie Marston
Segment Manager
San Bernardino Associated Government
1170 West Third Street, Second Floor
San Bernardino, CA 92410-1715

File: 08-SBd-10-PM 8.20/33.43
Ontario to Redlands, from Haven Avenue
to Ford Street Undercrossing
08-224-0C2500

Dear Ms Marston:

District Preliminary Geotechnical Report

We have reviewed the District Preliminary Geotechnical Report (DPGR) received on January 26, 2009 for the Interstate10 (I-10) / High Occupancy Vehicle (HOV) Lane Addition project located between Haven Avenue in the City of Ontario and Ford Street in the City of Redlands, County of San Bernardino. We now concur with the DPGR, with further implementation of the presented methodology in the Geotechnical Design Report (GDR-PS&E Stage). We look forward to reviewing the GDR in the future.

If you have any questions regarding these comments, please contact me at (909) 659 7483.

Sincerely,

Mark Lancaster

MARK LANCASTER
Project Manager
Program/Project Management

c: David Speirs, Parsons

Earth Mechanics, Inc.
Geotechnical & Earthquake Engineering

January 12, 2009

EMI Project No. 08-103

PARSONS
2201 Dupont Drive, Suite 200
Irvine, California 92612

Attention: Mr. David Speirs

Subject: ***District Preliminary Geotechnical Report***
I-10 HOV Project
San Bernardino County, California
08-SBd-10-PM 8.20/33.43, EA 0C2500

Dear Mr. Speirs:

Attached is the District Preliminary Geotechnical Report (DPGR) for the I-10 HOV Project. The report is intended to provide preliminary geotechnical information to assist Parsons in preparing the preliminary cost estimate for the project.

Conclusions and recommendations given in this report are based on available as-built subsurface soil information. Conclusions and recommendations are considered preliminary and should be verified in the future by conducting additional site-specific geotechnical field investigations, laboratory soil testing, and analyses.

An earlier version of District Preliminary Geotechnical Report, dated July 15, 2008, was prepared by EMI and reviewed by Caltrans. A copy of the review sheet and EMI responses are attached in Appendix A of this report. This report has been revised to incorporate our responses to those review comments.

We appreciate the opportunity to provide geotechnical services for the project. If you have any questions please call us.

Sincerely,
EARTH MECHANICS, INC.

REGISTERED PROFESSIONAL ENGINEER
CHIEN-TAI YANG
NO. C66374
EXP. 06-30-2010
CIVIL
STATE OF CALIFORNIA

Chien-Tai Yang, CE 66374
Project Engineer

REGISTERED PROFESSIONAL ENGINEER
LINO C. CHEANG
NO. GE 2345
EXP. 9/30/09
GEOTECHNICAL
STATE OF CALIFORNIA

Lino Cheang, GE 2345
Project Manager

DISTRICT PRELIMINARY GEOTECHNICAL REPORT
I-10 HOV PROJECT
SAN BERNARDINO COUNTY, CALIFORNIA
08-SBd-10-PM 8.20/33.43, EA 0C2500

Prepared for:

PARSONS
2201 Dupont Drive, Suite 200
Irvine, California 92612

Prepared by:

Earth Mechanics, Inc.
17660 Newhope Street, Suite E
Fountain Valley, California 92708

EMI Project Number: 08-103

January 12, 2009

Earth Mechanics, Inc.
Geotechnical & Earthquake Engineering

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APPENDIX

1.0 INTRODUCTION

This District Preliminary Geotechnical Report (DPGR) presents findings and conclusions of a geotechnical study conducted by Earth Mechanics, Inc. (EMI) for proposed improvements at the Interstate-10 (I-10) HOV project located in San Bernardino County. The project location is shown on the Site Location Map (Figure 1). The purpose of this report is to provide preliminary geotechnical information to assist Parsons in preparing the preliminary engineering plans and cost estimates. Pavement recommendations are addressed in the Preliminary Materials Memorandum (EMI, 2008).

2.0 EXISTING FACILITIES AND PROPOSED IMPROVEMENTS

The San Bernardino Associated Governments (SANBAG), in cooperation with the California Department of Transportation (Caltrans) District 8, is proposing to construct high occupancy vehicle (HOV) lanes along Interstate 10 (I-10) in the Cities of Ontario, Fantana, Rialto, Colton, San Bernardino, Loma Linda and Redlands. This project is about 25 miles long from post-mile 8.20 to 33.43. I-10 in the project area trends in an east-west direction and carries traffic from Los Angeles County, through San Bernardino and Riverside Counties and towards the California/Arizona border. The affected bridges within this contract limit are listed below and shown in Figure 2.

- Milliken Avenue Overcrossing (Bridge No. 54-0539),
- Day Canyon Channel Bridge (Bridge No. 54-0351),
- Etiwanda Wash Bridge (Bridge No. 54-0378 L/R/S),
- Etiwanda Avenue Overcrossing (Bridge No. 54-0563),
- Valley Boulevard Off-Ramp Undercrossing (Bridge No. 54-0030 L/R),
- Etiwanda-San Sevaine Flood Control Channel Bridge (Bridge No. 54-054 L/R/S),
- San Sevaine Creek Bridge (Bridge No. 54-0434),
- Kaiser Spur Overhead (Bridge No. 54-0416),
- Mulberry Creek Bridge (Bridge No. 54-0425M),
- Pepper Avenue Overcrossing (Bridge No. 54-0539),
- Slover Mountain Underpass (Bridge No. 54-0835),
- Colton Overhead (Bridge No. 54-0464 L/R),
- La Cadena Drive Undercrossing (Bridge No. 54-0462),
- La Cadena Drive Undercrossing – EB Off-Ramp (Bridge No. 54-0462S),
- Ninth Street Undercrossing (Bridge No. 54-0461),
- Pavillion Spur Overhead (Bridge No. 54-0460),
- Mount Vernon Avenue Overcrossing (Bridge No. 54-0459),
- Warm Creek Bridge (Bridge No. 54-0830 L/R),
- Santa Ana River Bridge (Bridge No. 54-0292 L/R),
- Hunt Lane Undercrossing (Bridge No. 54-0601),
- Waterman Avenue Undercrossing (Bridge No. 54-0600),
- San Timoteo Creek Bridge (Bridge No. 54-0599),
- San Timoteo Creek Bridge – W10 On-Ramp (Bridge No. 54-1105K),

- Richardson Street Overcrossing (Bridge No. 54-0597),
- Mountain View Avenue Undercrossing (Bridge No. 54-0596),
- West Redlands Overhead (Bridge No. 54-0570),
- California Street Undercrossing (Bridge No. 54-0595),
- Nevada Street Undercrossing (Bridge No. 54-0595),
- Alabama Street Undercrossing (Bridge No. 54-0593),
- Tennessee Street Overcrossing (Bridge No. 54-0592),
- E30-E10 Connector Overcrossing (Bridge No. 54-0929G),
- Colton and New York Avenue Undercrossing (Bridge No. 54-0591),
- Texas Street Undercrossing (Bridge No. 54-0583),
- Eureka Street Undercrossing (Bridge No. 54-0580),
- Interstate 10/State Route 38 Separation (Bridge No. 54-0581),
- Sixth Street Undercrossing (Bridge No. 54-0579L/R),
- Church Street Undercrossing (Bridge No. 54-0578L/R),
- Redlands Overhead (Bridge No. 54-0572L/R),
- University Street Undercrossing (Bridge No. 54-0582L/R),
- Citrus Avenue Undercrossing (Bridge No. 54-0584L/R),
- Palm Avenue Undercrossing (Bridge No. 54-0586L/R),
- Highland Street Undercrossing (Bridge No. 54-0587L/R),
- Ford Street Undercrossing (Bridge No. 54-0588L/R), and
- Redlands Blvd Off-Ramp Undercrossing (Bridge No. 54-0589L/R).

In addition to the “No Build” alternative (Alternative 1), two other alternatives are currently under consideration:

- Alternative 2 (Full Standard Alternative) would provide an HOV lane in each direction of I-10 with a standard 10-ft inside shoulder and a standard 4-foot carpool lane buffer. It will results in widening of some bridges and reconstruction of some overcrossings.

- Alternative 3 (Reduced Standard Alternative) is similar to the Full Standard Alternative, but proposes the non-standard shoulder widths where constraints such as existing bridge columns and abutments do not allow a full standard shoulder. The non-standard shoulder widths would vary between 1 and 9 feet.

The significant improvements for the proposed project include:

- construction of HOV lanes,
- construction of a concrete median barrier,
- addition of California Highway Patrol enforcement areas,
- construction of retaining walls and ramp work.
- addition of auxiliary lanes at some locations, and
- other corridor improvements such as construction of draining facilities.

There are ramp work and new retaining walls for this project. At this time, a noise study is being conducted to determine if new sound walls will be required. Most of ramp work is widening the existing ramp from one lane to two lanes. Locations of ramp work are listed below:

- Haven Avenue Eastbound (EB) On-Ramp and Westbound (WB) Off-Ramp
- Milliken Avenue WB and EB On-Ramp
- Etiwanda Avenue EB Off-Ramp
- Sierra Avenue EB Off-Ramp
- Pepper Avenue EB On- and Off-Ramps and WB On- and Off-Ramps
- Rancho Avenue EB On- and Off-Ramps and WB Off-Ramp
- Ninth Street EB On-Ramp
- Mt. Vernon Avenue EB Off-Ramp
- Waterman Avenue EB On-Ramp and WB On-Ramp
- Tippecanoe Avenue EB On-Ramp
- Richardson Street EB On-Ramp
- Mountain View Avenue EB On- and Off-Ramps and WB On- and Off-Ramps
- Eureka Street WB On-Ramp
- Sixth Street EB On-Ramp
- West Redland Overhead EB On-Ramp
- California Street EB On- and Off-Ramps
- Palm Avenue EB On-Ramp
- Ford Street EB Off-Ramp

Locations of proposed retaining walls are listed below:

- Haven Avenue WB Off-Ramp
- Cherry Avenue EB Off-Ramp
- Sierra Avenue EB Off-Ramp
- Cedar Avenue EB On- and Off-Ramps
- Pepper Avenue EB Off-Ramp and WB On-Ramp
- Rancho Avenue EB On-Ramp
- La Cadena Drive EB Off-Ramp
- EB Mainline near Ninth Street
- Mountain Vernon Avenue EB Off-Ramp and WB On- and Off-Ramps
- Hunt Lane EB On- and Off-Ramps
- Waterman Avenue EB On- and Off-Ramps
- EB and WB Mainlines near Mountain View Avenue
- West Redland Overhead EB On-Ramp
- EB and WB Mainlines near California Street and California Street EB On- and Off-Ramps
- EB Mainline near Nevada Street
- Alabama Street EB Off-Ramp
- Palm Avenue EB On- and Off-Ramps and WB On- and Off-Ramps
- EB Mainline near Highland Avenue
- Ford Street EB Off-Ramp and WB On-Ramp

3.0 PHYSICAL SETTING

3.1 Climate

The climate of the site region is semi arid. The hottest months are July and August when high temperatures average about 98°F and low temperatures average about 60°F. The coolest temperatures are in the winter months of December and January when average highs are in the 65°F range and average low is 36°F.

The extreme high temperatures range from the 80s in the winter months to more than 110°F in July, August, and September. The extreme low temperatures range from about 20°F in December and January to the low 50s in the summer months. Although freezing occurs occasionally on the winter nights, the freezing is generally of short duration (a couple hours) and does not commonly result in a "hard" freeze. Snowfall is rare and has occurred in the winter months, but the snow generally melts the same day it falls.

Annual precipitation is about 11 inches with most of the rain falling between November and March. Monsoon-type thunder showers occasionally occur in the summer and can cause local flash flooding.

3.2 Topography

The I-10 HOV project area traverses the central part of the Upper Santa Ana River plain (USAR) (Figure 3). The native ground surface along the corridor is flat to very gently undulating. The freeway roadway across this terrain is a mixture of shallow excavated cuts and low embankment fills constructed to form a relatively flat roadway. Elevations in the western end of the corridor are about 1,000 feet and these elevations are maintained from the west end to about Riverside Avenue where a series of rounded, linear, north- south-trending ridges and swales cross the corridor. These ridges are present to about the Warm Creek bridge. Warm Creek and the adjacent Santa Ana River pass under the freeway in channels that are about 20 to 30 feet below the general level of the plain. East of the Santa Ana River, in the Colton area, elevations rise gently to the Redlands area where elevations culminate at about 1400 feet. As the I-10 corridor turns southeast through Redlands, elevations rise more abruptly and at Ford Avenue, the end of the project, elevations are about 1700 feet.

3.3 Regional and Local Geology

3.3.1 Physiography

The project corridor traverses the USAR Valley from the Ontario area to the Redlands area. The USAR Valley is a relatively flat plain that slopes gently southerly from the San Gabriel Mountains within the Western Transverse Ranges physiographic province in the north, to the Perris Highlands (Perris Block) and the Crafton Hills of the Peninsular Ranges physiographic province on the south (Figure 3). The USAR Valley is bounded by the Puente/Chino Hills and San Jose Hills on the west, and by the San Bernardino Mountains on the east. There are a few hills scattered across the USAR plain; these include Red Hill in the northwest, the Norco Hills in the southwest, and the Jurupa Hills in the south-central area. The nearest hill to the project is Slover Mountain just south of the corridor between Pepper and Rancho Streets. The natural height of Slover Mountain has been reduced substantially due to mining.

The major river in the province is the Santa Ana River which flows westerly from the San Bernardino Mountains along the southern margin of the USAR Valley. Major tributaries to the Santa Ana River are Lytle Creek and Cajon Wash which flow from the north, Warm Creek which flows from the San Bernardino Mountains in the east, and San Timoteo Creek which flows from the south. Other smaller intermittent creeks flow into the USAR from all the surrounding hills and mountains. Most of the natural stream and river channels have been modified to confine flow within concrete and rip-lined aqueducts.

3.3.2 Stratigraphy

The surficial materials along the I-10 corridor consist of Quaternary alluvial sediments. In the west, the sediments are wind-blown sands that form a veneer over alluvial fan deposits of sand and gravel. Just east of the I-15 interchange, the sediments comprise alluvial fan deposits with local patches of older alluvium that form a series of north-south trending linear ridges. The deposits in the channels of Warm Creek and the Santa Ana River are loose sands and gravels deposited on a broad flood plain. East of Santa Ana River, the surficial deposits are young stream-channel and fan alluvium. At Redlands, the surficial materials are generally dense, old alluvium that has been strongly oxidized to reddish-brown colors, hence the name red lands.

In general, the alluvial deposits along the corridor consist of loose to compact sand and gravel except for the old alluvium in the Redlands area which comprises dense to slightly indurated, clay-rich sands with gravel stringers.

The alluvium is underlain by crystalline igneous and metamorphic rocks generally assumed to be Mesozoic age. Based on the data of Dutcher and Garrett (1963) and Fife et al. (1976), the alluvium is about 1,100 feet thick in the west near Haven Avenue and gradually thins to about 900 feet at Sierra Avenue. Alluvium thins easterly from there to about 200 feet thick between Pepper Avenue and Rancho Avenue near the Slover Mountain in the Colton area. Near the Rancho Avenue overcrossing, the alluvium abruptly becomes thickens to 500-600 feet at a ground-water barrier. The thickness of alluvium increases to more than 800 feet at the I-215 interchange where it crosses several ground-water barriers and increases to 1,000 feet at Richardson Street. The Quaternary alluvium east of I-215 may be underlain by Pliocene-age deposits of the San Timoteo Formation. The thickness remains about 1,000 feet to California Street, and then thins gradually to 600 feet at the 210 (SR 30) interchange. The thickness then varies from 600 to 800 feet to the end of the project corridor at Ford Street.

The thickness of alluvium and depth to basement rocks increases considerably east of the 215 Interchange. In contrast to the basement rocks to the west which are primarily igneous rocks, the basement rock in the area to the east is generally Mesozoic metamorphic rocks of Pelona Schist.

3.3.3 Geologic Structure

The major earthquake fault crossing the project corridor is the San Jacinto fault which trends northwest-southeast across the corridor near the I-215 interchange (Bortugno and Spittler, 1986; Jennings, 1994) (Figure 3). Geophysical data (Stephenson et al., 2004; Catchings et al., 2008) indicate a broad rupture zone extending from west of the Santa Ana River to the Loma Linda area. This faulted zone includes the Rialto-Colton fault, the San Jacinto fault, and the Loma Linda fault, as well as several branches and splays of these faults. The Rialto-Colton fault trends northwesterly away from the San Jacinto fault and crosses the project corridor near Mt Vernon Avenue (Figure 3). Geophysical data (Anderson et al., 2004; Catchings et al., 2008) indicate that it is a major basement fault, but there is little surface evidence for the feature to indicate that it has been highly active in late Quaternary time.

The geophysical investigations indicate that there are other faults in the area, but the data are not adequate to allow reliable correlations between geophysical lines. Schell (2008) discovered lineaments associated with active surface faults to the north near the Shandin Hills that project to the southeast and coincide with the geophysical faults, and has suggested the possibility of a significant fault in the central San Bernardino Valley that would cross the project corridor near Waterman Avenue.

No geologic structures are known to be associated with the Fontana seismic zone, but the area has not been investigated in detail.

A major zone of east-west trending faults, the Crafton Hills fault zone, occurs at the eastern part of the project area (Figure 3). The Crafton Hills fault zone comprises several normal type faults. These include from north to south, the Redlands fault, Reservoir Canyon fault, Yucaipa fault, and Chicken Hill fault. The Redlands fault crosses the project area near Highland Avenue but the others are south of the project.

3.3.4 Geologic Hazards

The shallow groundwater along with the abundance of young cohesionless alluvium within the Santa Ana River Wash led Matti and Carson (1991) to classify the area as having a high to moderately high susceptibility for liquefaction during a large earthquake. The susceptibility is low along most of the rest of the project corridor except perhaps near the small drainages that cross the corridor (e.g. Day Creek, Etiwanda Creek, etc.).

4.0 SEISMICITY

4.1 Seismicity

The site is in seismically active southern California and the project area is near the boundary between the Pacific and the North American tectonic plates. The principal faults of the plate boundary are the San Andreas and San Jacinto fault zones. Seismicity maps indicate several dense clusters of earthquakes in the USAR Valley region, as well as more widely distributed events throughout the region. The main clusters occur 1) along the southern margin of the San

Gabriel Mountains, 2) along the San Jacinto fault in the southern end of the Upper Santa Ana River Valley, 3) near the Shandin Hills, 4) in the Fontana Plain, and 5) in the Crafton Hills area.

A seismicity map of instrumentally recorded earthquakes within the project region is provided in Figure 4. The approximate locations of pre-instrumentally located events that occurred in the years of 1923 and 1899 are designated by circles with the numbers 23 and 99, respectively. Note that the report erroneously gave the date of the 1899 event as 1918. An instrumentally located event that occurred in 1998 near the junction of the San Jacinto fault and the Crafton Hills fault is also shown and designated by the number 98 within a circle.

The largest historical earthquakes in the region have occurred along the San Jacinto fault. During historical times, the San Jacinto fault system may have produced more earthquakes than any other fault in southern California. Since about 1890, as many as eleven earthquakes in the magnitude 6 to 7 range have occurred on the San Jacinto fault. One of the largest earthquake appears to have been the 1918 event on the San Bernardino Valley segment that had a magnitude of about M ~ 6.8. An earthquake of similar magnitude (M = 6.3) occurred in 1923 at the southern end of the valley (Dozer 1992).

A small earthquake (M= 4.5) occurred near the eastern end of the project area in 1998. Although the event was small, it is notable because it yielded a normal-fault focal mechanism, and it may have been associated with the Crafton Hills fault system where it intersects the San Jacinto fault.

The Fontana seismic zone crosses the project corridor between about Etiwanda Avenue and Citrus Avenue. This zone comprises a dense cluster of earthquakes but they are small events (M < 5). Many of the events are shallow (2-3 miles), but there are many deep events (> 10 miles) suggesting that the seismic zone is related to basement-involved tectonic activity.

4.2 Ground Motions

Based on Mualchin (1996a), several nearby faults are capable of generating relatively significant ground motions within the project area. These faults are listed in the following table:

Fault Name	Style of Fault[(1)]	Maximum Magnitude (M)
Redhill-Etiwanda Avenue fault (RHE)	XX	7.0
Rialto-Colton-Claremont (RCC)	XX	6.75
San Jacinto fault (SJO)	ST	7.5
Crafton Hills fault (CRH)	XX	6.5
San Andreas fault (SAC)	ST	8.0
Note: (1) XX : Unknown; ST: Strike-Slip (After Mualchin, 1996a)		

According to Mualchin (1996a), the RHE, RCC and CRH style of fault is unknown. The RHE fault is assumed to be a reverse-thrust fault (detailed explanation can be referred to EMI responses to Comment 13 in Appendix A). The RCC and CRH faults are found to be normal faults by Schell (2008) and Anderson et. al. (2004). Since Sadigh et. al. (1997) concluded that there is no significant different in their ground motion model between normal and strike-slip faulting, these faults (RCC and CRH) are assumed to be strike-slip.

Peak Bedrock Accelerations (PBA) were determined using the above styles of fault, the tabulated maximum earthquake magnitudes and distances extracted from the Caltrans Seismic Hazard Map (Mualchin, 1996b). Both the Mualchin (1996a) and Sadigh et al (1997) attenuation relationships were used and the larger of the two PBA's is reported below. The zones of PBAs within the project limit are shown in Figure 5.

- For the structures between Haven Avenue OC and Mulberry Creek Bridge, the controlling fault is the Redhill-Etiwanda Avenue fault (RHE). The range of PBA's is estimated to be 0.5 to 0.6g.

- For the structures between Cherry Avenue OC and Mountain Vernon Avenue OC, the controlling fault is the Rialto-Colton-Claremont fault (RCC). The range of PBA's is estimated to be 0.4 to 0.6g between Cherry Avenue OC and Cedar Avenue OC, and 0.7 to 0.8g between Riverside Avenue OC and Mountain Vernon Avenue OC.

- For the structures between Warm Creek Bridge and Alabama Street OC, the controlling fault is the San Jacinto fault (SJO). The range of PBA's is estimated to be 0.6 to 0.8g.

- For the structures between Tennessee Street OC and Highland Avenue UC, the controlling fault is the San Andreas fault (SAC). The range of PBA's is estimated to be 0.6.

- For the remaining structures, the controlling fault is the Crafton Hills fault (CRH). The range of PBA's is estimated to be 0.6 to 0.7g.

4.3 Ground Rupture

There has been no ground ruptures related to faulting in the project area in historical time. Trenching studies in the Santa Ana River wash near Hunts Lane by Wesnouski et al. (1991) found evidence of young (Holocene) faulting along the San Jacinto fault indicating a potential for surface ruptures. Aerial photographs indicate that the latest surface ruptures of the San Jacinto fault extends under the embankment fill of the northbound connector to the I-215 from the west bound I-10. The California Geological Survey has established an Alquist-Priolo Earthquake Fault Zone along the surface trace of the latest rupture of the San Jacinto fault but this zone does not include much of the deformed area indicated by the geophysical data.

A large, east-west trending, surface escarpment represents the Redlands fault near Highland Avenue in Redlands. The height of the feature (>100 feet) indicates a long history of multiple surface ruptures in Quaternary time, but actual ages of that faulting have never been determined. The fault is believed to be a normal fault with the north side faulted down relative to the south side.

Fault rupture investigation including aerial photos interpretation and field verification using geophysical survey and/or trenching are on-going.

5.0 SUBSURFACE SOIL AND GROUNDWATER CONDITIONS

5.1 Subsurface Soil Conditions

To assess the subsurface conditions, the following as-built Log-of-Test-Borings (LOTB) sheets for bridges within this project limit were reviewed:

- Milliken Avenue Overcrossing (Bridge No. 54-0539),
- Day Canyon Channel Bridge (Bridge No. 54-0351),
- Etiwanda Wash Bridge (Bridge No. 54-0378 L/R/S),
- Etiwanda Avenue Overcrossing (Bridge No. 54-0563),
- Valley Boulevard Off-Ramp Undercrossing (Bridge No. 54-0030 L/R),
- Etiwanda-San Sevaine Flood Control Channel Bridge (Bridge No. 54-054 L/R/S),
- Pepper Avenue Overcrossing (Bridge No. 54-0539),
- Slover Mountain Underpass (Bridge No. 54-0835),
- Colton Overhead (Bridge No. 54-0464 L/R),
- Ninth Street Undercrossing (Bridge No. 54-0461),
- Pavillion Spur Overhead (Bridge No. 54-0460),
- Warm Creek Bridge (Bridge No. 54-0830 L/R),
- Santa Ana River Bridge (Bridge No. 54-0292 L/R),
- Waterman Avenue Undercrossing (Bridge No. 54-0600),
- San Timoteo Creek Bridge (Bridge No. 54-0599),
- Richardson Street Overcrossing (Bridge No. 54-0597),
- Mountain View Avenue Undercrossing (Bridge No. 54-0596),
- West Redlands Overhead (Bridge No. 54-0570),
- California Street Undercrossing (Bridge No. 54-0595), and
- Nevada Street Undercrossing (Bridge No. 54-0595).

In general, the subsurface materials consist of loose to medium dense sand in the top 10 to 15 feet. Below the sandy material consistency increases with the depth but sometimes lens of silt layers are interbedded. In general, below depths of 40 to 50 feet, the materials are dense to very dense with trace to significant amounts of gravel.

The above soil descriptions are general and are intended to describe the subsurface in very broad terms. Soil type and consistency at locations of proposed improvements should be verified by excavating additional site-specific exploratory borings during the PS&E phase of the project.

5.2 Groundwater

Ground water is generally deep along the project corridor. Regional studies (e.g. Fife et al, 1996; Matti and Carson, 1991) indicate water is about 500 feet deep in the western part of the project area. The water becomes shallower to about 100-200 feet in the Pepper-Rancho area and reaches depths as shallow as about 10 feet at the Santa Ana River wash. During the winter and spring rainy seasons, the river bed may be filled with flowing water. The depth to ground water remains shallow eastward to about the Waterman Avenue area, and then gradually deepens to 75-100 feet from Richardson Street to the Redlands area. At the eastern end of the project, the water becomes shallower again and is about 50 feet deep at Highland Avenue.

5.3 Soil Corrosivity

Corrosion test results are not available; therefore, corrosion potential of on-site soils is not known. Based on EMI's experience, clay soils have a higher tendency to be corrosive, whereas sands and silts tend to be non-corrosive.

According to the Caltrans Corrosion Guidelines (2003), soils are considered corrosive if the pH is 5.5 or less, or chloride content is 500 parts per million (ppm) or greater, or sulfate content is 2,000 ppm or greater.

For preliminary cost estimating purposes, culvert material recommendations are provided in the table below for two assumed conditions under non-abrasive conditions with a flow velocity less than 5 fps: (1) non-corrosive soils having a pH equal to 7.0, soluble chloride content less than 500 ppm, soluble sulfate less than 2,000 ppm, and minimum resistivity of 1,500 ohm-cm; and (2) mildly-corrosive conditions assuming soil has a minimum resistivity of 800 ohm-cm, chloride content of 600 ppm, sulfate content of 1,000 ppm, and pH equal to 7.0.

Culvert Material	***Non-Corrosive Soils***	***Mildly-Corrosive Soils***
Reinforced Concrete Pipe (RCP)	Standard concrete mix design should be suitable for RCP. Type IP (MS) modified cement or Type II modified cement is recommended.	For chloride resistant RCP, a cement content of 23.7 pcf should be used in the mix design. Concrete cover should be a minimum 2 inches.
Corrugated Steel Pipe (CSP)	Minimum 10-gage pipe or 16-gage pipe with bituminous coating on the soil side of the pipe.	Minimum 8-gage pipe or 14-gage pipe with bituminous coating on the soil side of the pipe.
Aluminum or Aluminized Steel Pipe	Aluminum pipe can be used if abrasive conditions do not exist. Aluminized steel pipe can be used.	Should not be used due to corrosive soil conditions.
Plastic Pipe	Plastic pipe may be used; however, abrasion should be evaluated by the project civil engineer.	Plastic pipe may be used; however, abrasion should be evaluated by the project civil engineer.
Notes: 1. Recommendations are for an estimated service life of 50 years. 2. Culvert materials were determined using the CULVERT4 computer program developed by Caltrans.		

The termini of any plastic pipes should be protected from potential physical or fire damage such as by constructing concrete headwalls, or by concrete or metal treatment. The above corrosivity recommendations are only for corrosion and the culvert may require additional thickness for strength, overfill or higher flow velocities.

6.0 MATERIAL SOURCES

Numerous commercial suppliers for sand, gravel, aggregate base, and concrete are located in the San Bernardino and Riverside counties, which will be identified during the PS&E phase of the project. Pulverizing existing pavement, during construction, might be performed. Pulverized AC material (or Reclaimed Asphalt Pavement – RAP) can be used as aggregate base (AB) provied the material meets the quality requirements of AB specified in Section 26 “Aggregate Bases” of the Caltrans Standard Specifications (2006). Pulverized AC material may also be used within Aggregated Subbase (AS), if it meets the requirements of Section 25 “Aggregate Subbases” of the Caltrans Standard Specifications (2006). Pulverized AC material may also be used within certain Hot Mix Asphalt (HMA) mixes, such as HMA Type A, if pulverized AC material and its processing complies with Standard Special Provision (SSP) # S1-020H.

7.0 MATERIAL DISPOSAL

According to the civil designer, import material will most likely be required to achieve proposed grades. Therefore, disposal of on-site soils is not anticipated (from a geotechnical standpoint).

8.0 CONCLUSIONS AND RECOMMENDATIONS

8.1 Earthwork

Earthwork should be conducted in accordance with Section 19 of the latest Caltrans Standard Specifications. In areas where compacted fill will be placed, removal of compressible surficial materials including topsoil, loose or soft alluvium or fill soil, dry or saturated soil, and unsuitable fill is required prior to fill placement. A minimum overexcavation of 2 feet is recommended within areas to receive fill; the overexcavation should extend horizontally a minimum distance of 2 feet from edges of new fills or structures. Fill placed on sloping ground should be properly keyed and benched into existing ground and placed as specified in Section 19-6 of the Caltrans Standard Specifications. Overexcavations should be observed by qualified geotechnical personnel to verify that firm and unyielding bottoms are exposed. Overexcavated areas should be cleaned of loose soils and debris and should be observed to be firm and unyielding before receiving fill. These on-site materials can be excavated using conventional heavy-duty earth-moving equipment and the materials are not expected to pose a rippability problem.

8.2 Soil Expansion Potential

On-site soils are expected to have an expansion potential varying from non-expansive to very low. However, there may be localized, discontinuous clayey sand and sandy lean clay soils which can exhibit expansion potential ranging from low to medium. Soils having high or very high expansion potential are not anticipated.

8.3 Soil Erosion Potential

In general, the erosion potential of soils is expected to be minor to moderate considering the provisions for site drainage, slope planting and other measures required by Caltrans. In order to minimize potential erosion, all finish slopes should be planted as soon as practical after grading.

8.4 Liquefaction Potential and Seismically-Induced Settlement

Liquefaction is the loss of shear strength in generally cohesionless, saturated soils when the pore-water pressure induced in the soil by a seismic event becomes equal to or exceeds the overburden pressure. Primary factors influencing liquefaction potential include: groundwater elevation, soil type and grain-size distribution, relative density of soil, initial confining pressure, and intensity and duration of ground shaking. Soils most susceptible to liquefaction are saturated low-density sands and silty sands within 50 feet of the ground surface.

In general, shallow groundwater is not present in this project; therefore, liquefaction of subsurface soils is unlikely and seismically-induced settlement is expected to be negligible.

However, the area close to the Santa Ana River has shallow groundwater table. Several structures are located in the shallow ground area including Mount Vernon Avenue OC, Warm Creek Bridge, Santa Ana River Bridge, I-10/I-215 Interchange, Waterman Avenue UC and San Timoteo Creek Bridge. We expect liquefaction potential at these bridge sites to range from medium to high and seismically-induced settlement could be up to 3 inches.

8.5 Embankment Settlement

The project involves constructing new earthen embankments for median HOV lane and widening existing embankments to create new alignments and configurations. The proposed embankments are anticipated up to about 30 feet embankments.

Because the subsurface soils are predominantly granular, the soils are not expected to undergo large consolidation settlement (settlement over long periods of time). However, the soils can undergo "immediate" elastic settlement which usually occurs during earthwork activities and shortly thereafter. For new embankments and the proposed widening of existing embankments, total settlement is estimated in the following table. Linear interpolation can be used for settlements of other embankment heights within the tabulated range.

Embankment Height (feet)	Total Settlement (inches)
3	0.75
5	1.1
10	1.8
15	2.4
20	2.9
25	3.3
30	3.6

We recommend a settlement period of about 10 calendar days for abutment pile construction at the bridge locations. Settlement magnitudes and time rates of settlement should be verified by supplemental site-specific exploratory borings, laboratory soil testing, and analysis during the PS&E phase of the project.

8.6 Stability of Embankment Slopes

Per Caltrans HDM Topic 304, 1V:4H side slopes or flatter should be used where possible.

Assuming the earthen embankments will be constructed using compacted fill having a minimum friction angle of 32 degrees and minimum cohesion of 200 psf, slopes up to 30 feet high and with inclinations of 2H:1V or flatter are expected to be globally stable (i.e. minimum factor-of-safety is 1.5 and 1.1 under static and pseudo-static conditions, respectively). Foundation soils (existing soils below the proposed embankments) are anticipated to be stable with respect to global slope stability.

In addition, using a minimum friction angle of 32 degrees and minimum cohesion of 200 psf, the slopes are expected to be surficially stable based on the infinite slope method. Soil shear strength parameters or fines content and plasticity of soils, used to construct the earthen embankments, will need to be verified during construction.

8.7 Earth Retaining Structures

Cantilevered retaining walls are proposed at various locations throughout the project including along the on- and off-ramps. The retaining walls are proposed to be standard Caltrans retaining walls. Based on the subsurface information shown on the available as-built boring logs, spread footings are suitable for supporting standard Caltrans retaining walls with heights equal to or less than 16 feet. Pile foundation might be required to support taller retaining walls. Some amount of remedial earthwork below the proposed spreading footings to remove loose near-surface soils should be anticipated; remedial overexcavations will most likely be less than 3 feet.

8.8 Hazardous Waste Considerations

If for any reason hazardous or toxic materials are believed to exist within the project area, an environmental specialist should be consulted.

8.9 Supplemental Geotechnical Investigations

EMI recommends excavating numerous exploratory borings throughout the project area, during the PS&E phase of the project, to investigate site-specific soils and conditions and to collect samples of subsurface soils for laboratory testing. The locations and depths of the borings should be selected once locations of proposed improvements have been finalized. Since groundwater is anticipated to be deep for most locations, a truck-mounted drilling rig equipped with hollow-stem augers should be adequate. For the area close to the Santa Ana River, a mud-rotary drilling rig is recommended due to the shallow groundwater table.

Soil samples recovered during the supplemental field investigation should be tested to determine soil type, soil shear strength, compressibility characteristics, and corrosion potential.

9.0 LIMITATIONS

This DPGR is intended for use by Parsons, SANBAG and Caltrans for proposed improvements for the I-10 HOV Project. This report is based on the project as described herein and available as-built subsurface information. Soils and subsurface conditions described in the as-built exploratory borings are presumed to be representative of the project site; however, subsurface conditions and characteristics of soils between exploratory borings can vary.

The data, opinions, and recommendations contained herein are applicable to the project which is the subject of this report. Data, opinions, and recommendations herein have no applicability to any other design elements or to any other locations, and any and all subsequent users accept any and all liability resulting from any use or reuse of the data, opinions, and recommendations without the prior written consent of EMI.

Services performed by EMI were conducted in a manner consistent with that level of care and skill ordinarily exercised by members of the profession currently practicing in the same locality under similar conditions. No other representation, expressed or implied, and no warranty or guarantee is included or intended.

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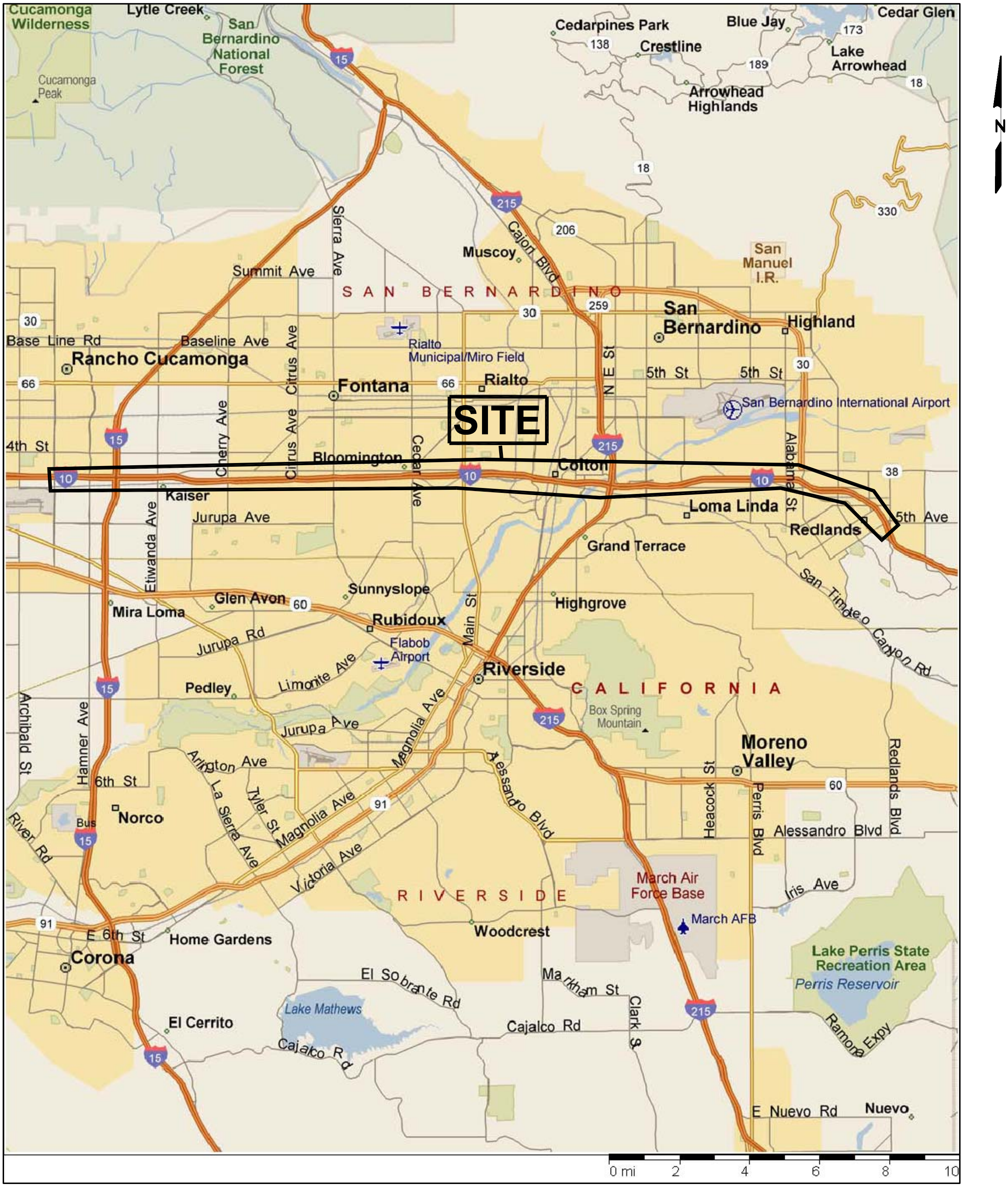

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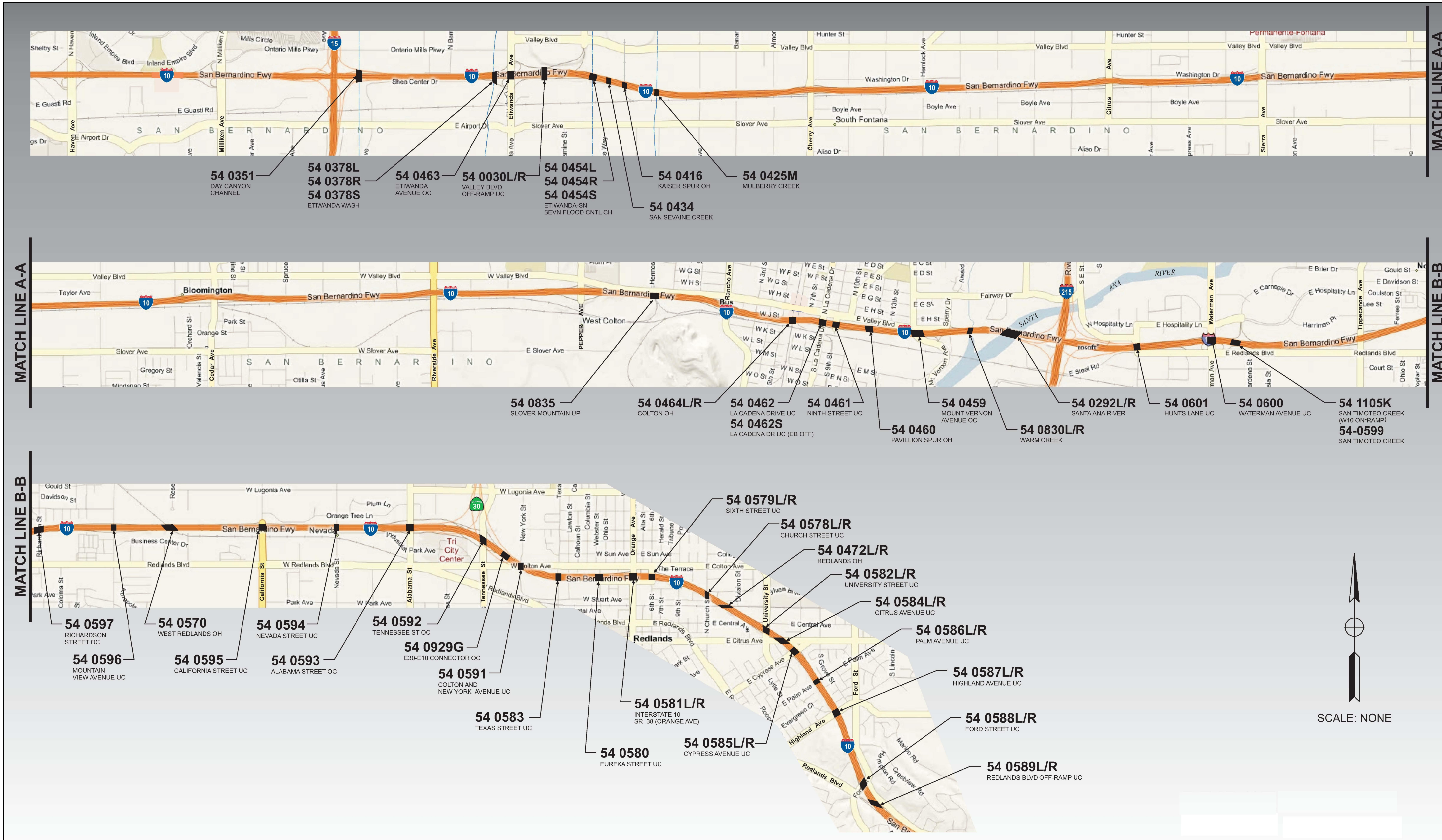
I-10 HOV PROJECT

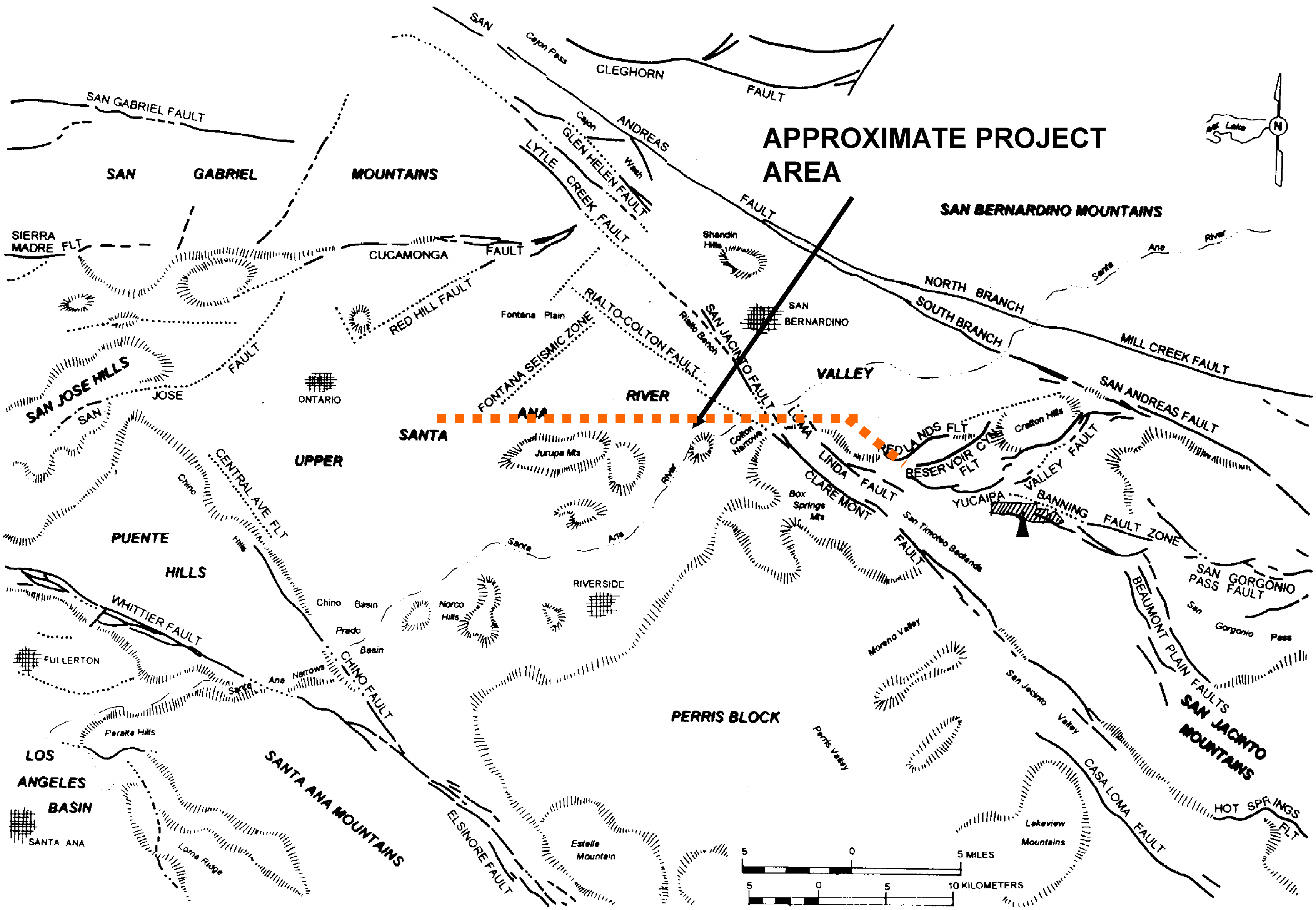
SITE LOCATION MAP

Figure 1

Project No. 08-103 **Date:** 07-15-08



Earth Mechanics, Inc. Geotechnical & Earthquake Engineering	I-10 HOV Project		Bridge Location Map
	EMI Project No.: 08-103	Date: 12-19-08	Figure 2



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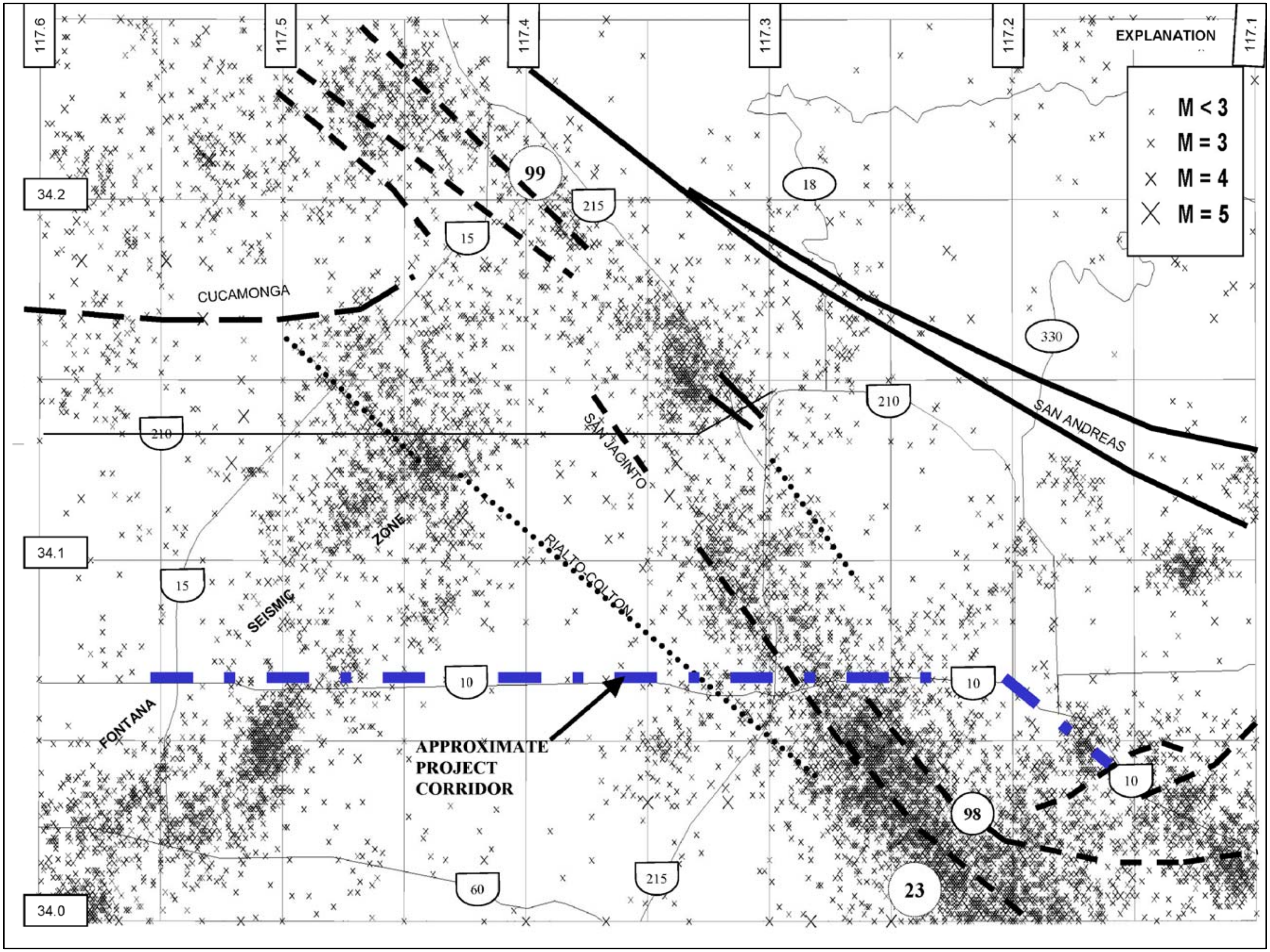
I-10 HOV PROJECT

Project No. 08-103

Date: 7-14-2008

REGIONAL PHYSIOGRAPHY AND FAULT MAP

FIGURE 3



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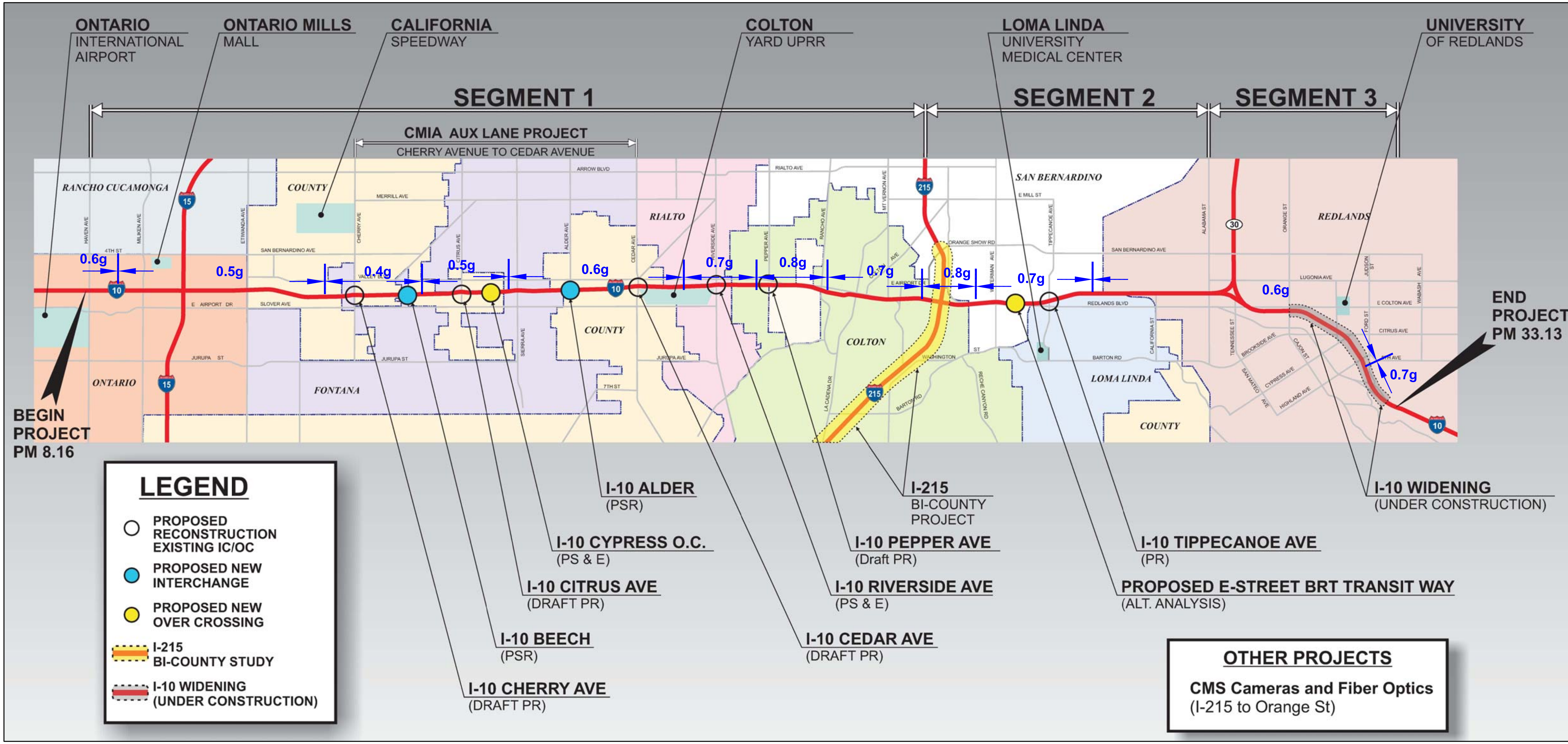
I-10 HOV Project

Project No. 08-103

Date: 11-25-08

RECORDED EARTHQUAKE MAP

FIGURE 4



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I-10 HOV Project

EMI Project No.: 08-103 | Date: 11-25-08

Peak Bedrock Accelation Map

Figure 5

APPENDIX A CALTRANS REVIEW COMMENTS AND EMI'S RESPONSES

DISTRICT PRELIMINARY GEOTECHNICAL REPORT REVIEW COMMENTS AND RESPONSES

Co-Rte-PM 08-SBd-10-8.2/33.43 Reviewer Various
Cost Center-EA 08224 –0C2500 Functional Unit Various
PA&ED Stage District Preliminary Geotechnical Report (DPGR) Review Date 10/30/08

No.	Page No.	Comments	Response/Actions	Initials (a)	Initials (b)
1	General	Add a section (paragraph) regarding the project site's climatic conditions to the DPGR. There is no information regarding climatic conditions in this report. Please note that the climate will affect the designs of proposed structures and pavements. Projects that are miles-long may straddle different climate areas. Refer to the Plans, Specifications, and Estimate (PS&E) Guide (Section 4 describes Climate Areas # I through III versus freeze-thaw), and Topics 615 (climate), 623 (Engineering Procedures for New and Reconstruction Projects), and 632 (Engineering Criteria) of the Highway Design Manual (HDM). Address the coldest and hottest known temperatures that the structures and roadways will have to endure.	The following paragraph will be inserted into the report. "The climate of the site region is semi arid. The hottest months are July and August when high temperatures average about 96ºF and low temperatures average about 61ºF. The coolest temperatures are in the winter months of December and January when average highs are in the 69ºF range and average low is 41ºF. The extreme high temperatures range from the 90s in the winter months to more than 110ºF in July, August, and September. The extreme low temperatures range from about 17ºF in December and January to the high 40s in the summer months. Although freezing occurs occasionally on the winter nights, the freezing is generally of short duration (a couple hours) and does not commonly result in a "hard" freeze. Snowfall is rare and has occurred in the winter months, but the snow generally melts the same day it falls. Annual precipitation is about 15 inches with most of the rain falling between November and March. Monsoon-type thunder showers occasionally occur in the summer and can cause local flash flooding."	CY	LC
2	General	Describe what types of drainage facilities will be constructed by this project. ▪ Will this project extend any existing culverts, and/or construct any new culverts? ▪ Will it include inspection of existing drainage structures such as culverts and providing rehabilitation strategies or replacing culverts that are corroded or damaged?	This project will extend existing culverts to the new embankment limits. No new culverts are planned to be installed at this time. The drainage report recommends culvert inspection during PS&E in which culverts corroded or damaged will be identified. Necessary replacements will be determined by the Consultant and Caltrans during PS&E.	CY	LC

DISTRICT PRELIMINARY GEOTECHNICAL REPORT REVIEW COMMENTS AND RESPONSES

3	Page 1 Section 2.0	Existing Facilities and Proposed Improvements: Apparently, This report did not mention any proposals for ramp-work, retaining walls, or soundwalls. Will any ramp-work, and/or retaining walls and/or soundwalls past the gores be constructed by this project? If so, add their work descriptions to the report. It should also be mentioned in the report if this project will not construct any ramps or walls.	See attached Sheets 1 and 2.	CY	LC
4	Section 2.0	Existing Facilities and Proposed Improvements: The sentence “construction of HOV lane” implies only one lane will be built. Please indicate two HOV lanes be constructed. In the sentence “addition of California Highway Portal enforcement areas”, “Portal” should be changed to “Patrol”.	We will comply.	CY	LC
5	Page 1 & 9 Section 1.0 - Introduction & Section 5.3 - Soil Corrosivity	This DPGR currently offers very little Corrosivity information. Please provide a thorough Corrosivity section in the DPGR. Note that culverts, foundations of bridges and walls will require mitigation against potential corrosion. Also note that the Geotechnical and Structural offices typically review District Geotechnical Reports (DGRs) and/or Foundation Reports, but those offices might not receive Materials Reports. The Corrosivity Study in the Preliminary Materials Report (PMR) could be included in the DPGR, upon making a few changes.	See attached Sheet 3.	CY	LC

DISTRICT PRELIMINARY GEOTECHNICAL REPORT REVIEW COMMENTS AND RESPONSES

6	Page 9 Section 6.0 Material Sources	The recycling of Reclaimed Asphalt Pavement (RAP), or "pulverized Asphalt Concrete (AC) material"): It is acceptable to use RAP within Aggregate Base (AB) provided the RAP meets the AB requirements of the Caltrans Standard Specifications, but indicate the applicable Section, for clarity (Section 26 "Aggregate Bases"). Note that RAP may also be used within Aggregate Subbase (AS), if it meets Section 25 "Aggregate Subbases" of the Caltrans Standard Specifications. Note that RAP may also be used within certain Hot Mix Asphalt (HMA) mixes, such as HMA Type A, if the RAP and its processing complies with Amended Section 39 (the new Hot Mix Asphalt specifications), which is currently found within Standard Special Provision (SSP) # S1-020H.	We will add the following paragraph to the DPGR. "Numerous commercial suppliers for sand, gravel, aggregate base, and concrete are located in the San Bernardino and Riverside counties, which will be identified during the PS&E phase of the project. Pulverizing existing pavement, during construction, might be performed. Pulverized AC material (or Reclaimed Asphalt Pavement – RAP) can be used as aggregate base (AB) provied the material meets the quality requirements of AB specified in Section 26 "Aggregate Bases" of the Caltrans Standard Specifications (2006). Pulverized AC material may also be used within Aggregated Subbase (AS), if it meets the requirements of Section 25 "Aggregate Subbases" of the Caltrans Standard Specifications (2006). Pulverized AC material may also be used within certain Hot Mix Asphalt (HMA) mixes, such as HMA Type A, if pulverized AC material and its processing complies with Standard Special Provision (SSP) # S1-020H."	CY	LC
7	Pages 11 & 12 Section 8.6 Stability of Embankment Slopes	Please include the Caltrans standard to specify 1:4 (Vertical:Horizontal) side slopes or flatter where possible in the slope stability recommendations, as per HDM Topic 304 "Side Slopes". District recommend 1:4 (V:H) side slopes or flatter for both cut and fill slopes.	We will add a sentence "Per Caltrans HDM Topic 304, 1V:4H side slopes or flatter should be used where possible."	CY	LC

8	General	Based on the Report Titles and Guidelines dated January 1, 2006, *http://www.dot.ca.gov/hq/esc/geotech/requests/reportstitlesandguidelines.pdf*, the title of the report should be designated as either District Preliminary Geotechnical Report (DPGR) or Structure Preliminary Geotechnical Report (SPGR).	We will use DPGR as the revised report title.	CY	LC
9	Title Page	Please correct District-County-Route to read as 08-SBd-10-PM 8.20/33.43.	We will comply.	CY	LC
10	General	Provide the list of bridges within the contract limit and show these bridges on a plan.	We will add the list of bridges within the contract limit and the corresponding plan in the revised DPGR.	CY	LC
11	General	Draw cross sections to show site stratigraphy.	We are requesting the reviewer to waive this requirement. At this point, the DPGR already contains a brief description of the stratigraphy in Section 3.2.2; the DPGR also contains very preliminary design information which will be updated during PS&E. In our current work, our understanding of the site stratigraphy is based on our review of available geologic maps, and the existing as-built LOTB sheets for the bridge structures. Adding cross-sections of the stratigraphy will not change the preliminary design information contained in the DPGR. Also, these cross sections are not of great significance to the stake holders and civil designers and therefore, will likely be omitted from the Project Report.	CY	LC
12	Page 6 Section 4.1 Seismicity	The descriptions of recorded earthquakes have been provided. Please show these records on a Seismicity map.	A seismicity map of instrumentally recorded earthquakes within the project region is provided in the attached Figure 1. The approximate locations of pre-instrumentally located events that occurred in the years of 1923 and 1899 are designated by circles with the numbers 23 and 99, respectively. Note that the report erroneously gave the date of the 1899 event as 1918. An instrumentally located event that occurred in 1998 near the junction of the San Jacinto fault and the Crafton Hills fault is also shown and designated by the number 98 within a circle.	CY	LC

DISTRICT PRELIMINARY GEOTECHNICAL REPORT REVIEW COMMENTS AND RESPONSES

13	Page 7 Section 4.2 Ground Motions	Redhill-Etiwanda Ave. Fault (RHE) is assumed to be reverse-thrust fault. Please indicate the justification.	The Red Hill-Etiwanda fault (RHE) comprises a short surface scarp in alluvium at the northeast end (i.e. the Etiwanda Avenue fault) and subsurface barriers to ground-water flow between the scarp and Red Hill to the southwest (see report Figure 3). The Etiwanda Avenue scarp is shown as a reverse (=thrust) fault on the fault map of the San Bernardino 100K geologic map (Morton and Miller, 2003). The reverse sense of displacement on the Etiwanda Avenue fault is consistent with the regional tectonic regime which is one of north-south compression (approximately) within the "Big Bend" region of the San Andreas fault. This Big Bend represents a constriction or restraining bend to movement between the North America and the Pacific tectonic plates. This constriction results in the San Gabriel Mountains being thrust up and over sediments of the valleys south of the mountain front. The majority of this thrusting in the Upper Santa Ana River Valley is along the Cucamonga fault. The close proximity (a few hundred feet) of the RHE fault to the Cucamonga fault suggests that the RHE should have similar compressional reverse type displacements. Therefore, we conservatively modeled the RHE as a reverse fault.	CY	LC
14	Page 7 Section 4.2 Ground Motions	It would be preferable if the zones of peak bedrock acceleration (PBA) would be shown on a plan.	See the attached Figure 2.	CY	LC
15	Page 12 Section 8.7 Earth Retaining Structures	It is not clear why options other than cantilevered retaining structures have not been considered.	Type of retaining walls has not yet been determined, however, based upon field conditions, constraints, and geotechnical recommendations, retaining wall type will be investigated as "best fit".	CY	LC

*Please give reasons if comments are not incorporated or no action is taken. Use additional sheet as necessary.
(a) Responder's initials. Responder's name Chien-Tai Yang
(b) Project Manager's initials. The Project Manager concurred with the Response/Actions.

Attachment of ***Response to EA# 0C250 District Preliminary Geotechnical Report Review Comments***

Response to Comment 3 regarding "*ramp-work, retaining walls, or soundwalls*"

There are ramp work and new retaining walls for this project. At this time, a noise study is being conducted to determine if new sound walls will be required. Most of ramp work is widening the existing ramp from one lane to two lanes. Locations of ramp work are listed below and this list will be included in the revised PMM and PGR:

- Haven Avenue Eastbound (EB) On-Ramp and Westbound (WB) Off-Ramp
- Milliken Avenue WB and EB On-Ramp
- Etiwanda Avenue EB Off-Ramp
- Sierra Avenue EB Off-Ramp
- Pepper Avenue EB On- and Off-Ramps and WB On- and Off-Ramps
- Rancho Avenue EB On- and Off-Ramps and WB Off-Ramp
- Ninth Street EB On-Ramp
- Mt. Vernon Avenue EB Off-Ramp
- Waterman Avenue EB On-Ramp and WB On-Ramp
- Tippecanoe Avenue EB On-Ramp
- Richardson Street EB On-Ramp
- Mountain View Avenue EB On- and Off-Ramps and WB On- and Off-Ramps
- Eureka Street WB On-Ramp
- Sixth Street EB On-Ramp
- West Redland Overhead EB On-Ramp
- California Street EB On- and Off-Ramps
- Palm Avenue EB On-Ramp
- Ford Street EB Off-Ramp

Locations of retaining walls are listed below and this list will be included in our revised PMM and PGR:

- Haven Avenue WB Off-Ramp
- Cherry Avenue EB Off-Ramp
- Sierra Avenue EB Off-Ramp
- Cedar Avenue EB On- and Off-Ramps
- Pepper Avenue EB Off-Ramp and WB On-Ramp
- Rancho Avenue EB On-Ramp
- La Cadena Drive EB Off-Ramp
- EB Mainline near Ninth Street
- Mountain Vernon Avenue EB Off-Ramp and WB On- and Off-Ramps
- Hunt Lane EB On- and Off-Ramps
- Waterman Avenue EB On- and Off-Ramps
- EB and WB Mainlines near Mountain View Avenue
- West Redland Overhead EB On-Ramp
- EB and WB Mainlines near California Street and California Street EB On- and Off-Ramps

- EB Mainline near Nevada Street
- Alabama Street EB Off-Ramp
- Palm Avenue EB On- and Off-Ramps and WB On- and Off-Ramps
- EB Mainline near Highland Avenue
- Ford Street EB Off-Ramp and WB On-Ramp

Response to Comment 5 regarding “*Corrosivity*”

The following Corrosivity Section will be added to the revised DPGR.

“Corrosion test results are not available; therefore, corrosion potential of on-site soils is not known. Based on EMI’s experience, clay soils have a higher tendency to be corrosive, whereas sands and silts tend to be non-corrosive.

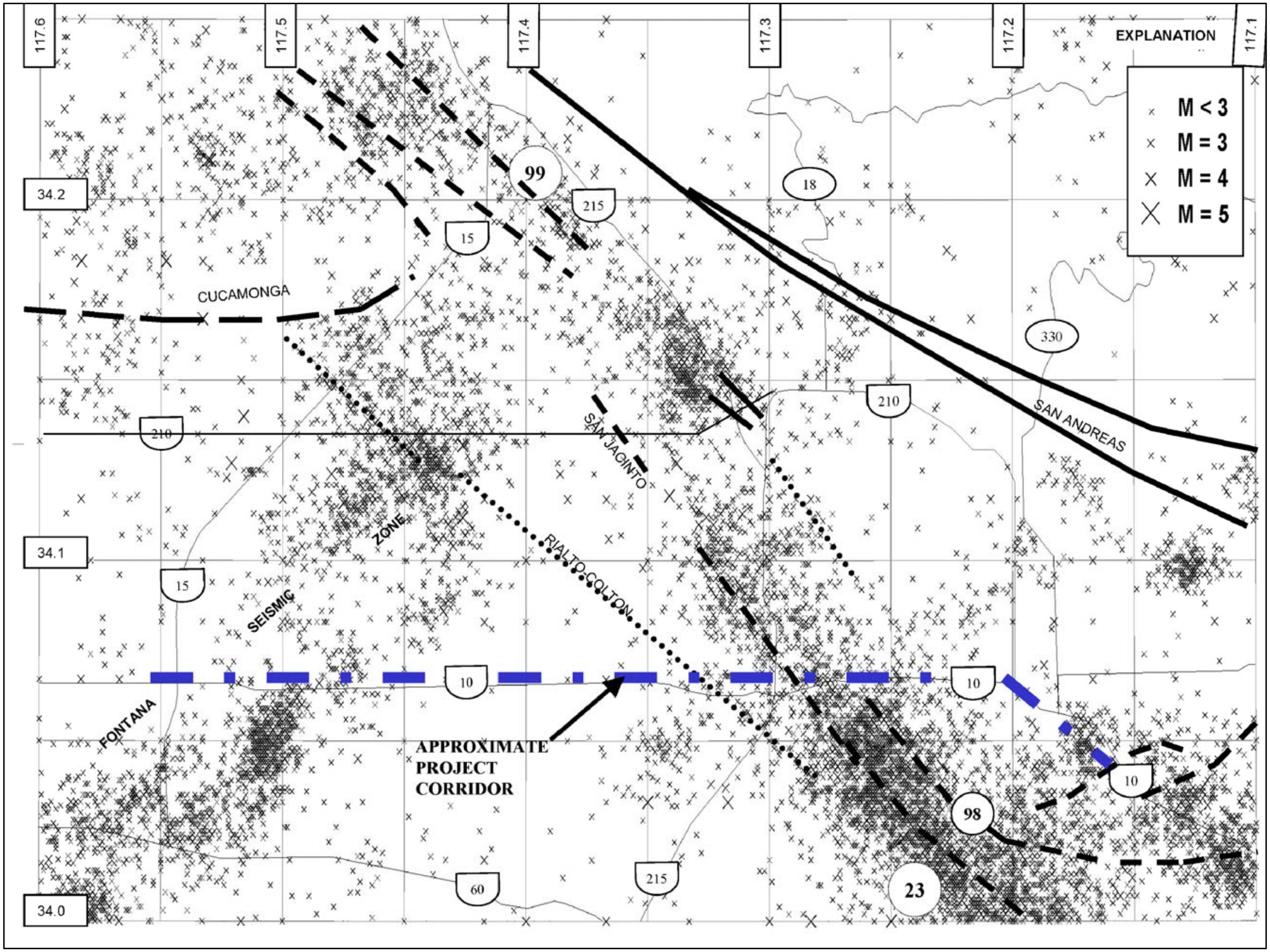
According to the Caltrans Corrosion Guidelines (2003), soils are considered corrosive if the pH is 5.5 or less, or chloride content is 500 parts per million (ppm) or greater, or sulfate content is 2,000 ppm or greater.

For preliminary cost estimating purposes, culvert material recommendations are provided in the table below for two assumed conditions under non-abrasive conditions with a flow velocity less than 1.5 m/sec (5 fps): (1) non-corrosive soils having a pH equal to 7.0, soluble chloride content less than 500 ppm, soluble sulfate less than 2,000 ppm, and minimum resistivity of 1,500 ohm-cm; and (2) mildly-corrosive conditions assuming soil has a minimum resistivity of 800 ohm-cm, chloride content of 600 ppm, sulfate content of 1,000 ppm, and pH equal to 7.0.

Culvert Material	*Non-Corrosive Soils*	*Mildly-Corrosive Soils*
Reinforced Concrete Pipe (RCP)	Standard concrete mix design should be suitable for RCP. Type IP (MS) modified cement or Type II modified cement is recommended.	For chloride resistant RCP, a cement content of 380 kg/cubic meter should be used in the mix design. Concrete cover should be a minimum 50 mm.
Corrugated Steel Pipe (CSP)	Minimum 10-gage (3.5 mm) pipe or 16-gage (1.6 mm) pipe with bituminous coating on the soil side of the pipe.	Minimum 8-gage (4.3 mm) pipe or 14-gage (2.0 mm) pipe with bituminous coating on the soil side of the pipe.
Aluminum or Aluminized Steel Pipe	Aluminum pipe can be used if abrasive conditions do not exist. Aluminized steel pipe can be used.	Should not be used due to corrosive soil conditions.
Plastic Pipe	Plastic pipe may be used; however, abrasion should be evaluated by the project civil engineer.	Plastic pipe may be used; however, abrasion should be evaluated by the project civil engineer.

Notes:
1. *Recommendations are for an estimated service life of 50 years.*
2. *Culvert materials were determined using the CULVERT4 computer program developed by Caltrans.*

The termini of any plastic pipes should be protected from potential physical or fire damage such as by constructing concrete headwalls, or by concrete or metal treatment. The above corrosivity recommendations are only for corrosion and the culvert may require additional thickness for strength, overfill or higher flow velocities.”



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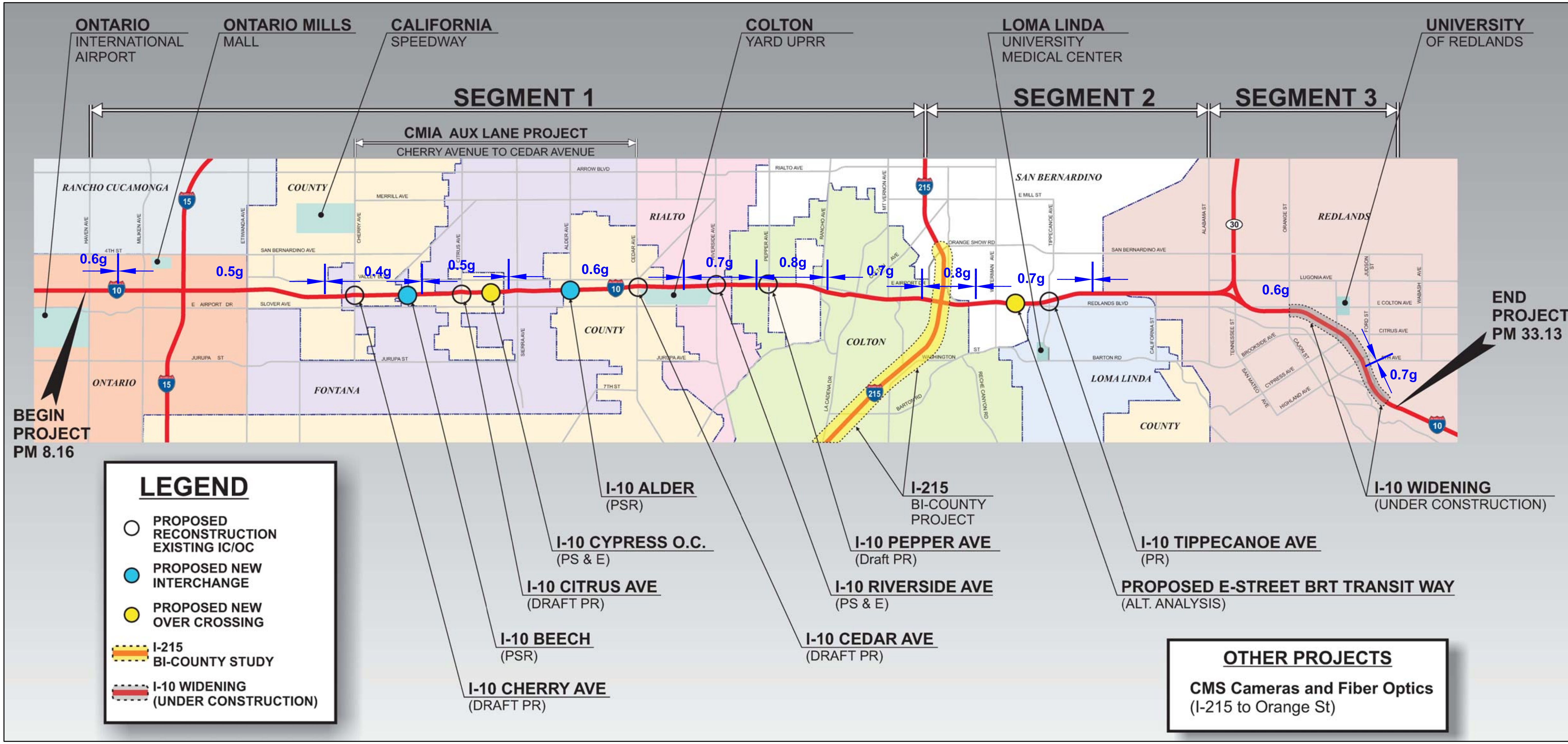
I-10 HOV Project

Project No. 08-103 | Date: 11-25-08

RECORDED EARTHQUAKE MAP

FIGURE 1



Earth Mechanics, Inc. Geotechnical & Earthquake Engineering	I-10 HOV Project		Peak Bedrock Accelation Plan
	EMI Project No.: 08-103	Date: 11-25-08	Figure 2

APPENDIX B

CALTRANS REVIEW COMMENTS AND EMI RESPONSES

District 8 Quality Review Comments - Summary

Dist-Co-Rte-PM: 08-SBd-10-PM 0/33.43
Project No. 0800000040 (EA 0C250) I-10 Corridor Project
Preliminary Geotechnical Design Report (Received on February 25, 2015)
Date: March 30, 2015

No.	Plan/SSP/ Page No.	Comments	Status/Changes
1	General	Please submit two (2) copies of revised Preliminary Geotechnical Design Report (PGDR). The resubmittal shall include resolutions and responses to all of the following comments. Please submit the responses in an excel format.	Will Comply.
2	General	This report also references an earlier PGDR dated 1-12-2009. In light of comment no. 3, please verify that other recent updates to standards/guidelines have been incorporated (i.e. Caltrans' latest Guidelines for preparing PGDRs, dated May 2013, etc.).	This report replaces the 2009 report. The 2009 report was included for background information only; and more important, to demonstrate that the Caltrans review comments of the 2009 report has been incorporated into the new report.
3	Section 4.2	Section 4.2 Ground Motion: It is stated that the report is based on the 2010 Caltrans' Seismic Design Criteria (SDC) which has been superseded. Please review and follow the latest SDC.	We will modify and follow the latest SDC.
4	Section 4.2	Section 4.2 Ground Motion: Please specify how the Peak Ground Accelerations (PGAs) were determined. Are the Vs30 values calculated or estimated for each structure?	The Vs30 values were calculated using the as-built Log-of-Test-Borings sheets and SPT correlations (Caltrans, 2012c) for each structures listed in Section 5.1. This statement will be added to the report.
5	Section 5.1	Section 5.1 Subsurface Soil Conditions: The subsurface conditions were described in a manner resembling a specific site. In light of the long span of the corridor, please consider if rewording may be beneficial.	We will change the description to more of a general nature.
6	Section 8.4	Section 8.4 Liquefaction Potential and Seimically-Induced Settlement: Seismic-induced settlements were specified as up to 3 inches. Is this supported by calculations? Please elaborate.	Soil liquefaction assessments were conducted for all the bridges listed in Section 5.1. Results of our assessment show that 5 bridges are founded on a potentially liquefiable site. For these 5 bridges, seismically-induced settlement was calculated and the maximum magnitude was determined to be about 3 inches. We will include the above sentences into the report and the seismically-induced settlement calculations are also inlcuded in the report.
7	Section 8.9	Section 8.9 Supplemental Geotechnical Investigations: The report implies that hollow stem augers should be used, where no water is expected. Please elaborate on the reason for the apparent exclusion of other methods, considering this method's limitations for deeper foundations in denser material.	We will remove the recommendation for the drilling method from the report.

APPENDIX C

SEISMICALLY-INDUCED SETTLEMENT ESTIMATES

SEISMIC SETTLEMENT CALCULATIONS I-10 Warm Creek Bridge EMI Project No. 08-103

LIQUEFACTION ANALYSIS , M = 7.7 ; ACC. = 0.845 g

FORMULAE:

Corrected blow count	$(N_1)_{60}$	=	$C_N * C_s * C_E * C_R * C_B * C_{ST} * N_{field}$
where:	N_{field}	=	Uncorrected field blow count
	C_N	=	Overburden correction factor (See Reference 1)
	C_E	=	Energy correction (Reference 2) = (Efficiency/60%)
	C_R	=	Rod Length correction
	C_s	=	Sampler correction (lined/unlined) (Reference 3)
	C_B	=	Borehole diameter correction
	C_{ST}	=	Sampler correction (Sampler diameter)

$K_0 = (1-\sin(\phi))$

$\sigma_m' = (1+2K_0)/3*\sigma_{0f}'$

$(K_2)_{max} = 20*(N_1)$^(1/3)

$G_{max} = 1000*(K_2)_{max}*(\sigma_m')$^(1/2)

$\gamma_{eff}*G_{eff}/G_{max} = 0.65*(a_{max}/g)*(\sigma_{0f}'/G_{max})*r_d$

r_d = 1.0 at the ground surface,

= 0.9 at 30 feet below the ground surface

= 0.6 at 70 feet below the ground surface

= 0.5 at 100 feet below the ground surface

$\tau_{av}/\sigma_{0f}' = 0.65*(a_{max}/g)*(\sigma_{0f}/\sigma_{0f}')*r_d$

γ_{eff} for a given $\gamma_{eff}*G_{eff}/G_{max}$ and σ_m' is read from Figure 11 (Tokimatsu and Seed, 1987)

ε_c for a given γ_{eff} and N_1 is read from Figure 13 (Tokimatsu and Seed, 1987)

Efficiency (%)	=	60%	C_E	1.00
Borehole Dia. (in)	=	5	C_B	1.00
Soil Unit Weight (pcf)	=	120		

CALCULATIONS:

Boring:	**B-1**	**Boring El. (ft MLLW):**	**942.0**			**EQ Mag =**	**7.7**
Water depth (ft bgs): (during drilling)	**2.0**	**Groundwater El. (ft MLLW):**	**940.0**			**Mag Scale Factor =**	**0.935**
Water depth (ft bgs): (design depth)	**2.0**	**Finished Grade El. (ft MLLW):**	**942.0**	**Design GW El. (ft MLLW):**	**940.0**	**a_{max} =**	**0.845**
						Height of Fill (ftl) :	**0.0**

Original Depth (ft bgs)	Final Depth (ft bgs)	Elev (ft msl)	Total Stress at Mid depth (psf)	Original Effective Stress at Mid depth (psf)	Sampler SPT = 1 CDS = 2	Uncorrected Blow Count (N)*	Sampler 1=Unlined 2=Lined	Soil Type (1=fine-grained, 2=coarse-grained)	C_N	C_{ST}	C_s	C_r	$(N_1)_{60}$	Estimated Percentage of Fines (%)	(N1)60-CS (NCEER - used if layer does not liquefy)	(N1)60-CS (Seed - used if layer liquefies)	Design Effective Stress at Mid depth (psf)	σ_m' (psf)	$(K_2)_{max}$	G_{max} (psf)	r_d	$\gamma_{eff} G_{eff}/G_{max}$	τ_{av}/σ_{0f}'	Cyclic Shear Strain, γ_{eff} (%)			Volumetric Strain (Dry Sand) ε_c (%)	Volumetric Strain (Saturated Sand) ε_c (%)	$2*\varepsilon_c$ (dry); ε_c (saturtd.)	Settlement of Each Layer (inches)	Sum.	$CRR_{7.5}$
0			0																													
5	5.0	937.0	600	413	1	7	1	2	1.70	1.00	1.20	0.75	10.7	15.0	13.7	11.7	413	275.2	4.54E+01	7.53E+05	0.99	4.63E-04	0.84	-	-	-	-	2.34E+00	2.34E+00	1.401	1.40	0.15
10	10.0	932.0	1200	701	1	23	1	2	1.69	1.00	1.20	0.80	37.3	15.0	41.6	41.6	701	467.2	6.93E+01	1.50E+06	0.98	4.60E-04	0.98	-	-	-	-	0.00E+00	5.00E-01	0.300	1.7	1.00
15	15.0	927.0	1800	989	1	32	1	2	1.42	1.00	1.20	0.85	46.4	15.0	51.2	51.2	989	659.2	7.42E+01	1.91E+06	0.97	5.36E-04	1.03	-	-	-	-	0.00E+00	0.00E+00	0.000	1.7	1.00
20	20.0	922.0	2400	1277	1	70	1	2	1.25	1.00	1.20	0.95	99.9	15.0	107.2	107.2	1277	851.2	9.50E+01	2.77E+06	0.95	4.85E-04	1.05	-	-	-	-	0.00E+00	0.00E+00	0.000	1.7	1.00
25	25.0	917.0	3000	1565	1	70	1	2	1.13	1.00	1.20	0.95	90.2	15.0	97.1	97.1	1565	1043	9.19E+01	2.97E+06	0.94	5.59E-04	1.06	-	-	-	-	0.00E+00	0.00E+00	0.000	1.7	1.00
30	30.0	912.0	3600	1853	1	70	1	2	1.04	1.00	1.20	1.00	87.3	15.0	94.0	94.0	1853	1235	9.09E+01	3.20E+06	0.93	6.16E-04	1.06	-	-	-	-	0.00E+00	0.00E+00	0.000	1.7	1.00
35	35.0	907.0	4200	2141	1	70	1	2	0.97	1.00	1.20	1.00	81.2	15.0	87.6	87.6	2141	1427	8.88E+01	3.36E+06	0.89	6.54E-04	1.03	-	-	-	-	0.00E+00	0.00E+00	0.000	1.7	1.00
36.5																																

Total (in) 1.7

SEISMIC SETTLEMENT CALCULATIONS **I-10 Santa Ana River Bridge** **EMI Project No.** **08-103**

LIQUEFACTION ANALYSIS , M = 7.7 ; ACC. = 0.888 g

FORMULAE:

Corrected blow count	$(N_1)_{60}$	=	$C_N * C_s * C_E * C_R * C_B * C_{ST} * N_{field}$
where:	N_{field}	=	Uncorrected field blow count
	C_N	=	Overburden correction factor (See Reference 1)
	C_E	=	Energy correction (Reference 2) = (Efficiency/60%)
	C_R	=	Rod Length correction
	C_s	=	Sampler correction (lined/unlined) (Reference 3)
	C_B	=	Borehole diameter correction
	C_{ST}	=	Sampler correction (Sampler diameter)

$K_0 = (1-\sin(\phi))$

$\sigma_m' = (1+2K_0)/3*\sigma_{0f}'$

$(K_2)_{max} = 20*(N_1)^\wedge(1/3)$

$G_{max} = 1000*(K_2)_{max}*(\sigma_m')^\wedge(1/2)$

$\gamma_{eff}*G_{eff}/G_{max} = 0.65*(a_{max}/g)*(\sigma_{0f}'/G_{max})*r_d$

r_d = 1.0 at the ground surface,

= 0.9 at 30 feet below the ground surface

= 0.6 at 70 feet below the ground surface

= 0.5 at 100 feet below the ground surface

$\tau_{av}/\sigma_{0f}' = 0.65*(a_{max}/g)*(\sigma_{0f}/\sigma_{0f}')*r_d$

γ_{eff} for a given $\gamma_{eff}*G_{eff}/G_{max}$ and σ_m' is read from Figure 11 (Tokimatsu and Seed, 1987)

ε_c for a given γ_{eff} and N_1 is read from Figure 13 (Tokimatsu and Seed, 1987)

Efficiency (%)	=	60%	C_E	1.00
Borehole Dia. (in)	=	5	C_B	1.00
Soil Unit Weight (pcf)	=	120		

CALCULATIONS:

Boring:	**B-8**	**Boring El. (ft MLLW):**	**944.5**			**EQ Mag =**	**7.7**
Water depth (ft bgs): (during drilling)	**2.5**	**Groundwater El. (ft MLLW):**	**942.0**			**Mag Scale Factor =**	**0.935**
Water depth (ft bgs): (design depth)	**2.5**	**Finished Grade El. (ft MLLW):**	**944.5**	**Design GW El. (ft MLLW):**	**942.0**	**a_{max} =**	**0.888**
						Height of Fill (ftl) :	**0.0**

Original Depth (ft bgs)	Final Depth (ft bgs)	Elev (ft msl)	Total Stress at Mid depth (psf)	Original Effective Stress at Mid depth (psf)	Sampler SPT = 1 CDS = 2	Uncorrected Blow Count (N)*	Sampler 1=Unlined 2=Lined	Soil Type (1=fine-grained, 2=coarse-grained)	C_N	C_{ST}	C_s	C_r	$(N_1)_{60}$	Estimated Percentage of Fines (%)	(N1)60-CS (NCEER - used if layer does not liquefy)	(N1)60-CS (Seed - used if layer liquefies)	Design Effective Stress at Mid depth (psf)	σ_m' (psf)	$(K_2)_{max}$	G_{max} (psf)	r_d	$\gamma_{eff}\ G_{eff}/G_{max}$	τ_{av}/σ_{0f}'	Cyclic Shear Strain, γ_{eff} (%)			Volumetric Strain (Dry Sand) ε_c (%)	Volumetric Strain (Saturated Sand) ε_c (%)	$2*\varepsilon_c$ (dry); ε_c (saturtd.)	Settlement of Each Layer (inches)	Sum.	$CRR_{7.5}$
0			0																													
5	5.0	939.5	600	444	1	16	1	2	1.70	1.00	1.20	0.75	24.5	15.0	28.2	25.5	444	296	5.89E+01	1.01E+06	0.99	3.62E-04	0.82	-	-	-	-	1.16E+00	1.16E+00	0.696	0.70	0.38
10	10.0	934.5	1200	732	1	32	1	2	1.65	1.00	1.20	0.80	50.8	15.0	55.7	55.7	732	488	7.64E+01	1.69E+06	0.98	4.29E-04	0.99	-	-	-	-	0.00E+00	5.00E-01	0.300	1.0	1.00
15	15.0	929.5	1800	1020	1	32	1	2	1.40	1.00	1.20	0.85	45.7	15.0	50.4	50.4	1020	680	7.39E+01	1.93E+06	0.97	5.57E-04	1.05	-	-	-	-	0.00E+00	0.00E+00	0.000	1.0	1.00
20	20.0	924.5	2400	1308	1	22	1	2	1.24	1.00	1.20	0.95	31.0	15.0	35.0	35.0	1308	872	6.54E+01	1.93E+06	0.95	7.32E-04	1.08	-	-	-	-	0.00E+00	0.00E+00	0.000	1.0	1.00
25	25.0	919.5	3000	1596	1	70	1	2	1.12	1.00	1.20	0.95	89.3	15.0	96.1	96.1	1596	1064	9.16E+01	2.99E+06	0.94	5.84E-04	1.09	-	-	-	-	0.00E+00	0.00E+00	0.000	1.0	1.00
30	30.0	914.5	3600	1884	1	70	1	2	1.03	1.00	1.20	1.00	86.5	15.0	93.2	93.2	1884	1256	9.07E+01	3.21E+06	0.93	6.43E-04	1.10	-	-	-	-	0.00E+00	0.00E+00	0.000	1.0	1.00
35	35.0	909.5	4200	2172	1	48	1	2	0.96	1.00	1.20	1.00	55.3	15.0	60.4	60.4	2172	1448	7.85E+01	2.99E+06	0.89	7.72E-04	1.06	-	-	-	-	0.00E+00	0.00E+00	0.000	1.0	1.00
40	40.0	904.5	4800	2460	1	50	1	2	0.90	1.00	1.20	1.00	54.1	15.0	59.2	59.2	2460	1640	7.79E+01	3.16E+06	0.85	7.97E-04	1.02	-	-	-	-	0.00E+00	0.00E+00	0.000	1.0	1.00
45	45.0	899.5	5400	2748	1	43	1	2	0.85	1.00	1.20	1.00	44.0	15.0	48.6	48.6	2748	1832	7.30E+01	3.12E+06	0.81	8.62E-04	0.98	-	-	-	-	0.00E+00	5.00E-01	0.000	1.0	1.00
46.5																																

Total (in) **1.0**

SEISMIC SETTLEMENT CALCULATIONS | I-10 Waterman Ave UC Bridge | EMI Project No. 08-103

LIQUEFACTION ANALYSIS , M = 7.7 ; ACC. = 0.852 g

FORMULAE:

Corrected blow count	$(N_1)_{60}$	=	$C_N * C_s * C_E * C_R * C_B * C_{ST} * N_{field}$
where:	N_{field}	=	Uncorrected field blow count
	C_N	=	Overburden correction factor (See Reference 1)
	C_E	=	Energy correction (Reference 2) = (Efficiency/60%)
	C_R	=	Rod Length correction
	C_s	=	Sampler correction (lined/unlined) (Reference 3)
	C_B	=	Borehole diameter correction
	C_{ST}	=	Sampler correction (Sampler diameter)

Efficiency (%)	=	60%	C_E	1.00
Borehole Dia. (in)	=	5	C_B	1.00
Soil Unit Weight (pcf)	=	120		

$K_0 = (1-\sin(\phi))$

$\sigma_m' = (1+2K_0)/3*\sigma_{0f}'$

$(K_2)_{max} = 20*(N_1)$^(1/3)

$G_{max} = 1000*(K_2)_{max}*(\sigma_m')$^(1/2)

$\gamma_{eff}*G_{eff}/G_{max} = 0.65*(a_{max}/g)*(\sigma_{0f}'/G_{max})*r_d$

r_d = 1.0 at the ground surface,

= 0.9 at 30 feet below the ground surface

= 0.6 at 70 feet below the ground surface

= 0.5 at 100 feet below the ground surface

$\tau_{av}/\sigma_{0f}' = 0.65*(a_{max}/g)*(\sigma_{0f}/\sigma_{0f}')*r_d$

γ_{eff} for a given $\gamma_{eff}*G_{eff}/G_{max}$ and σ_m' is read from Figure 11 (Tokimatsu and Seed, 1987)

ε_c for a given γ_{eff} and N_1 is read from Figure 13 (Tokimatsu and Seed, 1987)

CALCULATIONS:

Boring:	**B-1**	**Boring El. (ft MLLW):**	**1016.0**		**EQ Mag =**	**7.7**
Water depth (ft bgs): (during drilling)	**5.0**	**Groundwater El. (ft MLLW):**	**1011.0**		**Mag Scale Factor =**	**0.935**
Water depth (ft bgs): (design depth)	**5.0**	**Finished Grade El. (ft MLLW):**	**1016.0**	**Design GW El. (ft MLLW): 1011.0**	**a_{max} =**	**0.852**
					Height of Fill (ftl) :	**0.0**

Original Depth (ft bgs)	Final Depth (ft bgs)	Elev (ft msl)	Total Stress at Mid depth (psf)	Original Effective Stress at Mid depth (psf)	Sampler SPT = 1 CDS = 2	Uncorrected Blow Count (N)*	Sampler 1=Unlined 2=Lined	Soil Type (1=fine-grained, 2=coarse-grained)	C_N	C_{ST}	C_s	C_r	$(N_1)_{60}$	Estimated Percentage of Fines (%)	(N1)60-CS (NCEER - used if layer does not liquefy)	(N1)60-CS (Seed - used if layer liquefies)	Design Effective Stress at Mid depth (psf)	σ_m' (psf)	$(K_2)_{max}$	G_{max} (psf)	r_d	$\gamma_{eff} G_{eff}/G_{max}$	τ_{av}/σ_{0f}'	Cyclic Shear Strain, γ_{eff} (%)			Volumetric Strain (Dry Sand) ε_c (%)	Volumetric Strain (Saturated Sand) ε_c (%)	$2*\varepsilon_c$ (dry); ε_c (saturtd.)	Settlement of Each Layer (inches)	Sum.	$CRR_{7.5}$
0			0																													
5	5.0	1011.0	600	600	1	6	1	2	1.70	1.00	1.20	0.75	9.2	15.0	12.1	10.2	600	400	4.33E+01	8.67E+05	0.99	4.05E-04	0.59	1.00E+02	-6.48E-07	#######	1.94E+02	2.47E+00	3.88E+02	0.000	0.00	0.13
10	10.0	1006.0	1200	888	1	19	1	2	1.50	1.00	1.20	0.80	27.4	15.0	31.2	31.2	888	592	6.30E+01	1.53E+06	0.98	4.53E-04	0.78	-	-	-	-	0.00E+00	0.00E+00	0.000	0.0	0.58
15	15.0	1001.0	1800	1176	1	5	1	1	1.30	1.00	1.20	0.85	-	90.0	-	-	1176	784	-	-	0.97	-	0.88	-	-	-	-	-	3.00E-01	0.000	0.0	1.00
20	20.0	996.0	2400	1464	1	8	1	1	1.17	1.00	1.20	0.95	-	90.0	-	-	1464	976	-	-	0.95	-	0.93	-	-	-	-	-	4.00E-01	0.000	0.0	1.00
25	25.0	991.0	3000	1752	1	23	1	2	1.07	1.00	1.20	0.95	28.0	15.0	31.9	31.9	1752	1168	6.34E+01	2.17E+06	0.94	7.73E-04	0.96	-	-	-	-	0.00E+00	0.00E+00	0.000	0.0	0.70
30	30.0	986.0	3600	2040	1	39	1	2	0.99	1.00	1.20	1.00	46.3	15.0	51.1	51.1	2040	1360	7.42E+01	2.74E+06	0.93	7.25E-04	0.97	-	-	-	-	0.00E+00	5.00E-01	0.000	0.0	1.00
35	35.0	981.0	4200	2328	1	35	1	2	0.93	1.00	1.20	1.00	38.9	15.0	43.3	43.3	2328	1552	7.02E+01	2.77E+06	0.89	8.00E-04	0.95	-	-	-	-	0.00E+00	4.00E-01	0.000	0.0	1.00
40	40.0	976.0	4800	2616	1	9	1	1	0.87	1.00	1.20	1.00	-	90.0	-	-	2616	1744	-	-	0.85	-	0.92	-	-	-	-	-	4.00E-01	0.000	0.0	1.00
45	45.0	971.0	5400	2904	1	11	1	1	0.83	1.00	1.20	1.00	-	90.0	-	-	2904	1936	-	-	0.81	-	0.89	-	-	-	-	-	3.00E-01	0.000	0.0	1.00
50	50.0	966.0	6000	3192	1	100	1	2	0.79	1.00	1.20	1.00	95.0	15.0	102.1	102.1	3192	2128	9.35E+01	4.31E+06	0.77	6.33E-04	0.85	-	-	-	-	0.00E+00	3.00E-01	0.000	0.0	1.00
60	60.0	956.0	7200	3768	1	100	1	2	0.73	1.00	1.20	1.00	87.4	15.0	94.1	94.1	3768	2512	9.10E+01	4.56E+06	0.69	6.42E-04	0.78	-	-	-	-	0.00E+00	3.00E-01	0.000	0.0	1.00
61.5																																

Total (in) 0.0

SEISMIC SETTLEMENT CALCULATIONS — **I-10 San Timoteo Creek Bridge** — **EMI Project No. 08-103**

LIQUEFACTION ANALYSIS , M = 7.7 ; ACC. = 0.855 g

FORMULAE:

Corrected blow count	$(N_1)_{60}$	=	$C_N * C_s * C_E * C_R * C_B * C_{ST} * N_{field}$
where:	N_{field}	=	Uncorrected field blow count
	C_N	=	Overburden correction factor (See Reference 1)
	C_E	=	Energy correction (Reference 2) = (Efficiency/60%)
	C_R	=	Rod Length correction
	C_s	=	Sampler correction (lined/unlined) (Reference 3)
	C_B	=	Borehole diameter correction
	C_{ST}	=	Sampler correction (Sampler diameter)

Efficiency (%)	=	60%	C_E	1.00
Borehole Dia. (in)	=	5	C_B	1.00
Soil Unit Weight (pcf)	=	120		

$K_0 = (1-\sin(\phi))$

$\sigma_m' = (1+2K_0)/3*\sigma_{0f}'$

$(K_2)_{max} = 20*(N_1)$^(1/3)

$G_{max} = 1000*(K_2)_{max}*(\sigma_m')$^(1/2)

$\gamma_{eff}*G_{eff}/G_{max} = 0.65*(a_{max}/g)*(\sigma_{0f}'/G_{max})*r_d$

r_d = 1.0 at the ground surface,

= 0.9 at 30 feet below the ground surface

= 0.6 at 70 feet below the ground surface

= 0.5 at 100 feet below the ground surface

$\tau_{av}/\sigma_{0f}' = 0.65*(a_{max}/g)*(\sigma_{0f}/\sigma_{0f}')*r_d$

γ_{eff} for a given $\gamma_{eff}*G_{eff}/G_{max}$ and σ_m' is read from Figure 11 (Tokimatsu and Seed, 1987)

ε_c for a given γ_{eff} and N_1 is read from Figure 13 (Tokimatsu and Seed, 1987)

CALCULATIONS:

Boring:	**B-1**	**Boring El. (ft MLLW):**	**1027.0**			**EQ Mag =**	**7.7**
Water depth (ft bgs): (during drilling)	**5.0**	**Groundwater El. (ft MLLW):**	**1022.0**			**Mag Scale Factor =**	**0.935**
				Design GW El. (ft MLLW):	**1022.0**	**a_{max} =**	**0.855**
Water depth (ft bgs): (design depth)	**5.0**	**Finished Grade El. (ft MLLW):**	**1027.0**			**Height of Fill (ftl) :**	**0.0**

Original Depth (ft bgs)	Final Depth (ft bgs)	Elev (ft msl)	Total Stress at Mid depth (psf)	Original Effective Stress at Mid depth (psf)	Sampler SPT = 1 CDS = 2	Uncorrected Blow Count (N)*	Sampler 1=Unlined 2=Lined	Soil Type (1=fine-grained, 2=coarse-grained)	C_N	C_{ST}	C_s	C_r	$(N_1)_{60}$	Estimated Percentage of Fines (%)	(N1)60-CS (NCEER - used if layer does not liquefy)	(N1)60-CS (Seed - used if layer liquefies)	Design Effective Stress at Mid depth (psf)	σ_m' (psf)	$(K_2)_{max}$	G_{max} (psf)	r_d	$\gamma_{eff}G_{eff}/G_{max}$	τ_{av}/σ_{0f}'	Cyclic Shear Strain, γ_{eff} (%)			Volumetric Strain (Dry Sand) ε_c (%)	Volumetric Strain (Saturated Sand) ε_c (%)	$2*\varepsilon_c$ (dry); ε_c (saturtd.)	Settlement of Each Layer (inches)	Sum.	$CRR_{7.5}$
0			0																													
5	5.0	1022.0	600	600	1	4	1	2	1.70	1.00	1.20	0.75	6.1	15.0	8.9	7.1	600	400	3.85E+01	7.70E+05	0.99	4.58E-04	0.59	1.00E+02	-6.48E-07	######	3.18E+02	3.08E+00	6.36E+02	0.000	0.00	0.10
10	10.0	1017.0	1200	888	1	8	1	1	1.50	1.00	1.20	0.80	-	90.0	-	-	888	592	-	-	0.98	-	0.78	-	-	-	-	-	3.00E-01	0.180	0.2	1.00
15	15.0	1012.0	1800	1176	1	23	1	2	1.30	1.00	1.20	0.85	30.6	15.0	34.6	34.6	1176	784	6.51E+01	1.82E+06	0.97	5.66E-04	0.88	-	-	-	-	0.00E+00	3.00E-01	0.180	0.4	1.00
20	20.0	1007.0	2400	1464	1	14	1	2	1.17	1.00	1.20	0.95	18.7	15.0	22.0	19.7	1464	976	5.40E+01	1.69E+06	0.95	8.07E-04	0.93	-	-	-	-	1.45E+00	1.45E+00	0.867	1.2	0.24
25	25.0	1002.0	3000	1752	1	25	1	2	1.07	1.00	1.20	0.95	30.5	15.0	34.4	34.4	1752	1168	6.51E+01	2.22E+06	0.94	7.56E-04	0.96	-	-	-	-	0.00E+00	5.00E-01	0.300	1.5	1.00
30	30.0	997.0	3600	2040	1	45	1	2	0.99	1.00	1.20	1.00	53.5	15.0	58.5	58.5	2040	1360	7.77E+01	2.86E+06	0.93	6.95E-04	0.98	-	-	-	-	0.00E+00	5.00E-01	0.000	1.5	1.00
35	35.0	992.0	4200	2328	1	52	1	2	0.93	1.00	1.20	1.00	57.8	15.0	63.1	63.1	2328	1552	7.96E+01	3.14E+06	0.89	7.08E-04	0.95	-	-	-	-	0.00E+00	5.00E-01	0.000	1.5	1.00
40	40.0	987.0	4800	2616	1	44	1	2	0.87	1.00	1.20	1.00	46.2	15.0	50.9	50.9	2616	1744	7.41E+01	3.10E+06	0.85	7.82E-04	0.93	-	-	-	-	0.00E+00	4.00E-01	0.000	1.5	1.00
50	50.0	977.0	6000	3192	1	15	1	1	0.79	1.00	1.20	1.00	-	90.0	-	-	3192	2128	-	-	0.77	-	0.86	-	-	-	-	-	3.00E-01	0.270	1.8	1.00
55	55.0	972.0	6600	3480	1	24	1	2	0.76	1.00	1.20	1.00	21.8	15.0	25.4	22.8	3480	2320	5.67E+01	2.73E+06	0.73	1.04E-03	0.82	-	-	-	-	1.26E+00	1.26E+00	1.134	2.9	0.30
65	65.0	962.0	7800	4056	1	35	1	2	0.70	1.00	1.20	1.00	29.5	15.0	33.4	33.4	4056	2704	6.44E+01	3.35E+06	0.64	8.93E-04	0.74	-	-	-	-	0.00E+00	0.00E+00	0.000	2.9	1.00
66.5																																

Total (in) 2.9

SEISMIC SETTLEMENT CALCULATIONS | **I-10 San Timoteo Creek WB On-Ramp Bridge** | **EMI Project No.** **08-103**

LIQUEFACTION ANALYSIS , M = 7.5 ; ACC. = 0.806 g

FORMULAE:

Corrected blow count	$(N_1)_{60}$	=	$C_N * C_s * C_E * C_R * C_B * C_{ST} * N_{field}$
where:	N_{field}	=	Uncorrected field blow count
	C_N	=	Overburden correction factor (See Reference 1)
	C_E	=	Energy correction (Reference 2) = (Efficiency/60%)
	C_R	=	Rod Length correction
	C_s	=	Sampler correction (lined/unlined) (Reference 3)
	C_B	=	Borehole diameter correction
	C_{ST}	=	Sampler correction (Sampler diameter)

Efficiency (%)	=	75%	C_E	1.25
Borehole Dia. (in)	=	5	C_B	1.00
Soil Unit Weight (pcf)	=	120		

$K_0 = (1-\sin(\phi))$

$\sigma_m' = (1+2K_0)/3*\sigma_{0f}'$

$(K_2)_{max} = 20*(N_1)\text{^}(1/3)$

$G_{max} = 1000*(K_2)_{max}*(\sigma_m')\text{^}(1/2)$

$\gamma_{eff}*G_{eff}/G_{max} = 0.65*(a_{max}/g)*(\sigma_{0f}'/G_{max})*r_d$

r_d = 1.0 at the ground surface,

= 0.9 at 30 feet below the ground surface

= 0.6 at 70 feet below the ground surface

= 0.5 at 100 feet below the ground surface

$\tau_{av}/\sigma_{0f}' = 0.65*(a_{max}/g)*(\sigma_{0f}/\sigma_{0r})*r_d$

γ_{eff} for a given $\gamma_{eff}*G_{eff}/G_{max}$ and σ_m' is read from Figure 11 (Tokimatsu and Seed, 1987)

ε_c for a given γ_{eff} and N_1 is read from Figure 13 (Tokimatsu and Seed, 1987)

CALCULATIONS:

Boring:	**B-1**	**Boring El. (ft MLLW):**	**1022.0**		**EQ Mag =** **7.5**
Water depth (ft bgs): (during drilling)	**14.0**	**Groundwater El. (ft MLLW):**	**1008.0**		**Mag Scale Factor =** **1.000**
Water depth (ft bgs): (design depth)	**14.0**	**Finished Grade El. (ft MLLW):**	**1022.0**	**Design GW El. (ft MLLW):** **1008.0**	a_{max} **=** **0.806**
					Height of Fill (ftl) : **0.0**

Original Depth (ft bgs)	Final Depth (ft bgs)	Elev (ft msl)	Total Stress at Mid depth (psf)	Original Effective Stress at Mid depth (psf)	Sampler SPT = 1 CDS = 2	Uncorrected Blow Count (N)*	Sampler 1=Unlined 2=Lined	Soil Type (1=fine-grained, 2=coarse-grained)	C_N	C_{ST}	C_s	C_r	$(N_1)_{60}$	Estimated Percentage of Fines (%)	(N1)60-CS (NCEER - used if layer does not liquefy)
0			0												
1	1.0	1021.0	120	120	2	24	2	2	1.70	0.50	1.00	0.75	19.1	15.0	22.5
2.5	2.5	1019.5	300	300	2	30	2	2	1.70	0.50	1.00	0.75	23.9	15.0	27.6
5	5.0	1017.0	600	600	1	15	1	1	1.70	1.00	1.20	0.75	-	90.0	-
7.5	7.5	1014.5	900	900	2	14	2	1	1.49	0.50	1.00	0.75	-	90.0	-
10	10.0	1012.0	1200	1200	1	9	1	2	1.29	1.00	1.20	0.80	13.9	25.0	19.8
12.5	12.5	1009.5	1500	1500	2	15	2	2	1.15	0.50	1.00	0.80	8.7	15.0	11.6
15	15.0	1007.0	1800	1738	1	9	1	2	1.07	1.00	1.20	0.85	12.3	15.0	15.4
20	20.0	1002.0	2400	2026	1	14	1	2	0.99	1.00	1.20	0.95	19.8	15.0	23.3
25	25.0	997.0	3000	2314	2	20	2	2	0.93	0.50	1.00	0.95	11.0	50.0	18.2
30	30.0	992.0	3600	2602	1	24	1	2	0.88	1.00	1.20	1.00	31.6	15.0	35.6
35	35.0	987.0	4200	2890	1	68	1	2	0.83	1.00	1.20	1.00	84.9	15.0	91.4
40	40.0	982.0	4800	3178	1	48	1	2	0.79	1.00	1.20	1.00	57.1	15.0	62.4
45	45.0	977.0	5400	3466	1	16	1	2	0.76	1.00	1.20	1.00	18.2	15.0	21.6
50	50.0	972.0	6000	3754	1	22	1	2	0.73	1.00	1.20	1.00	24.1	15.0	27.7
55	55.0	967.0	6600	4042	1	23	1	2	0.70	1.00	1.20	1.00	24.3	15.0	27.9
60	60.0	962.0	7200	4330	1	16	1	1	0.68	1.00	1.20	1.00	-	90.0	-
65	65.0	957.0	7800	4618	1	43	1	2	0.66	1.00	1.20	1.00	42.4	15.0	47.0
70	70.0	952.0	8400	4906	1	26	1	2	0.64	1.00	1.20	1.00	24.9	15.0	28.6
71.5															

Original Depth (ft bgs)	(N1)60-CS (Seed - used if layer liquefies)	Design Effective Stress at Mid depth (psf)	σ_m' (psf)	$(K_2)_{max}$	G_{max} (psf)	r_d	$\gamma_{eff}\,G_{eff}/G_{max}$	τ_{av}/σ_{0f}'	Cyclic Shear Strain, γ_{eff} (%)			Volumetric Strain (Dry Sand) ε_c (%)	Volumetric Strain (Saturated Sand) ε_c (%)	$2*\varepsilon_c$ (dry); ε_c (saturtd.)	Settlement of Each Layer (inches)	Sum.	$CRR_{7.5}$
0																	
1	-	120	80	5.65E+01	5.05E+05	1.00	1.24E-04	-	-	#N/A	#N/A	-	-	0.00E+00	0.000	0.00	0.25
2.5	-	300	200	6.04E+01	8.54E+05	0.99	1.83E-04	-	2.12E-01	-3.70E+00	-2.52E+00	1.45E-01	-	0.00E+00	0.000	0.0	0.35
5	-	600	400	-	-	0.99	-	-	-	-	-	-	-	0.00E+00	0.000	0.0	1.00
7.5	-	900	600	-	-	0.98	-	-	-	-	-	-	-	0.00E+00	0.000	0.0	1.00
10	-	1200	800	5.41E+01	1.53E+06	0.98	4.01E-04	-	2.05E+00	-1.69E+00	-1.33E+00	2.22E+00	-	4.44E+00	0.000	0.0	0.21
12.5	-	1500	1000	4.52E+01	1.43E+06	0.97	5.33E-04	-	5.14E+00	-2.00E+00	-8.88E-07	1.09E+01	-	2.18E+01	0.000	0.0	0.13
15	13.3	1738	1158	4.74E+01	1.61E+06	0.97	5.64E-04	0.52	-	-	-	-	2.10E+00	2.10E+00	0.945	0.9	0.16
20	20.8	2026	1350	5.50E+01	2.02E+06	0.95	5.93E-04	0.59	-	-	-	-	1.37E+00	1.37E+00	0.822	1.8	0.26
25	13.0	2314	1542	4.71E+01	1.85E+06	0.94	8.01E-04	0.64	-	-	-	-	2.10E+00	2.10E+00	1.260	3.0	0.19
30	35.6	2602	1734	6.58E+01	2.74E+06	0.93	6.41E-04	0.67	-	-	-	-	0.00E+00	0.00E+00	0.000	3.0	1.00
35	91.4	2890	1926	9.01E+01	3.95E+06	0.89	4.95E-04	0.68	-	-	-	-	0.00E+00	0.00E+00	0.000	3.0	1.00
40	62.4	3178	2118	7.93E+01	3.65E+06	0.85	5.85E-04	0.67	-	-	-	-	0.00E+00	0.00E+00	0.000	3.0	1.00
45	19.2	3466	2310	5.36E+01	2.58E+06	0.81	8.87E-04	0.66	-	-	-	-	1.45E+00	1.45E+00	0.000	3.0	0.24
50	25.1	3754	2502	5.85E+01	2.93E+06	0.77	8.23E-04	0.64	-	-	-	-	1.16E+00	1.16E+00	0.000	3.0	0.36
55	25.3	4042	2694	5.87E+01	3.05E+06	0.73	8.25E-04	0.62	-	-	-	-	1.16E+00	1.16E+00	0.000	3.0	0.37
60	-	4330	2886	-	-	0.69	-	0.60	-	-	-	-	-	0.00E+00	0.000	3.0	1.00
65	47.0	4618	3078	7.22E+01	4.00E+06	0.64	6.58E-04	0.57	-	-	-	-	0.00E+00	0.00E+00	0.000	3.0	1.00
70	25.9	4906	3270	5.92E+01	3.38E+06	0.60	7.86E-04	0.54	-	-	-	-	1.16E+00	1.16E+00	0.000	3.0	0.39
71.5																	

Total (in) **3.0**