Earth Mechanics, Inc.

Geotechnical & Earthquake Engineering

July 29, 2020

EMI Project No. 20-126

HNTB Corporation
200 E Sandpointe Avenue, Suite 200
Santa Ana, CA 92707

Attention: Mr. Yung-Nien Wang, PE

Subject: **Preliminary Geotechnical Report**
XpressWest Extension Project
Rancho Cucamonga to Apple Valley, California

Dear Mr. Wang:

Attached is our Preliminary Geotechnical Report for the proposed XpressWest Extension Project. This report is prepared to support the preliminary 15% design phase of the project.

The recommendations and conclusions provided in this report are based on available subsurface soil information. These conclusions and recommendations are considered preliminary and should be verified in the future by conducting additional site-specific geotechnical field investigations, laboratory testing, and engineering analyses.

We appreciate the opportunity to provide geotechnical services for this project. If you have any questions, please do not hesitate to contact us.

Sincerely,

EARTH MECHANICS, INC.

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1.0 PROJECT DESCRIPTION

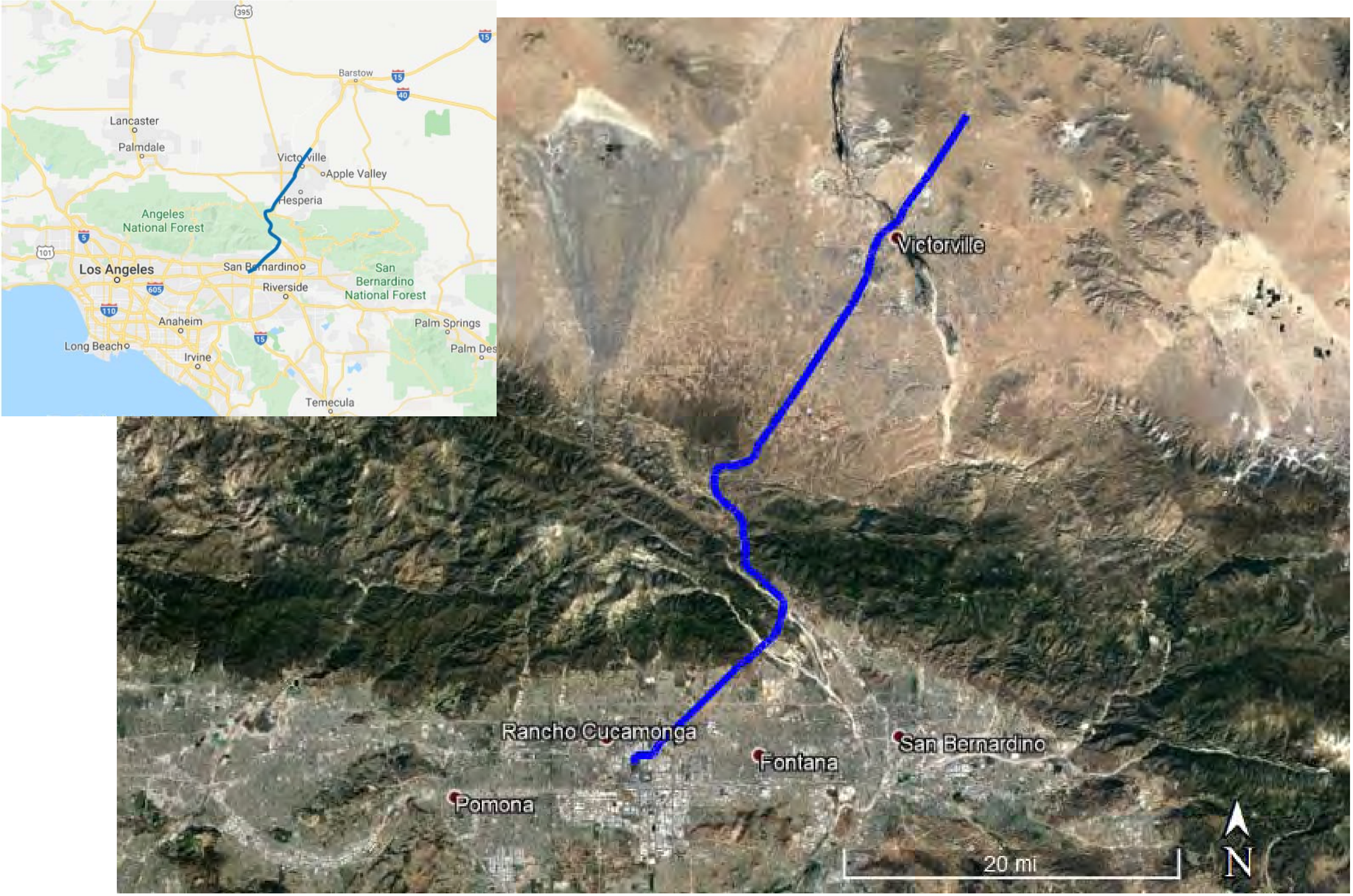
The XpressWest Extension is a Federally authorized high speed passenger railroad that proposes to connect Rancho Cucamonga and Apple Valley. The route will be a 50-mile track through the Cajon Pass into Rancho Cucamonga and an expansion of the planned XpressWest service from Apple Valley to Las Vegas. The proposed alignment will generally follow the existing Caltrans' right of way through the Cajon Pass, along the Interstate 15 freeway and connect with the Rancho Cucamonga Metrolink station. The fully electric high-speed trains would make the trip along the I-15 corridor to Las Vegas at speeds in excess of 150 mph.

The main proposed improvements of the project include construction of over 50 miles of single and double track that travels along the I-15 freeway and crosses existing bridges. The HSR track alignment will travel parallel to and within I-15 freeway corridor and adjacent to the bent supports of the existing bridges. Several existing structures will also be replaced as part of the overall project. The project location is presented in Figure 1.

2.0 SCOPE OF WORK

This Preliminary Geotechnical Report (PGR) has been prepared to provide preliminary geotechnical information for the XpressWest Extension alignment and to assist the structural designers in the preliminary phase of the XpressWest Extension project. The preliminary recommendations provided in this report are based on subsurface information contained on the as-built Log-of-Test-Borings (LOTB) sheets included in Appendix A. A site-specific geotechnical investigation will be performed for these bridges during the final design phase; therefore, the following preliminary recommendations require verification when additional site-specific information becomes available.

The geotechnical scope of work included: (1) reviewing available geotechnical/geologic information including reports, published geologic maps, and seismic hazard reports, (2) reviewing as-built plans of nearby existing bridges, (3) reviewing preliminary structure exhibits prepared by the structural designers; and, (4) assessing the foundation types for the proposed bridge structures. The geotechnical and geologic references reviewed for this project are listed in the references section of this report.



Earth Mechanics, Inc. **Geotechnical and Earthquake Engineering**	XpressWest Extension	Project Location
	Project No. 20-126	Date: July 2020	Figure 1

3.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

3.1 Regional Geology

The XpressWest Extension track alignment extends across three distinct geomorphic provinces through highly varied, faulted, and complex geology. From the southern terminus in Rancho Cucamonga, the alignment begins in the northern portion of the Peninsular Ranges Province. Near the juncture of the Sierra Madre (Cucamonga segment) and San Jacinto (Lytle Creek segment) faults, the alignment crosses into the mountainous terrain of the Transverse Ranges Province, and traverses Cajon Canyon between the San Gabriel Mountains and San Bernardino Mountains. Within the Transverse Ranges, the alignment crosses the San Jacinto, San Andreas, and Cleghorn fault zones. Descending from Cajon Summit, the alignment then enters the Mojave Desert Province about 12 miles southwest of Victorville. The discussion of geologic conditions along alignment will be in three sections, subdivided generally by geomorphic province. Regional geologic maps are presented in Figures 2-6.

3.1.1 Peninsular Ranges Geomorphic Province, Rancho Cucamonga Section, Sta.12929+00 to Sta. 12100+00

From Rancho Cucamonga to Sierra Avenue, the alignment proceeds northwesterly across large alluvial fans emanating from the San Gabriel Mountains to the north. Topography is generally level, with a regional slope of about 2.5% down to the south. At the base of the mountains is the east-west trending Cucamonga segment of the Sierra Madre thrust fault. Headwaters of local creeks originate in the nearby San Gabriel Mountains and drainage is to the south. Most local creeks have been channelized for flood control and urban development. Creeks crossed by the alignment include the Day Canyon Channel and the East Etiwanda Creek. The Day Canyon Channel is located at Sta 12523+00 and, to the west of the I-15/I-210 interchange, near Sta. 12364+00, the alignment crosses East Etiwanda Creek. A large flood control catch basin is located to the north of the alignment at the I-15/I-210 interchange for control of stormwater from winter rains.

This portion of the alignment crosses Quaternary (less than 2.6 million years old) and Holocene (less than 11,000 years old) aged alluvial fan sediments consisting of unconsolidated to slightly consolidated, dense, sand and silty sand with granitic gravel, cobbles, and boulders. Overall, sediments generally become more coarse-grained with higher percentages of gravels, cobbles, and boulders to the northwest as the alignment comes closer to the base of the San Gabriel Mountains.

Within the Peninsular Ranges geomorphic province, the alignment does not cross any faults. The alignment does come within 1000 feet of the Sierra Madre fault from approximately Sta. 12131+00 to 12155+50 and at Sta.12102+00, the eastern terminus of the fault. The alignment is located south of the fault and oriented subparallel to the fault.

3.1.2 Transverse Ranges Geomorphic Province, Mountain and Cajon Pass Section, Sta. 12100+00 to Sta. 11200+00

The Transverse Ranges geomorphic province section is the most geologically complex portion of the proposed alignment. From Sierra Avenue to Oak Hill Road, the alignment passes through the mountainous Transverse Ranges geomorphic province, across the faulted boundary between the Pacific and North American tectonic plates, and over Cajon Pass before descending into the Mojave Desert. Elevations range between about 2000 feet at Lytle Creek to about 4200 feet at Cajon Pass. Within this section, the alignment crosses the San Bernardino segments of the San Jacinto and San Andreas fault zones. Together, the San Jacinto and San Andreas fault zones accommodate up to 80% of the slip rate between the North American and Pacific plates.

Major drainages include the northwest trending Lytle and Cajon Creeks. The orientation of both creeks is controlled by the San Jacinto and San Andreas faults. Lytle Creek is crossed by the alignment approximately between Sta. 12073+00 to Sta.12053+00. Just south of the I-15/I-215 interchange, Cajon Creek is crossed by the alignment approximately between Sta. 11915+00 to Sta. 11909+00.

Due to extensive faulting, subsurface conditions are highly variable within this section and defy broad generalization. Geologic units include Quaternary alluvium, Cenozoic sandstone and conglomerates, Cenozoic and Cretaceous aged granitics, and Mesozoic aged metamorphic rocks. Bedrock may be locally shallow.

The alignment crosses the San Jacinto, San Andreas, and Cleghorn faults within this section. The San Jacinto fault zone is a right-lateral Holocene-active fault with multiple strands and is zoned in accordance with the Alquist-Priolo Act. The fault is capable of producing a M7.7 earthquake. The width of the fault zone extends approximately 2.7 miles and includes the Lytle Creek, San Jacinto, and Glen Helen fault strands. The alignment crosses the fault at approximately Sta. 12109+80 (Lytle Creek fault strand), Sta. 11992+50 (San Jacinto fault strand), and Sta. 11943+80 (Glen Helen fault strand). Bridges less than 1000 ft from fault crossings include Sierra Ave., Lytle Creek, Glen Helen Parkway, and Glen Helen Road.

The San Andreas fault zone is a right-lateral Holocene-active fault and is zoned in accordance with the Alquist-Priolo Act. The fault is capable of producing a M7.9 earthquake. The alignment crosses a secondary strand of the fault (the Peters fault) at Kenwood Avenue at Sta. 11836+50 and the main fault at Oakie Flats at Sta. 11705+50. Bridges less than 1000 ft from fault crossings include Kenwood Avenue and Oakie Flats. Cleghorn Creek Bridge near Sta. 11652+00 is located within a mapped Alquist Priolo (AP) fault zone, but a previous Caltrans fault rupture evaluation found that the inferred fault strand is more than 15,000 years old and dismissed likelihood of surface rupture at the bridge.

The Southern Cleghorn section of the Cleghorn fault is a left-lateral fault and is dated as late Quaternary (less than 130,000 years old) in age by the USGS, while the Caltrans fault database dates it as Holocene active. It is not an AP-zoned fault. While Meisling (1984), considered the Southern Cleghorn section to have features indicative of Holocene surface rupture, Bryant (1987) believed the Holocene-aged features to be due to landsliding, not tectonic forces. The fault is capable of producing a M6.7 earthquake. The fault crosses the alignment at an oblique angle near

Sta. 1158+00 and is less than 1000 ft from alignment from about Sta.11506+00 to 11585+00. Bridges less than 1000 ft from the fault crossing include Cleghorn Rd and Brush Creek.

3.1.3 Mojave Desert Geomorphic Province, Apple Valley Section, Sta. 11200+00 to Sta. 10037+00

From Oak Hill Road to the XpressWest Extension terminus in Apple Valley, the alignment is within the Mojave Desert geomorphic province. The province is characterized by isolated mountain ranges, separated by expanses of desert plains, and broad playas. Most of the area is undeveloped, open desert terrain with extensive soil and rock exposures and sparse vegetation. Victorville is the only urban area in this section of the alignment. Elevations range from a high of about 4095 feet at Oak Hill Road to a low of about 2720 feet at the Mojave River.

The alignment crosses the California Aqueduct, which conveys water from Northern and Central California to Southern California, near Sta. 10911+00. The major river drainage in this section is the Mojave River. The Mojave River originates in the eastern slopes of the San Bernardino Mountains and flows northeastward for approximately 100 miles, terminating at the dry Soda Lake near Baker, in eastern California. Except for during extreme floods, most of the river’s flow is underground with the surface channels remaining dry. The alignment crosses the river between about Sta. 10410+00 and Sta. 10404+00

Most of the proposed alignment crosses alluviated areas underlain by Quaternary (less than 2.6 million years old) sediments. The Quaternary deposits include unconsolidated Holocene (less than 11,000 years old) sediments and generally more consolidated Pleistocene (11,000 to 2.6 million years old) alluvial fan and playa deposits. Shallow granitic bedrock, mostly quartz monzonite and granodiorite, may be present at Stoddard Wells Rd overcrossing and Bell Mountain Wash.

4.0 PRELIMINARY SEISMIC INFORMATION AND RECOMMENDATIONS

4.1 Faulting and Seismicity

The project area is located in seismically active southern California and is subject to shaking from both local and distant earthquakes. The XpressWest Extension alignment spans across a region of complex active faulting. The project alignment is crossed by or comes within 1000 feet of four major faults: the Sierra Madre (Cucamonga section), the San Jacinto (San Bernardino Valley section which includes the Lytle Creek, San Jacinto, and Glen Helen fault strands), the San Andreas (San Bernardino section), and the Cleghorn (Southern Cleghorn section). In accordance with Caltrans Memo To Designers 20-10 (Caltrans, 2013), the track alignment does have structures which fall within an Alquist-Priolo Earthquakes Fault Zone or within 1,000 ft of an unzoned fault that is Holocene or younger in age; therefore, further fault studies will be necessary.

Other major regional faults which do not cross the XpressWest Extension alignment include: the Red Hill-Etiwanda Ave, Fontana Seismic Trend, Waterman Canyon, Tunnel Ridge, Arraste Canyon Narrows, North Frontal Thrust, San Antonio, and Helendale-South Lockhart faults.

Fault details are summarized in Table 1 and regional faults are shown in Figure 7 with details of Alquist-Priolo fault zones shown in Figures 8-10.

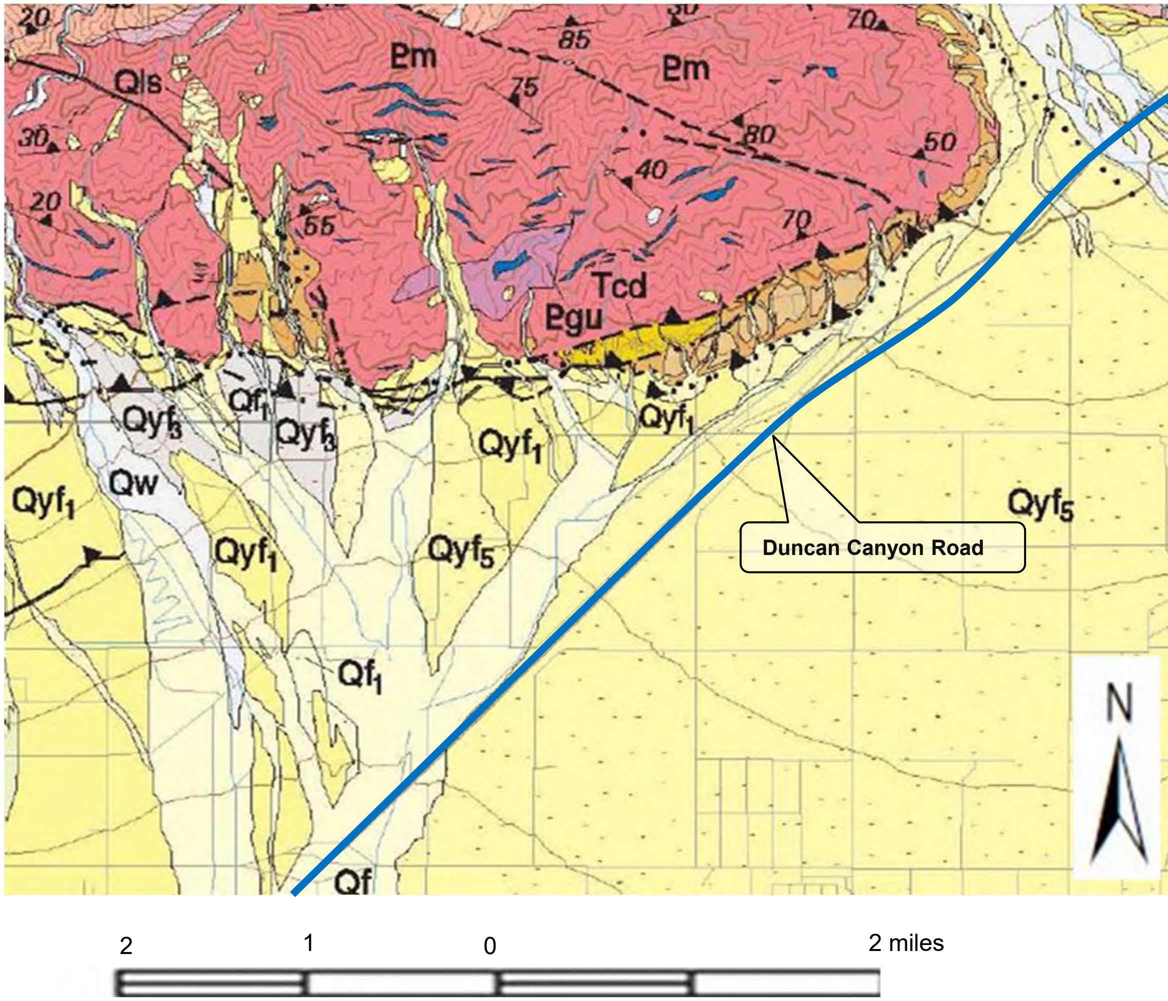
Table 1. Fault Data

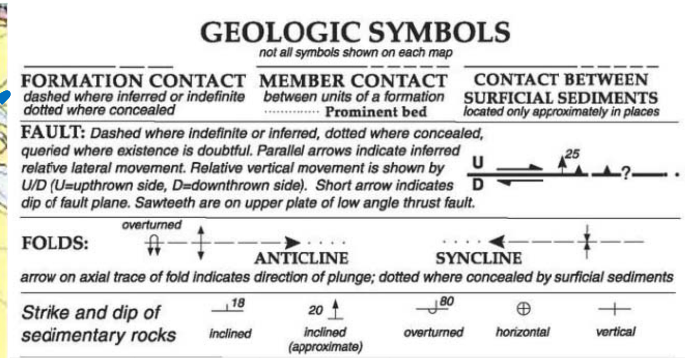
Fault	Crosses Alignment, Approx. Sta.	Nearest Structure(s)	Dist., km	Fault Type[1]	Slip Rate, mm/yr	Max Fault Surface Rupture Displacement[2] (ft)	Avg Strike of Fault	Dip	Fault Length, km	Fault Age[3]	Mag	AP Fault Zone?	Structure Outside AP Zone?
Sierra Madre (Cucamonga Section)	Does not cross	Duncan Canyon Rd	0.5	R	1.0-5.0	-	N78E	45	135	H	6.6	Yes	Yes
San Jacinto (San Bernardino Section)	Crosses at:			RL	16.1	23	N58W	65-90	244	H	7.7	Yes	
	~Sta. 12091+50	Sierra Ave	0.2										No
	~Sta. 12109+80	Lytle Creek Br	0.3										Yes
	~Sta. 11992+50	Glen Helen Pkwy	0.3										Yes
	~Sta. 11943+80	Glen Helen Rd	0.2										Yes
San Andreas (San Bernardino Mtns Section)	Crosses at:			RL	12.8 mm/yr	33	N79W	V	1100	H	7.9	Yes	No
	~Sta. 11836+50	Kenwood Ave	0, crosses structure										
	~Sta. 11705+50	Oakie Flats	0, crosses structure										
	~Sta. 11688+00 (Strand is >11k yr.)	Cleghorn Creek Bridge	0.9										
Cleghorn (Cleghorn Southern Section)	~Sta. 1158+00	Cleghorn Rd	0.2	LL	2.0-3.3	2.5	N82W	85	25	LQ/H	6.7	No	Yes
		Brush Creek Br	0.2										
Helendale-South Lockhart	834+50 (Crosses next segment of alignment.)	Quarry Rd Br	7.4	RL	0.2-1.0	13	N39W	North	35	H	7.4	Yes	Yes
Red Hill Etiwanda Ave	Does not cross	SR-210	2.8	LL	N/A	-	N60E	N50	15	H	6.2	Yes, NE portion	Yes
Fontana Seismic Trend	Does not cross	SR-210	5.1	LL	N/A	-	N39E	N80	9	H	6.5	No	Yes
Waterman Canyon	Does not cross	Cajon Wash/Cajon Blvd	4.1	R	N/A	-	N95E	N45	29	LQ	6.7	No	N/A

Fault	Crosses Alignment, Approx. Sta.	Nearest Structure(s)	Dist., km	Fault Type[1]	Slip Rate, mm/yr	Max Fault Surface Rupture Displacement[2] (ft)	Avg Strike of Fault	Dip	Fault Length, km	Fault Age[3]	Mag	AP Fault Zone?	Structure Outside AP Zone?
Tunnel Ridge	Does not cross	Cajon Wash/Cajon Blvd	17.3	LL	N/A	-	N45E	V	18	LQ	6.4	No	N/A
North Frontal Thrust	Does not cross	La Mesa Nisqualli Rd	15	R	0.2-1.0	-	N87W	S30-35	67	H	7.2	Yes	N/A
Arraste Canyon Narrows	Does not cross	Bear Valley Rd	21.3	R	N/A	-	N50E	V	11	LQ	6.2	No	N/A
San Antonio	Does not cross	SR-138	16.5	RL	N/A	-	N25E	V	25	LQ	6.5	No	N/A

Notes:

(1) RL=Right-lateral, LL=Left-lateral, R=Reverse
(2) Based on relationship between surface fault displacement and moment magnitude for strike-slip faulting (Wells and Coppersmith, 1994)
(3) H=Holocene, LQ=Late Quaternary





Qw, Qw_1, Qw_2	Very young wash deposits
Qf_1	Very young alluvial fan deposits
Qaf	Artificial fill
Qyf, Qyf_1, Qyf_2, Qyf_3, Qyf_4, Qyf_5	Young alluvial fan deposits
Qya	Young axial channel deposits
Qls	Landslide deposits
Qdg	Disturbed ground
Tcd	Conglomerate and sandstone
Tgtp	Granodiorite of Telegraph Peak
Kmm	Leucocratic muscovite monzogranite
Pm	Granulitic gneiss, mylonite, and cataclasite, retrograde
Pgu	Granulitic gneiss, mylonite, and cataclasite

Map Source: Morton, D.M., and Miller, F.K., 2006, Geologic map of the San Bernardino and Santa Ana 30' x 60' quadrangles, California: U.S. Geological Survey, Open-File Report OF-2006-1217, scale 1:100,000.

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XpressWest Extension

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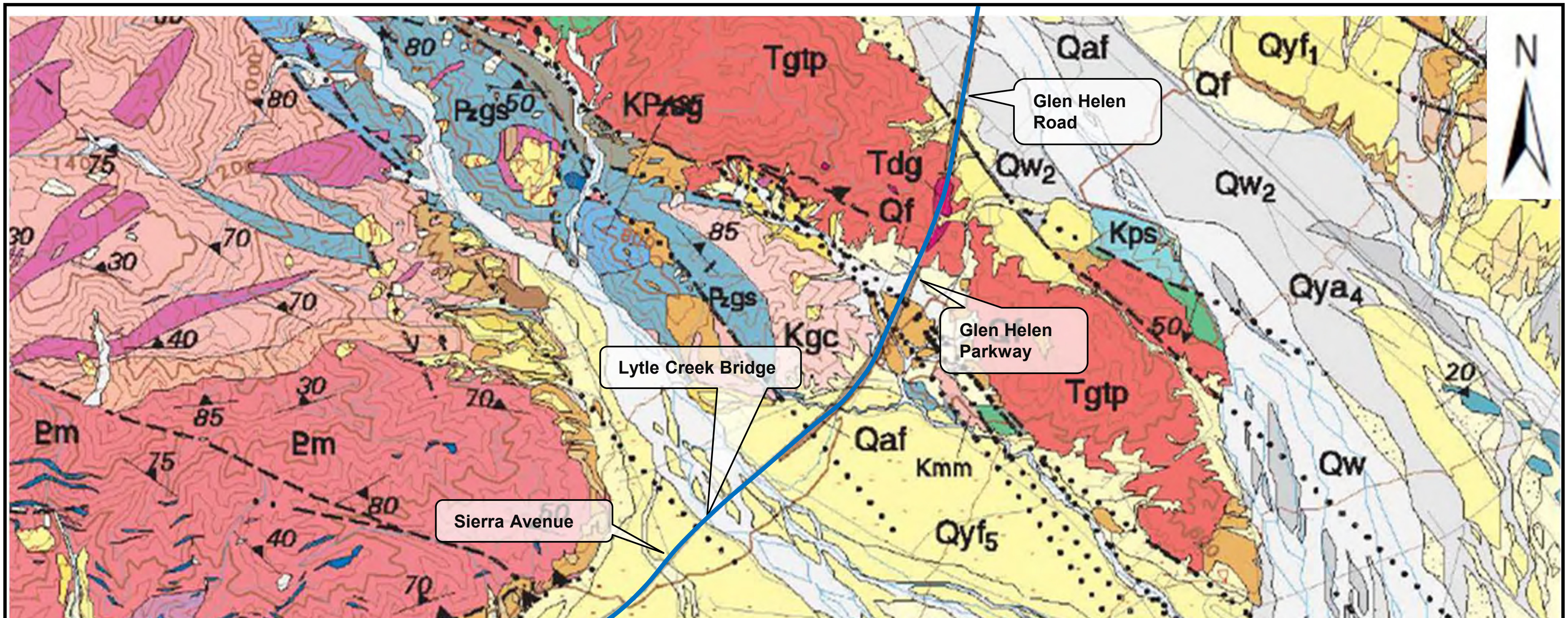
Peninsular Ranges Geomorphic Province Geologic Map

Figure 2



Qw	Qw_1	Qw_2				Very young wash deposits	
Qf	Qf_1					Very young alluvial fan deposits	
Qaf						Artificial fill	
Qyf	Qyf_1	Qyf_2	Qyf_3	Qyf_4	Qyf_5	Young alluvial fan deposits	
Qya						Young axial channel deposits	
Qls						Landslide deposits	
Qdg						Disturbed ground	
Tcd						Conglomerate and sandstone	

Tgtp	Granodiorite of Telegraph Peak
Tdg	Olivine diabase and gabbro
Kmm	Leucocratic muscovite monzogranite
Kgc	Mylonitized leucogranite
Pm	Granulitic gneiss, mylonite, and cataclasite, retrograde
Pgu	Granulitic gneiss, mylonite, and cataclasite
Pzgs	Metasedimentary schist and gneiss

Map Source: Morton, D.M., and Miller, F.K., 2006, Geologic map of the San Bernardino and Santa Ana 30' x 60' quadrangles, California: U.S. Geological Survey, Open-File Report OF-2006-1217, scale 1:100,000.

2 1 0 2 miles

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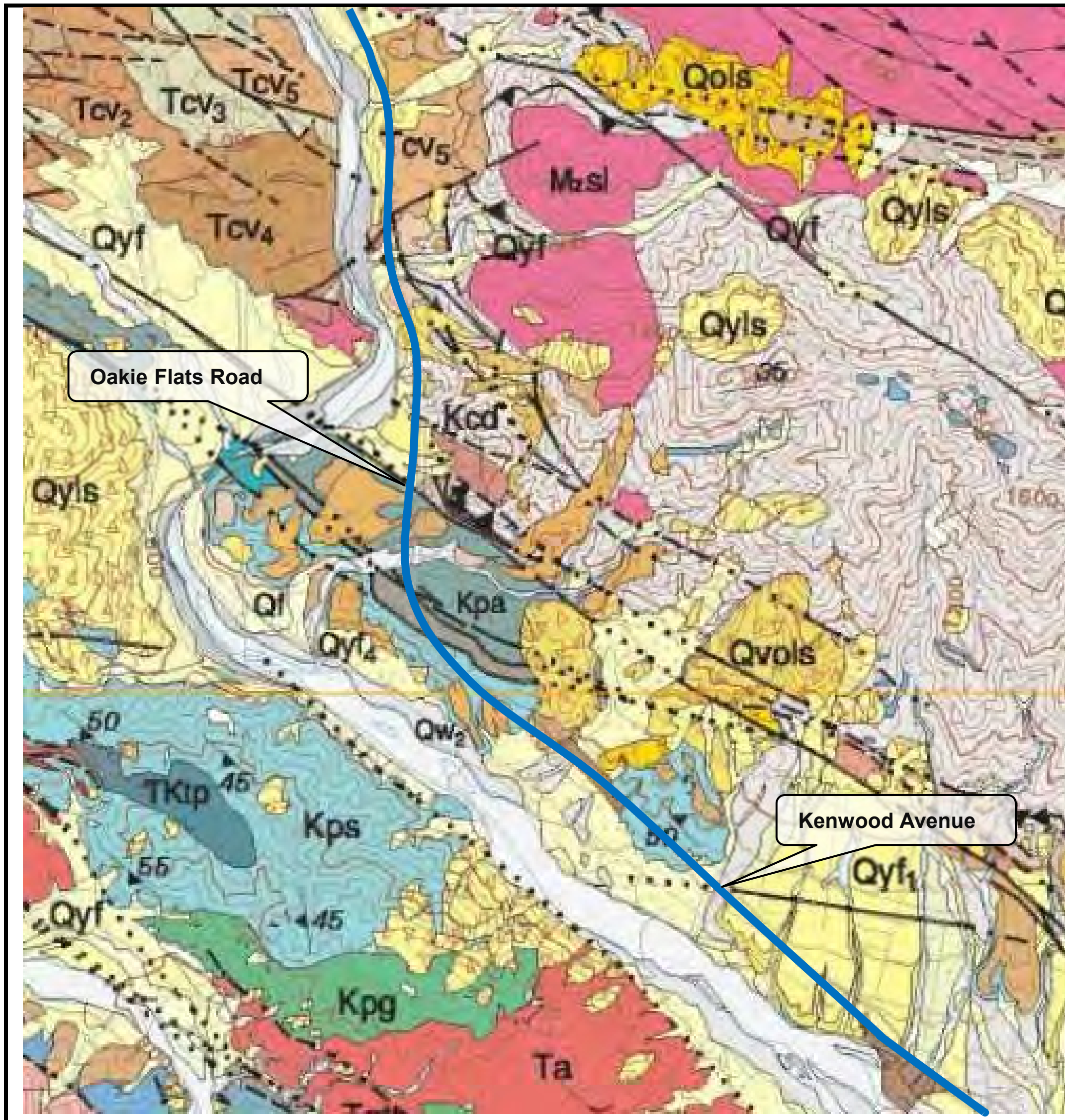
Transverse Ranges Geomorphic Province Geologic Map, 1 of 3

Figure 3



Qw, Qw_1, Qw_2	Very young wash deposits
Qf, Qf_1	Very young alluvial fan deposits
Qaf	Artificial fill
Qyf, Qyf_1, Qyf_2, Qyf_3, Qyf_4, Qyf_5	Young alluvial fan deposits
Qya	Young axial channel deposits
Qyls, Qols, Qvols	Landslide deposits
QTfz	Crushed rock in fault zones
Tcv_2, Tcv_3, Tcv_4, Tcv_5	Cajon Valley Formation
Tgtp	Granodiorite of Telegraph Peak
TKtp	Pelona Schist and granodiorite of Telegraph Peak
Kpa	Pelona Schist, amphibolite grade unit—
Kpg	Pelona Schist, greenstone unit
Kps	Pelona Schist, muscovite schist unit
Kcd	Sedimentary rocks of
MzPd	Gneiss of Devil Canyon
Mzsl	Mixed granitic rocks of Silverwood Lake

2 1 0 2 miles

N

Map Source: Morton, D.M., and Miller, F.K., 2006, Geologic map of the San Bernardino and Santa Ana 30' x 60' quadrangles, California: U.S. Geological Survey, Open-File Report OF-2006-1217, scale 1:100,000.

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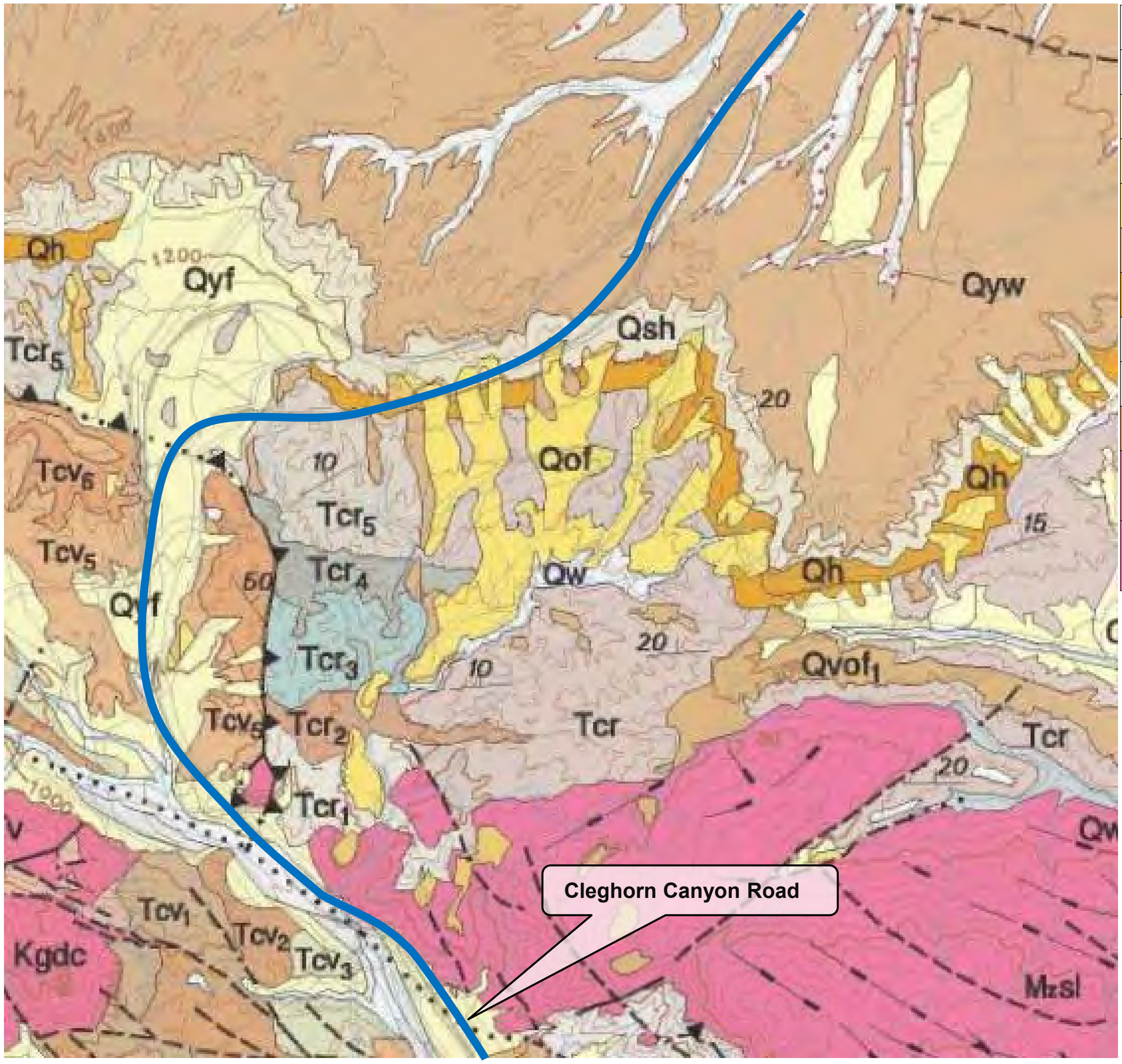
Transverse Ranges Geomorphic Province Geologic Map, 2 of 3

Figure 4



Qw, Qw_1, Qw_2	Very young wash deposits
Qyw	Young wash deposits
Qyf, Qyf_1, Qyf_2, Qyf_3, Qyf_4, Qyf_5	Young alluvial fan deposits
Qyf	Young alluvial fan deposits
Qof	Older alluvial fan deposits
Qvof	Very old alluvial fan deposits
Qh	Harold Formation
Qsh	Shoemaker gravel
Tcr_1, Tcr_2, Tcr_3, Tcr_4, Tcr_5	Crowder Formation
Tcv_2, Tcv_3, Tcv_4, Tcv_5	Cajon Valley Formation
Kgdc	Biotitie granodiorite, Cajon area
Mzsl	Mixed granitic rocks of Silverwood Lake

Map Source: Morton, D.M., and Miller, F.K., 2006, Geologic map of the San Bernardino and Santa Ana 30' x 60' quadrangles, California: U.S. Geological Survey, Open-File Report OF-2006-1217, scale 1:100,000.

2 1 0 2 miles

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Earth Mechanics, Inc. Geotechnical and Earthquake Engineering	XpressWest Extension		Transverse Ranges Geomorphic Province Geologic Map, 3 of 3
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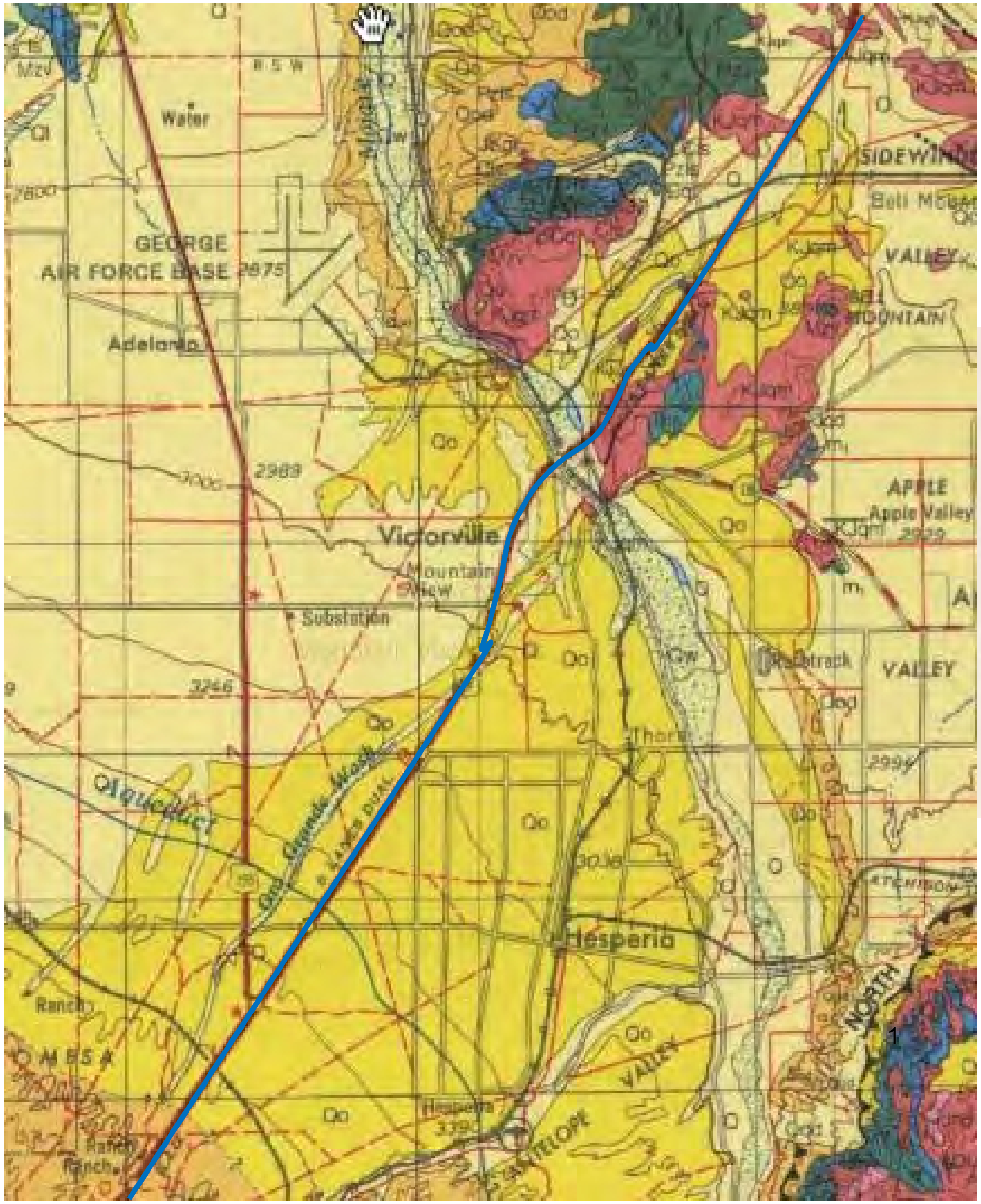
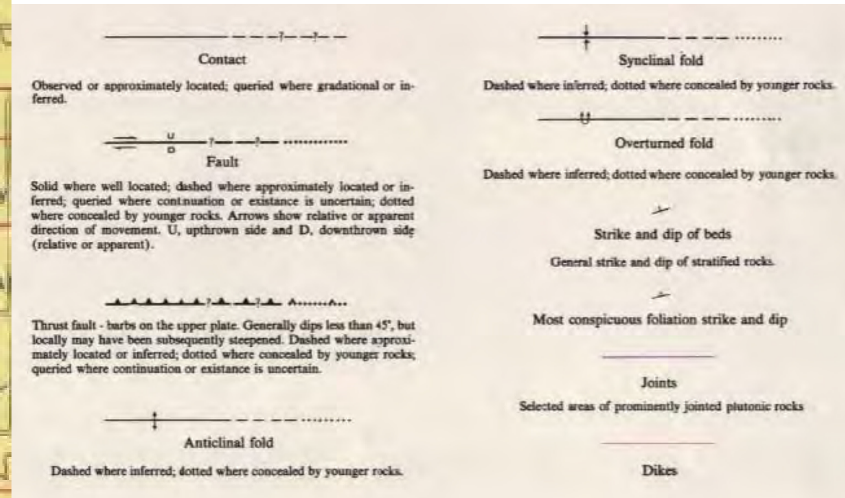
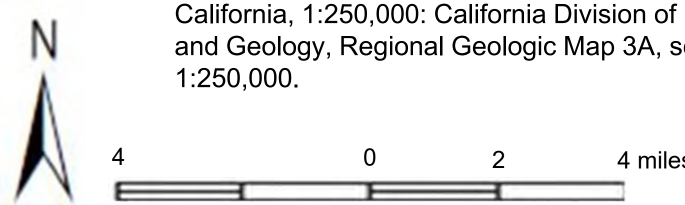


Qa	Quaternary alluvium
Qo	Older alluvium
Qw	Quaternary wash deposits
Kjqm	Cretaceous or Jurassic quartz monzonite
Mzv	Mesozoic metavolcanics rocks
ms	Metasedimentary rocks



Map Source: Bortugno, E.J., and Spittler, T.E., 1986, Geologic map of the San Bernardino quadrangle, California, 1:250,000: California Division of Mines and Geology, Regional Geologic Map 3A, scale 1:250,000.



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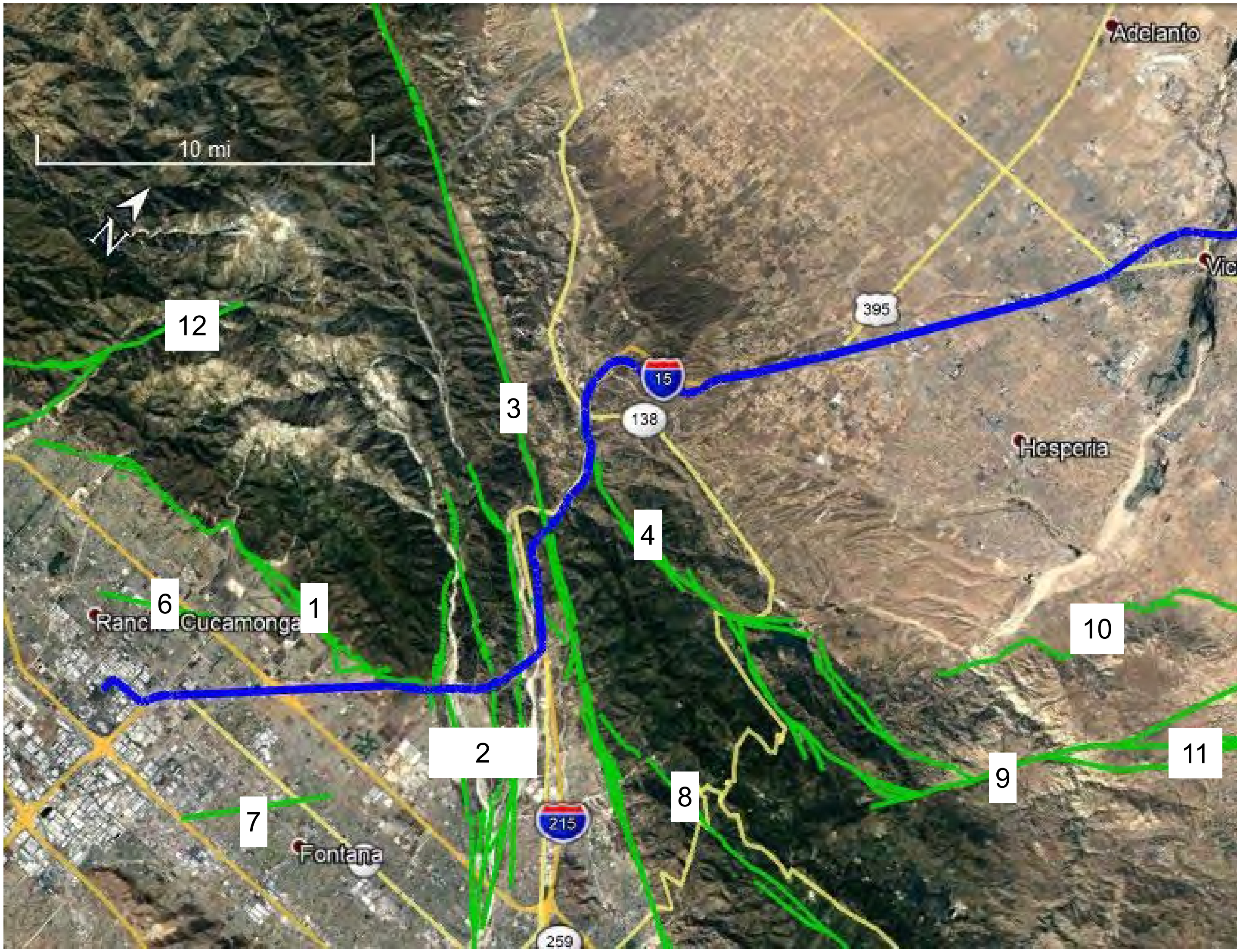
Mojave Desert Geomorphic Province Geologic Map

Figure 6



Fault No.	Fault Name	Max. Mag.
1	Sierra Madre	6.6
2	San Jacinto	7.0
3	San Andreas	7.4
4	Cleghorn	6.7
5	Helendale-South Lockhart	7.4
6	Red Hill Etiwanda Ave	6.2
7	Fontana Seismic Trend	6.5
8	Waterman Canyon	6.7
9	Tunnel Ridge	6.4
10	North Frontal Thrust	7.2
11	Arraste Canyon Narrows	6.2
12	San Antonio	6.5

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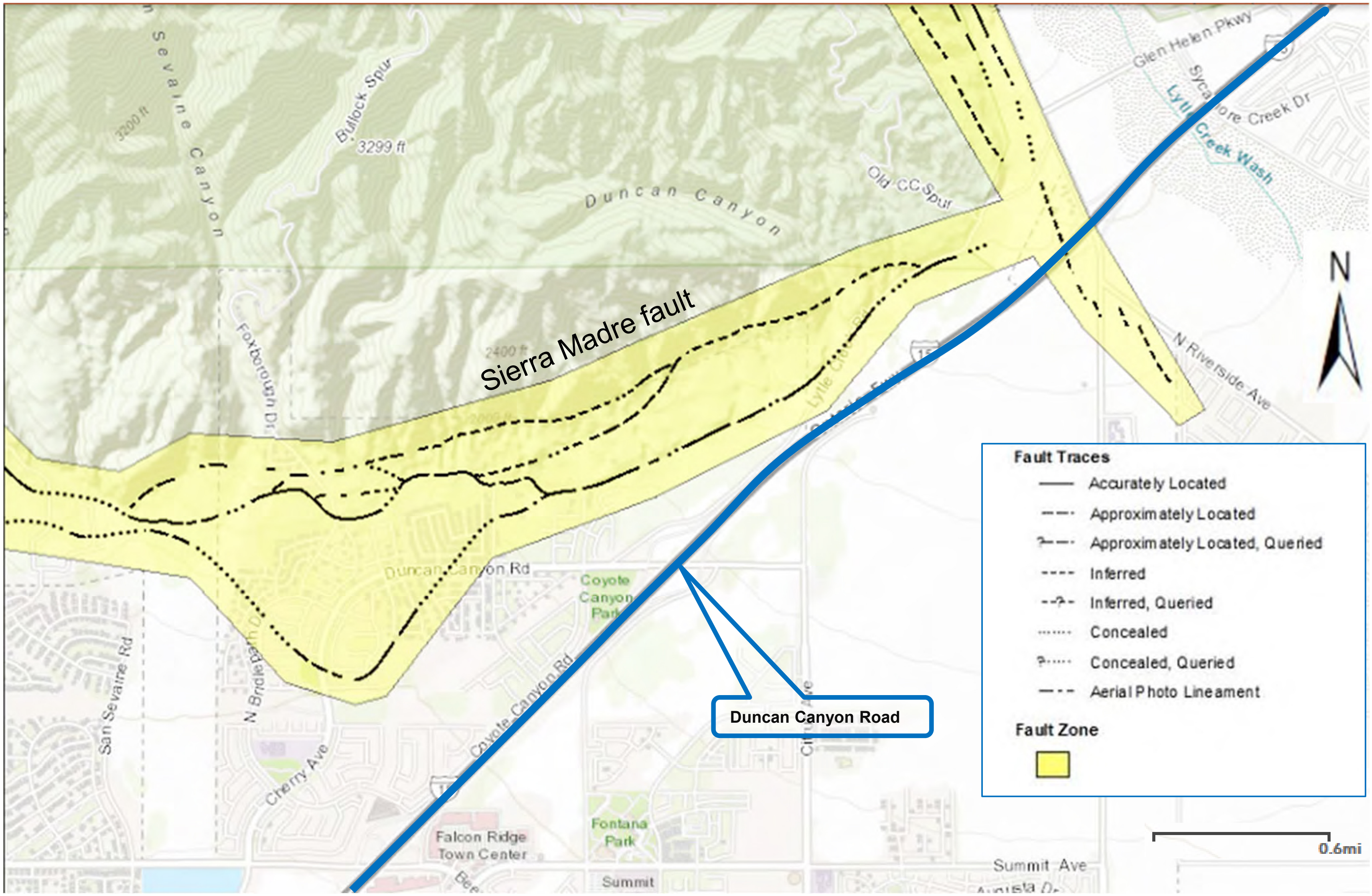
Overview of Regional Quaternary Faults

Figure 7



Map Source: California Division of Mines and Geology, 1995, Special Studies Zones Map, Devore quadrangle, scale 1:24,000.
https://gmw.conservation.ca.gov/SHP/EZRIM/Maps/DEVORE.PDF

Earth Mechanics, Inc. Geotechnical and Earthquake Engineering	XpressWest Extension	Sierra Madre Fault, Alquist-Priolo Map
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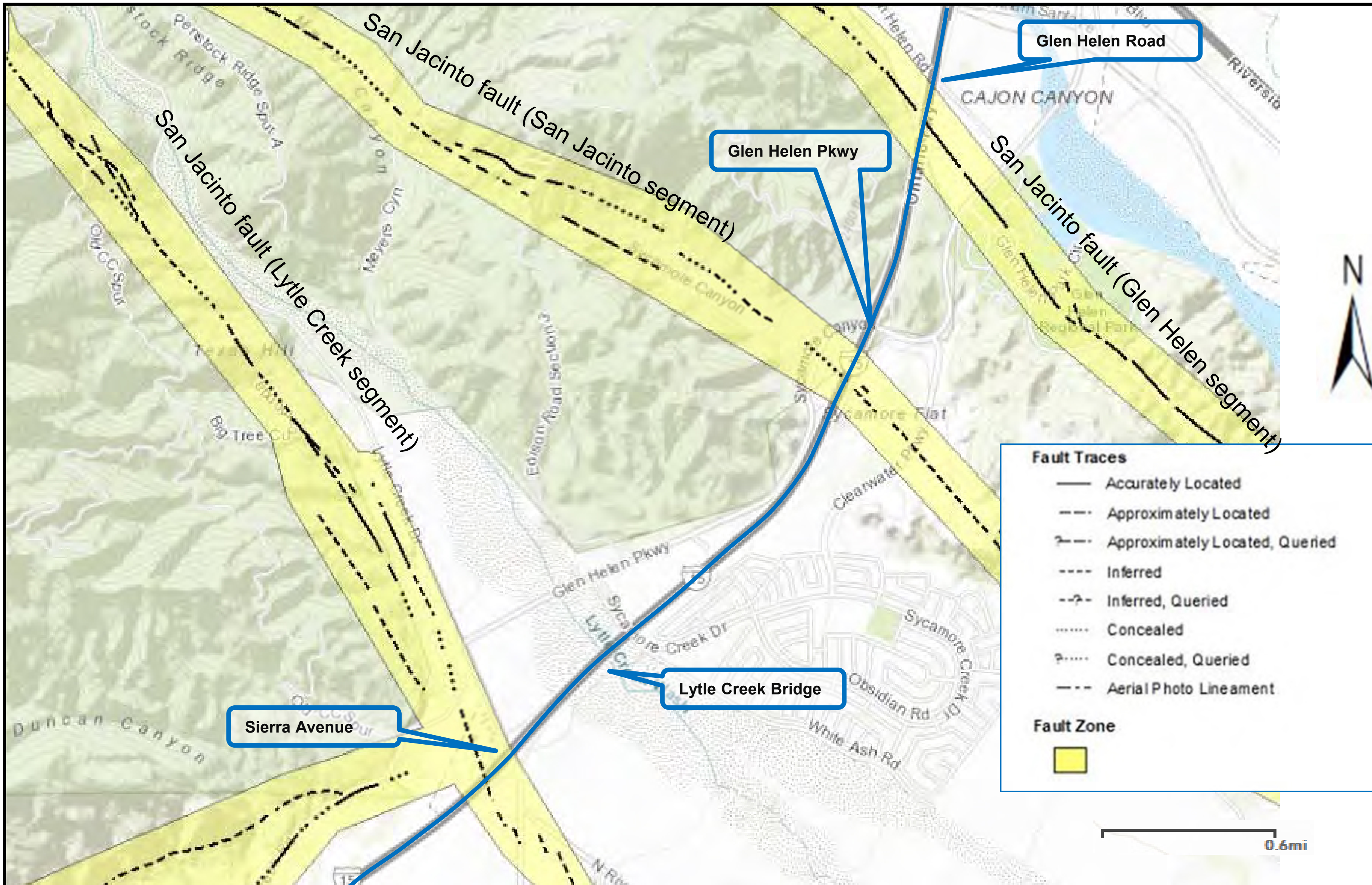

Map Source: California Division of Mines and Geology, 1995, Special Studies Zones Map, Devore quadrangle, scale 1:24,000.
https://gmw.conservation.ca.gov/SHP/EZRIM/Maps/DEVORE.PDF

Earth Mechanics, Inc. Geotechnical and Earthquake Engineering	XpressWest Extension		San Jacinto Fault, Alquist-Priolo Map
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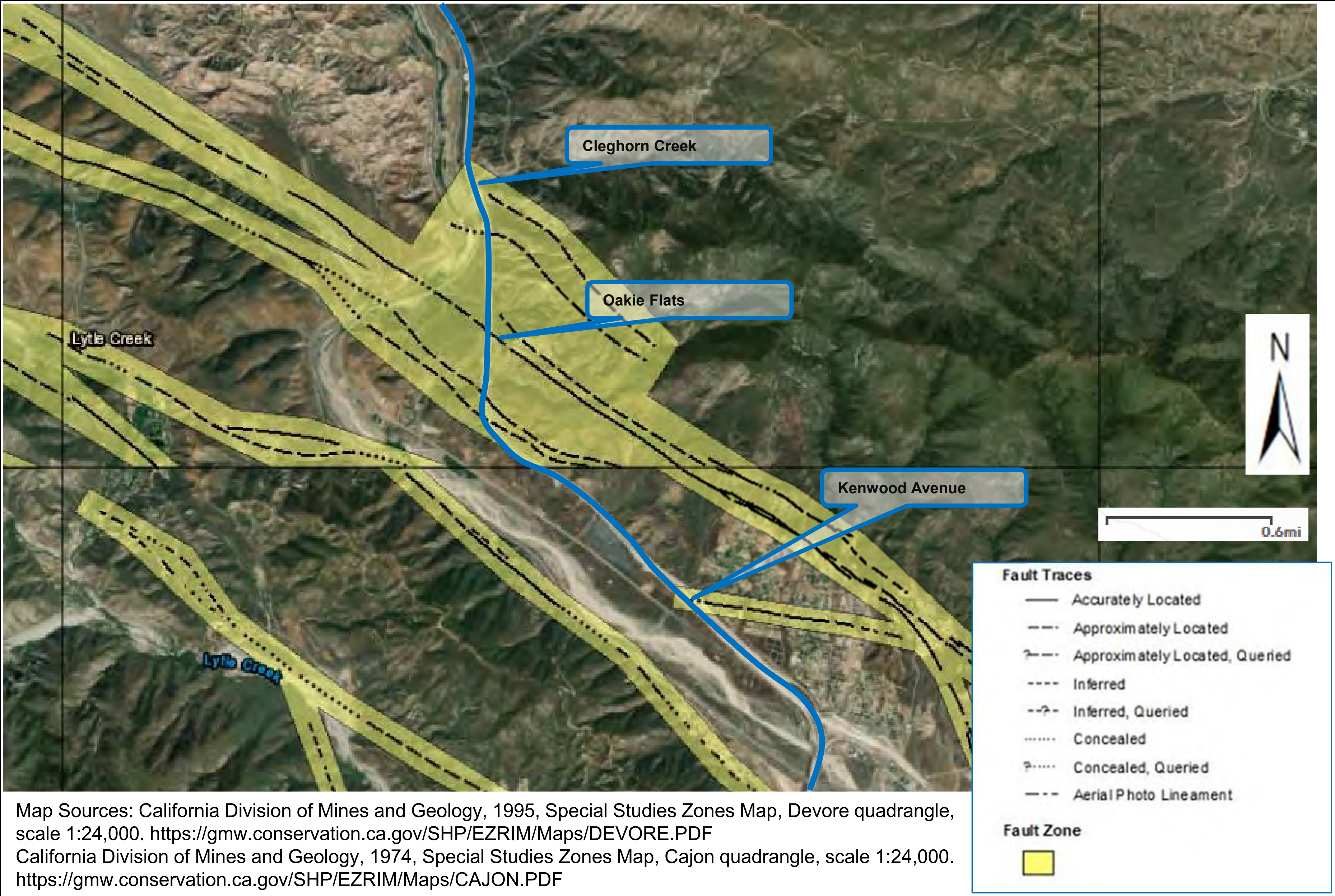


Map Sources: California Division of Mines and Geology, 1995, Special Studies Zones Map, Devore quadrangle, scale 1:24,000. https://gmw.conservation.ca.gov/SHP/EZRIM/Maps/DEVORE.PDF
California Division of Mines and Geology, 1974, Special Studies Zones Map, Cajon quadrangle, scale 1:24,000. https://gmw.conservation.ca.gov/SHP/EZRIM/Maps/CAJON.PDF

Earth Mechanics, Inc. Geotechnical and Earthquake Engineering	XpressWest Extension Project No. 20-126 — Date: July 2020	San Andreas Fault, Alquist-Priolo Map Figure 10

4.2 Seismic Design

The preliminary Acceleration Response Spectrum (ARS) curves were developed for three levels of Seismic Hazard Evaluation criteria as defined in Table 2. The ARS curves were developed using the USGS Unified Hazard Tool with the Dynamic: Conterminous U.S. 2014 (v4.2.0) edition.

Table 2. Project Seismic Design

Seismic Hazard Evaluation Level	Return Period (years)	Performance Level
Lower Level Earthquake (LLE)	50	Rail Serviceability
Functional Evaluation Earthquake (FEE)	225	Operational
Safety Evaluation Earthquake (SEE)	975	Life Safety

The preliminary ARS curves are presented in Figure 11 and were developed according to Caltrans ARS Online V3.0 (2019). The preliminary ARS curve, the design magnitude, and the preliminary PGA will be updated during the final design phase following the field investigation, based on a Vs30 measured with the P-S wave suspension logging or SPT correlations obtained from site-specific soil borings.

5.0 PRELIMINARY FOUNDATION RECOMMENDATIONS

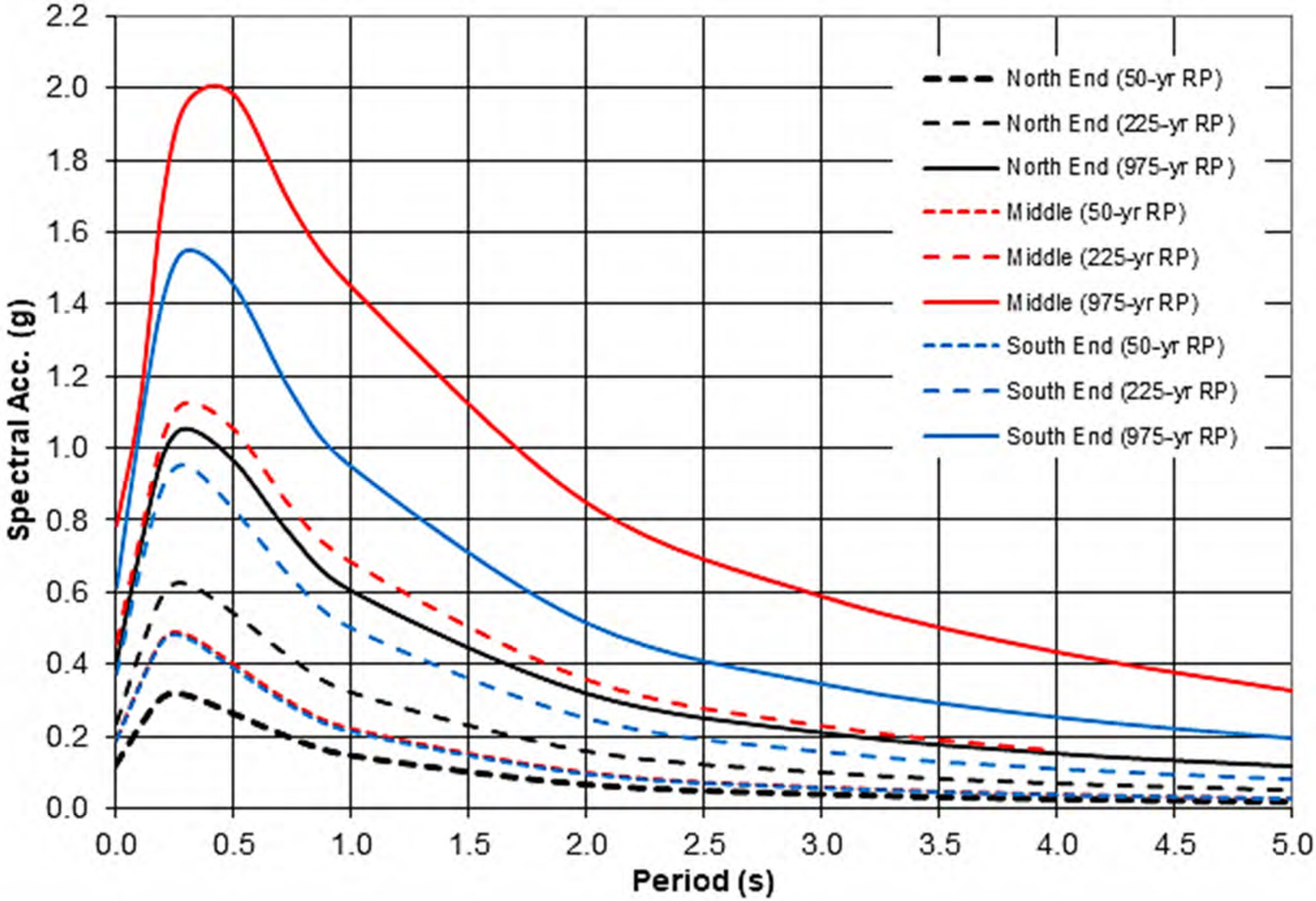
HNTB has currently proposed 52 structures for XpressWest Extension alignment. The proposed structures include:

- 2 Trench (T): HSR will enter into trench when it goes under existing overcrossings.
- 12 Trench with Retaining Wall (T/RW): HSR accommodated by widening the I-15 with Ground Anchor Wall in front of the existing bridge abutments.
- 3 Trench with Replacement Bridge (T/R): Replace the existing bridge to allow HSR under.
- 1 Siderunning Trench (T/SR): HSR goes under the existing railroad.
- 31 Underpass (UP): HSR goes over creek/river, local street, or railroad.
- 3 Viaduct (V): Viaduct lengths generally range between about 2900 and 9000 feet.

For the Underpass and Viaduct structures, based on the available subsurface information, the near-surface site soils are not anticipated to have sufficient bearing resistance to support the proposed structure on spread footings and therefore deep foundations are recommended. The preliminary recommendation is footing on piles for all abutments and bents. Of the deep foundation alternatives, site conditions may be conducive to driven or drilled piles.

Pile driving conditions for each of these structures will be highly variable due to the different geologic conditions at each bridge site. Difficult pile driving conditions, including shallow bedrock, cementation, or the presence of significant oversized materials (thick gravel layers, cobbles, or boulders), may exist at some locations.

Locations of proposed structures are shown in Appendix B.



Earth Mechanics, Inc. Geotechnical and Earthquake Engineering	XpressWest Extension		ARS Curves Figure 11
	Project No. 20-126	Date: July 2020	

6.0 REFERENCES

American Association of State Highway and Transportation Officials (AASHTO), 2018, AASHTO LRFD Bridge Design Specification, 8th Edition, Washington, DC: AASHTO.

Bortugno, E.J., and Spittler, T.E., 1986, Geologic map of the San Bernardino quadrangle, California, 1:250,000: California Division of Mines and Geology, Regional Geologic Map 3A, scale 1:250,000.

Burnett, J.L., and Hart, E.W., 1994, Holocene faulting on the Cucamonga, San Jacinto and related faults, San Bernardino County, California: California Division of Mines and Geology Fault Evaluation Report FER-240, 20 p., in Fault Evaluation Reports Prepared Under the Alquist-Priolo Earthquake Fault Zoning Act, Region 2 – Southern California: California Geological Survey CGS CD 2002-02 (2002).

Bryant, W.A., compiler, 2017, Fault number 325, Arrastre Canyon Narrows fault, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, https://earthquakes.usgs.gov/hazards/qfaults, accessed 06/24/2020 04:37 PM.

Bryant, W.A., compiler, 2017, Fault number 327, Tunnel Ridge fault, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, https://earthquakes.usgs.gov/hazards/qfaults, accessed 06/24/2020 03:49 PM.

Bryant, W.A., compiler, 2017, Fault number 328, San Antonio fault, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, https://earthquakes.usgs.gov/hazards/qfaults, accessed 06/24/2020 05:08 PM.

Bryant, W.A., compiler, 2017, Fault number 332, Red Hill-Etiwanda Avenue fault, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, https://earthquakes.usgs.gov/hazards/qfaults, accessed 06/24/2020 01:53 PM.

Bryant, W.A., compiler, 2017, Fault number 334, Waterman Canyon fault zone, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, https://earthquakes.usgs.gov/hazards/qfaults, accessed 06/23/2020 11:37 AM.

Bryant, W.A., compiler, 2017, Fault number 515, unnamed fault near Fontana, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, https://earthquakes.usgs.gov/hazards/qfaults, accessed 06/24/2020 02:54 PM.

Bryant, W.A., compiler, 2003, Fault number 109a, North Frontal thrust system, Western section, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, https://earthquakes.usgs.gov/hazards/qfaults, accessed 06/24/2020 04:14 PM.

Bryant, W.A., compiler, 2003, Fault number 108a, Cleghorn fault zone, Southern Cleghorn section, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, https://earthquakes.usgs.gov/hazards/qfaults, accessed 06/24/2020 12:19 PM.

Bryant, W.A., 1987, Cleghorn and related faults, San Bernardino County: California Division of Mines and Geology Fault Evaluation Report FER-187, microfiche copy in California Division of Mines and Geology Open-File Report 90-14, 9 p., scale 1:24,000.

Bryant, W.A., 1986, Western North Frontal Fault Zone and related faults, San Bernardino County, California: California Division of Mines and Geology Fault Evaluation Report 186, in Fault Evaluation Reports Prepared Under the Alquist-Priolo Earthquake Fault Zoning Act, Region 2 – Southern California: California Geological Survey CGS CD 2002-02 (2002).

Bryant, W.A., and Lundberg, M., compilers, 2002, Fault number 1i, San Andreas fault zone, San Bernardino Mountains section, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, https://earthquakes.usgs.gov/hazards/qfaults, accessed 06/23/2020 06:02 PM.

California Department of Transportation (Caltrans), 2019a, ARS Online Web Tool V2.3.09, http://dap3.dot.ca.gov/ARS_Online/.

____, 2019b, ARS Online Web Tool V3.0, http://dap3.dot.ca.gov/ARS_Online/.

——, 2019c, California Amendments to AASHTO LRFD Bridge Design Specifications - Eighth Edition, January.

——, 2019d, Caltrans Seismic Design Criteria, Version 2.0, April.

____, 2018a, Corrosion Guidelines, Version 3.0: Division of Engineering Services, Materials Engineering and Testing Services, Corrosion Branch, March.

____, 2018b, Foundation Reports for Bridges, August.

____, 2018c, Standard Specifications.

____, 2017, GeoDOG Digital Archive of Geotechnical Data, accessed July 13, 2020, https://geodog.dot.ca.gov/index.php .

____, 2013a, Memo To Designers 20-10, January.

____, 2013b, Memorandum "Seismic Design and Selection of Standard Retaining Walls", June.

____, 2012, Methodology for Developing Design Response Spectrum for Use in Seismic Design Recommendations, November.

Crook, R., Jr., Allen, C.R., Kamb, B., Payne, C.M., and Proctor, R.J., 1987, Quaternary geology and seismic hazard of the Sierra Madre and associated faults, western San Gabriel Mountains, in Recent reverse faulting in the Transverse Ranges, California: U.S. Geological Survey Professional Paper 1339, p. 27–63, scale 1:24,000.

Dibblee, T.W., Jr., 1975, Late Quaternary uplift of the San Bernardino Mountains on the San Andreas fault in southern California: California Division of Mines and Geology Special Report 118, p. 127-135.

Jennings, C.W., 1994, Fault activity map of California and adjacent areas, with locations of recent volcanic eruptions: California Division of Mines and Geology Geologic Data Map 6, 92 p., 2 pls., scale 1:750,000.

Meisling, K.E., 1984, Neotectonics of the North Frontal fault system of the San Bernardino Mountains, southern California, Cajon Pass to Lucerne Valley: Pasadena, California Institute of Technology, unpublished Ph.D. dissertation, 394 p., 2 pls., scale 1:24,000.

Meisling, K.E., and Weldon, R.J., 1989, Late Cenozoic tectonics of the northwestern San Bernardino Mountains, southern California: Geological Society of America Bulletin, v. 101, p. 106-128.

Mezger, L.L., and Weldon, R.J., 1983, Tectonic implications of the Quaternary history of lower Lytle Creek, southeast San Gabriel Mountains: Geological Society of America Abstracts with Programs, v. 15, no. 5, p. 418.

Miller, F.K., and Matti, J.C., 2001, Geologic map of the San Bernardino North 7.5" quadrangle, San Bernardino County, California: U.S. Geological Survey Open-File 01-131, 1:24,000.

Morton, D.M., and Miller, F.K., 2003, Preliminary geologic map of the San Bernardino 30’ x 60’ quadrangle, California: U.S. Geological Survey Open-File Report 03-293, scale 1:100,000.

Morton, D.M., and Yerkes, R.F., eds., 1987, Recent reverse faulting in the Transverse Ranges, California: U.S. Geological Survey Professional Paper 1339.

Sanders, C., and Magistrale, H., 1997, Segmentation of the northern San Jacinto fault zone, southern California: Journal of Geophysical Research, v. 102, no. B12, p. 27,453-27,467.

Sharp, R.V., 1967, San Jacinto fault zone in the Peninsular Ranges of southern California: Geological Society of America Bulletin, v. 78, p. 705–730.

Sieh, K.E., and Matti, J.C., 1992, San Andreas fault system between Palm Springs and Palmdale, Southern California, in Sieh, K.E., and Matti, J.C., ed., Earthquake geology, San Andreas fault system, Palm Springs to Palmdale: Association of Engineering Geologists, 35th annual meeting, Southern California section, Guidebook, v. 35, p. 1-12.

Treiman, J.A., compiler, 2000, Fault number 105h, Sierra Madre fault zone, Cucamonga section, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, https://earthquakes.usgs.gov/hazards/qfaults, accessed 06/23/2020 02:48 PM

Treiman, J.A., and Lundberg, M., compilers, 1999, Fault number 125a, San Jacinto fault, San Bernardino Valley section, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, https://earthquakes.usgs.gov/hazards/qfaults, accessed 06/23/2020 05:32 PM.

Wallace, R.E., 1990, General features, in Wallace, R.E., ed., The San Andreas fault system: U.S. Geological Survey Professional Paper 1515, p. 3-12.

Weldon, R.J., II, and Sieh, K.E., 1985, Holocene rate of slip and tentative recurrence interval for large earthquakes on the San Andreas fault, Cajon Pass, southern California: Geological Society of America Bulletin, v. 96, no. 6, p. 793-812.

Wells. D.L., and Coppersmith. K.J., 1994, "New empirical relationships among magnitude, rupture length, rupture width, and surface displacements", Bulletin of the Seismological Society of America, v. 84. p. 974-1002.