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To: MR. MATT HOLM
Bridge Design Branch 12, Chief
Office of Bridge Design – South 1

Date: October 15, 2012

File: 07-LA-14, PM R58.17
EA: 07-2600U10
Avenue "S" UC (Widen)
Bridge No. 53-1417

Attention: Mr. Doug Menzmer

From: DEPARTMENT OF TRANSPORTATION
DIVISION OF ENGINEERING SERVICES
Materials Engineering and Testing Services and Geotechnical Services
Office of Geotechnical Support – Geotechnical Instrumentation
Office of Geotechnical Design – South 2 Branch A

Subject: Evaluation of Fault Rupture Potential, Avenue "S" Undercrossing (UC) (Widen) (53-1417), Palmdale, California

SUMMARY

Avenue "S" Undercrossing was evaluated for fault rupture potential as part of the study for the High Desert Corridor Project. The bridge when widened will be approximately 270 feet southwest of the mapped historically-active main trace of the San Andreas Fault (Mojave section), and on projection from a short secondary trace shown on the USGS (2010) Google Earth map as 15,000 years or younger (Caltrans-active). A third trace identified by Caltrans in 1956 been shown as 400 feet south of the bridge.

Based on this evaluation, the main trace of the fault is correctly located with respect to the bridge and the first secondary trace is not considered to be an active fault as defined by Caltrans. The secondary trace first identified in 1956 does not project to the bridge. Additionally, no Caltrans-active faults were observed in trenches previously excavated by outside consulting firms perpendicular to the San Andreas Fault that would address possible sub-parallel traces that could underlie the footprint of the widened bridge.

Although no fault traces were identified that would directly impact the bridge in terms of surface rupture, we recommend that nine inches of displacement (vertical or horizontal, anywhere in the alignment in a direction parallel to the San Andreas Fault) be considered for the bridge widening per current fault rupture hazard analysis theory. No additional geologic fault rupture evaluation work is necessary at this time for the bridge.

INTRODUCTION

In response to your request dated January 11, 2012, the Office of Geotechnical Support (OGS) - Instrumentation Branch and the Office of Geotechnical Design (OGD2) have prepared this Fault Rupture Potential Evaluation for Avenue "S" UC, to be widened (Figure 1) as a part of the High Desert Corridor (HDC) project. Caltrans' policies regarding fault rupture at bridges are described in Memo to Designers (MTD) 20-10. Briefly, Caltrans requires a fault rupture evaluation if a bridge is located within an Alquist Priolo Earthquake Fault Zone (EFZ) or within 1,000 feet of an un-zoned fault 15,000 years or younger in age. Avenue "S" UC is located within the EFZ established for the Ritter Ridge Quadrangle; therefore a fault evaluation is required.

An initial estimate of potential offset was based on an analysis developed by Tom Shantz of Caltrans' Division of Research and Innovation, using methods presented in Petersen et al (2011) and Abrahamson (2008). Both a deterministic fault displacement analysis (DFDHA) and a probabilistic fault displacement analysis (PFDHA) were performed utilizing magnitude, slip rate (for PFDHA), mapping and base map errors, and likelihood of secondary fault traces. If a main trace is assumed to cross beneath the bridge the expected displacement is over 30 feet (see figure 7). Therefore additional work, documented herein, was performed to better define fault location and to address the possibility of additional fault strands crossing beneath the bridge.

San Andreas Fault

The San Andreas Fault (Mojave section) is historically active with the most recent rupture occurring in 1857. Average offset during that event was about 20 feet, and maximum offset was greater than 30 feet (Wells and Coppersmith, 1994). Maximum magnitude expected for this section of the San Andreas Fault is **M**7.9.

Figure 2 shows the most recent geologic mapping of area faults (completed in 1985 [Treiman, p.c. 2012]). Active faults nearest Avenue "S" bridge are strands of the San Andreas Fault (Mojave section). The bridge widening will be located 270 feet southwest of the main trace that most recently ruptured (during the 1857 **M**7.9 Fort Tejon Earthquake). This trace does not project towards the bridge site. The bridge is also located on strike with a secondary fault trace several hundred feet to the southeast and shown on the United States Geological Survey (USGS) (2010) Google Earth map as Caltrans-active. According to a 1956 Caltrans memo regarding early concerns with the San Andreas Fault crossing the proposed Avenue "S" bridge site, an unmapped secondary fault trace also exists 400 ft south of the site. The main fault trace of the San Andreas Fault and these two secondary fault traces as well as potential for unmapped faults occurring at the bridge are discussed below.

CURRENT EVALUATION

Review of aerial photos/Lidar data

Air photos taken in 1956 and in 1961, prior to construction of Avenue "S" UC in 1966, were reviewed (Figure 3). The main trace of the San Andreas Fault in this location consists of several linear strands seen clearly on the photos as aligned ridges and valleys, offset drainages, and a sag pond (namely Lake Palmdale southeast of the bridge). Secondary traces east and south east of the bridge appear as slight depressions/lineaments that are parallel to the main trace. In particular a lineament crosses Highway 14 about 400 feet due south of the bridge. This lineament is likely associated with the possible fault south of the bridge that was identified in 1956 (Figure 3).

Lidar imaging (Figure 4) clearly reveals the main trace of the San Andreas Fault including significant offset drainages. Man-made features such as the bridge and highway and associated construction obscure the secondary fault traces near the bridge and lidar imaging was therefore not useful in evaluating these smaller traces.

Review of existing data

Caltrans information

Memos regarding the 2006 widening of this bridge do not include reviews of potential fault rupture, but they do note that the bridge will be subject to significant ground shaking. In 1956 during site investigations for this bridge, the proposed bridge site was described as within a wedge bounded by the main trace of the San Andreas Fault and a secondary fault trace 400 feet to the south of the bridge site (see complete quote below). This southern trace is likely shown on the 1956 air photo as discussed above, and was probably encountered by outside consulting firms (see next section. The southern trace projects south of the bridge, and even if the trace is Caltrans-active it is unlikely to impact the bridge.

> The only other surface evidence of faulting in the immediate vicinity of the proposed structure is a contact between sandstone and granite which is indicated by a color change in the dirt roadbed as well as rock fragments about 450' south of the site. It is possible that the contact is an depositional contact of the Pliocene sandstone on the pre-Tertiary grani and not a fault contact, but without any evidence to the contrary the fault contact must be assumed.
>
> Thus, the structure site is located on a sliver or wedge of rock about 800' wide bounded by two faults. However, as nearly as can be ascertained by surface observation, no faults run directly through the structure site.

(D.R. Brown, California Division of Highways – Bridge Department August 3, 1956)

The memo describing the 1956 foundation investigation that was completed after D.R. Brown's observations states that, *"Test borings indicate that shear displacement across the structure is not expected"* (Caltrans, 1958). No evidence suggestive of faulting (e.g., clay seams, slickensides, offset formations, etc.) were encountered in a 2002 boring either.

Irregularities in ground water elevations are often hallmarks of fault zones. The Mojave section of the San Andreas Fault near Palmdale is known to be a major ground water barrier, with historic high ground water depths measured at greater than 50 feet northeast of the fault and from 0 to 30 feet southwest of the fault (CGS, 2008). Shallow ground water was not encountered in borings at the bridge suggesting the bridge is located south of significant fault traces. Please see the SPGR memo (revised) for this bridge dated 5/3/2012 for detailed discussion of ground water elevations.

OUTSIDE CONSULTING FIRMS

We reviewed reports completed for Alquist-Priolo (AP) Special Studies required for buildings designed for human occupancy located within regulatory fault zones, including fault investigations for a mini-mart northeast and a development east and southeast of the bridge (Figure 5). Trenches excavated for the northeast site revealed no strands outside of the known San Andreas Fault zone in that location, confirming the published mapping of the main trace. Trenches excavated for the development east and southeast of the bridge addressed both the known and unknown secondary traces which were found to be either not active per Caltrans criterion or not projecting towards the bridge.

California Geo/Systems, Inc. in 1991 performed an AP study northeast of the bridge that included trenching of the main trace of the San Andreas Fault. Two continuous trenches totaling approximately 475 feet in length and ranging from 5 to 12 feet in depth were logged and encountered the closely spaced strands that comprise the main trace. The study concluded that the strands of the main trace are confined to photo lineaments found during a review of aerial photographs, and those traces are consistent with those shown on the 1985 mapping (Figure 2).

Buena Engineers, Inc. conducted several studies east and southeast of Avenue "S" UC that also included trenching. In November, 1988, a trench 433 feet long and 6-10 feet deep was excavated for a development east of the bridge. This trench crossed the location of the Holocene-age fault shown on the 1985 Barrows mapping, but did not encounter the fault. The report concluded that this lineament was not an active fault. However, this trench may not have been excavated deep enough (i.e., the trench did not expose old enough un-faulted materials) to rule out the possibility of the lineament being a Caltrans-active fault (active in the past 15,000 years). In April, 1989, three additional trenches were excavated by Buena Engineers, Inc in this area. The longest trench (1340 feet in total length) paralleled the 433 foot long trench excavated in 1988 and was intended for assessment of soil ages. This trench was also deeper than the 1988 trench. Un-faulted soils described as at least 30,000 years old (Qoa) were exposed; therefore it is likely that any faulting that might have occurred there happened prior to 30,000 years and would not be considered Caltrans-active.

The 1988 Buena Engineers, Inc. report also referred to two trenches excavated by their firm in 1984. These trenches were located west of the 1988 site and closer to Avenue "S" UC. The log of the southernmost trench shows a possible fault zone approximately where the 1956 fault trace was postulated and where the southern air photo lineament was noted. The description is, "A possible fault zone in Qal_3. Clean sand lens in Qal2 [younger] not faulted." No absolute ages were provided, and the recommendation was made to setback any structures at least 50 feet on either side of this feature. During the April 1989 study, faults not considered Caltrans-active were observed displacing Early- to Mid-Pleistocene in age (1- to 2.5-million years old) Harold formation although in one instance Qoa was faulted near where the 1956 letter and air photo review showed faulting. Therefore this feature should be considered a Caltrans-active fault. However, the fault does not project towards the bridge, and was weighted 5% of the 100% considered in the design offset analysis.

As can be seen in Figure 5, transversely oriented trenches covered locations where parallel faults would have likely have been encountered, however except as discussed above, no other faulting was observed. No additional trenching would refine what we have learned from this work, with the exception of better age constraints on the southernmost fault. Since that fault projects south of the bridge and does not contribute significantly to the hazard analysis even when considered active, no further work is needed.

Field reconnaissance

We visited the bridge on two different occasions, and determined that the area east and southeast of the bridge had been reworked and we could observe no fault exposures there, however we were able to determine the approximate locations of the Buena Engineers 1988 and 1989 trenching. Figure 6 shows the scarp of the main trace of the fault north of the bridge.

RECOMMENDATIONS

Per methods described in Petersen et al (2011) and Abrahamson (2006) we calculated the expected offset at this bridge on a fault oriented parallel to the San Andreas Fault but trending anywhere beneath the site. Although the information discussed above likely rules out surface rupture potential, it is prudent to assume there may be errors in the locations, etc. See Figure 7 for the expected displacement both on the fault (12.3 m probabilistic value) and at the bridge (0.23 m or 9 inches). No additional work is recommended at this time.

If you have any questions, please contact Martha Merriam at (916) 227-7135 or Douglas Cook at (916) 227-4512.

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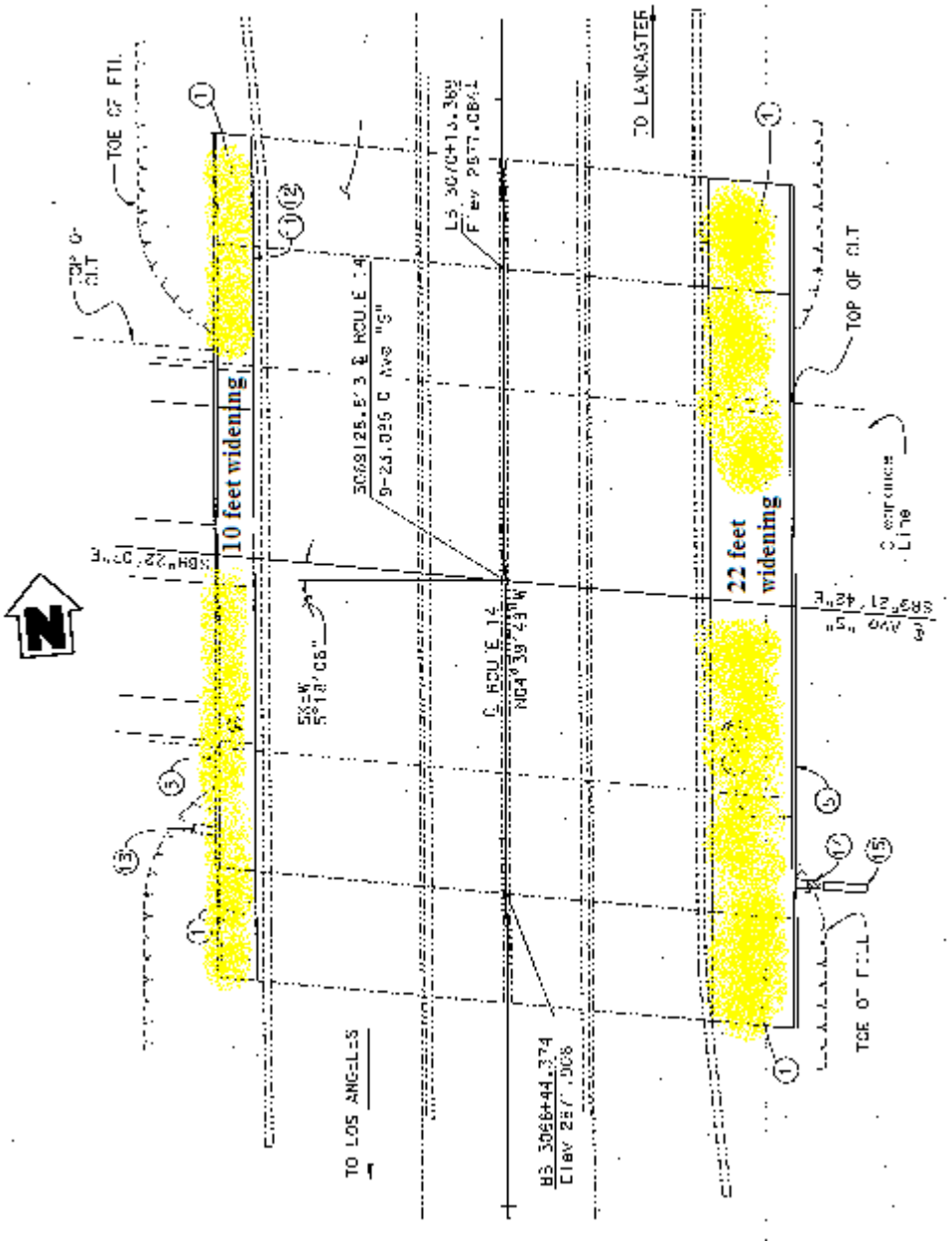


Figure 1. Avenue "S" UC (widen) Planning Study, 5/8/2012 showing location of proposed widening. Proposed widening (shown in yellow) is 10 feet on the west and 22 feet on the east.

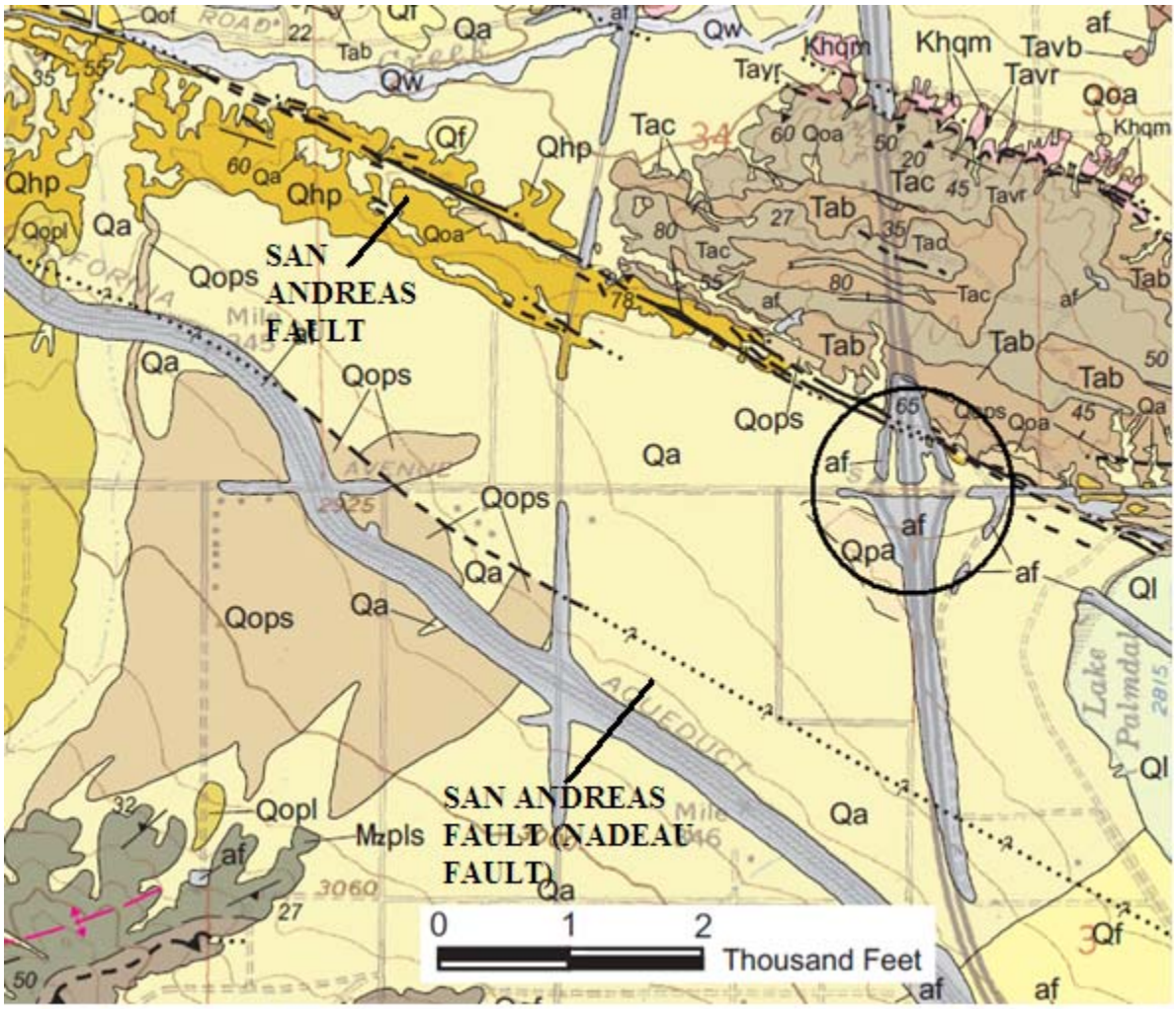


Figure 2. Geology of Avenue "S" UC location (circled). Mapped fault traces shown are from the latest (1985) mapping (Jerry Treiman, CGS, pc 2012). North is top of map.

Fault symbols: Solid where accurately located; long dash where approximately located, short dash where inferred; dotted where concealed; queried where uncertain.

Geologic symbols are here:
Preliminary Geologic Map of Ritter Ridge Quad, 2009, J. Hernandez
ftp://ftp.consrv.ca.gov/pub/dmg/rgmp/Prelim_geo_pdf/RitterRidge24k_prelim.pdf

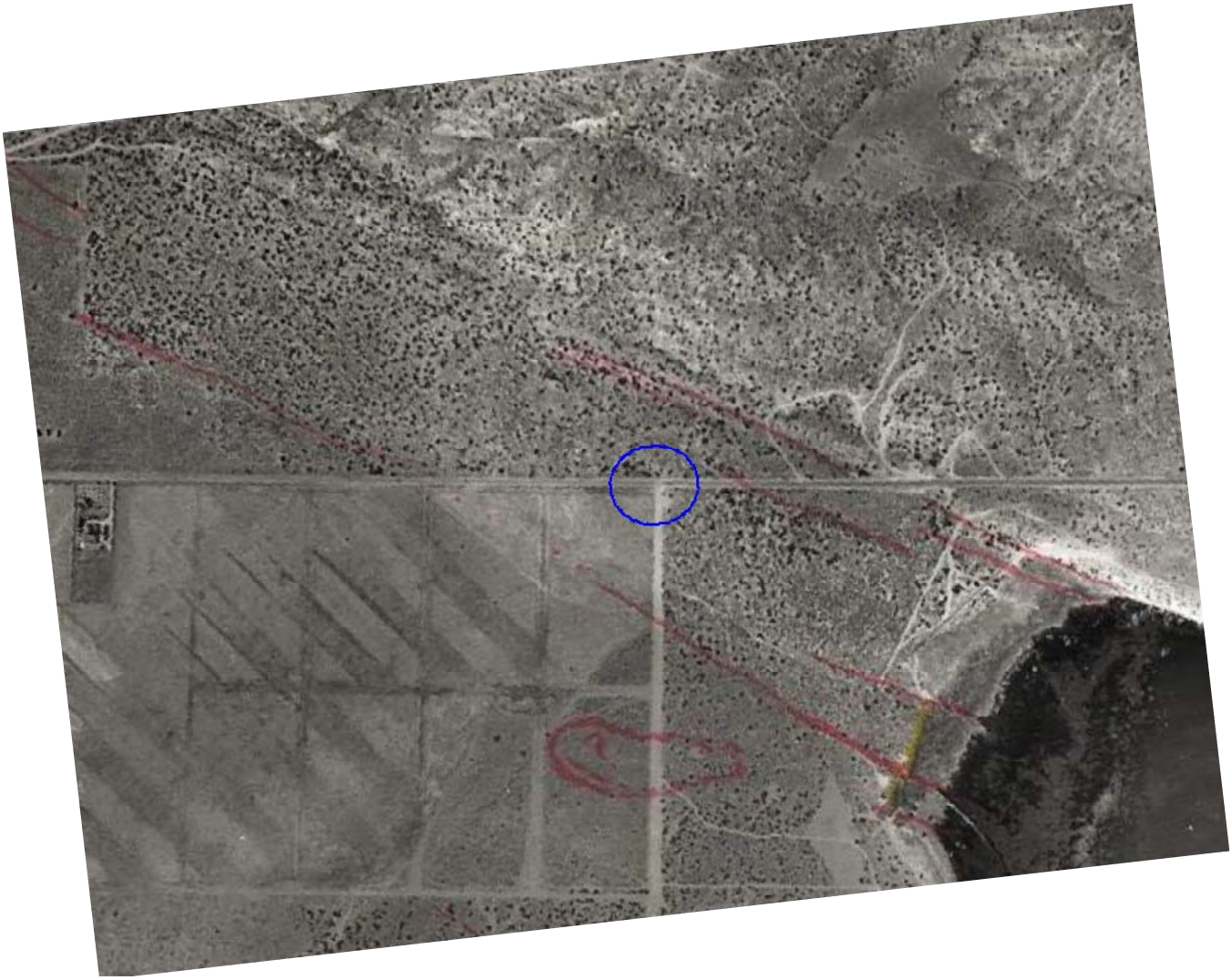
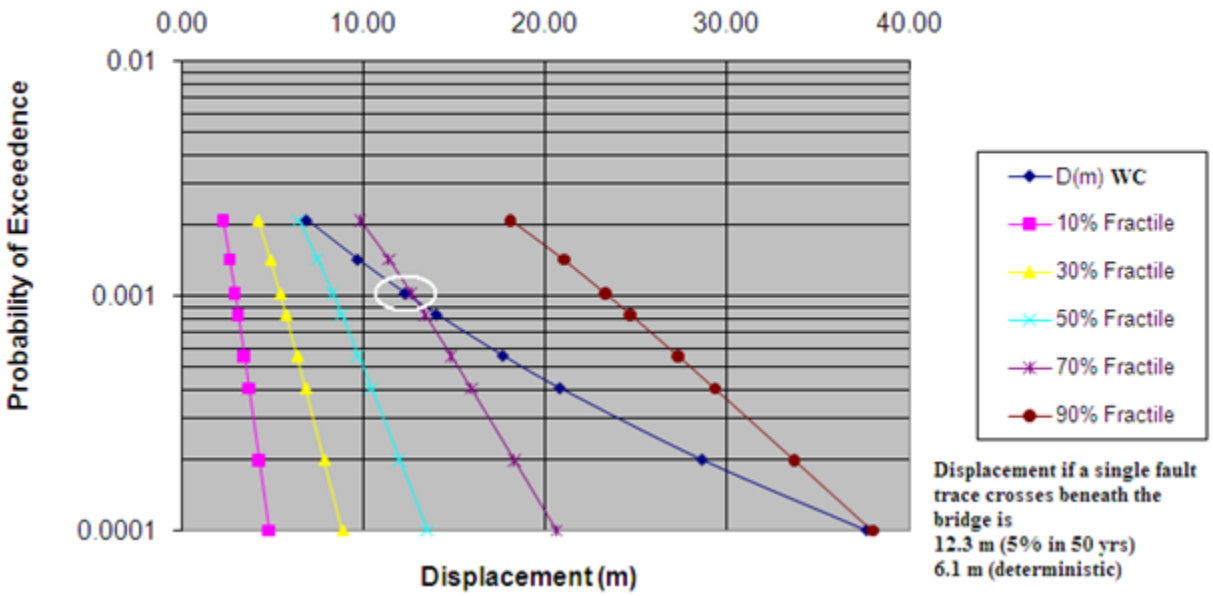


Figure 3. 1956 air photo annotated by CGS. Pre-construction bridge location is circled in blue; lineaments (possible faults or areas of faulting) are shown in red. North is top of photo. Lineament just north of blue circle is a secondary fault trace which is not Caltrans-active. The lineament appearing to cross the highway south of the circle is discussed in a 1956 memo and does not project to the bridge.

Figure 4. Lidar imagery, showing offset drainages and aligned ridges and valleys. Highway and other construction obliterate the natural ground features. Circled feature is drainage ditch. North is top of image.

Figure 5. Locations of nearby trenches excavated by consulting firms are shown in yellow. 1988 and 1989 trenches are referred to in text. Faults are from USGS (2010) and are historic (red), or 15,000 years or younger (yellow) in age. North is top of image.

Figure 6. San Andreas Fault scarp is the dashed change in slope. Major fault zone shown in road cut in background.



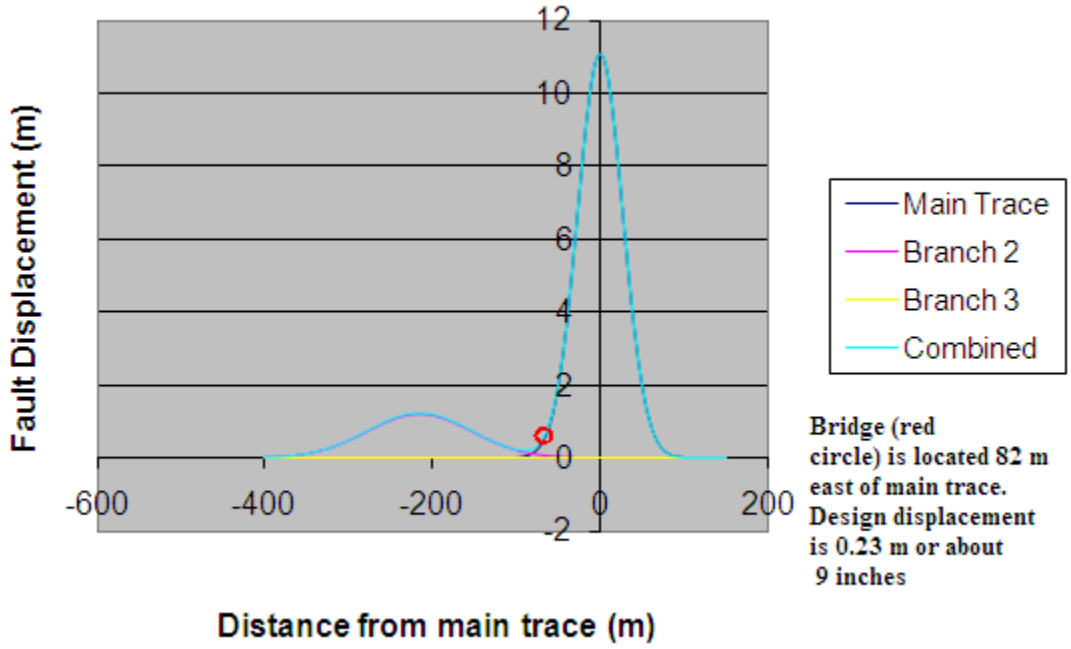


Figure 7. Design offset (based on **M**Max =7.9, slip rate=37 mm/yr, asf= 0, main trace is weighted 95%; secondary trace is 5%). Upper chart shows displacement if the main fault trace crossed beneath the bridge; the lower chart shows displacement **(about 9 inches)** if the main trace is 270 ft (82 m) east of the bridge and there is a secondary trace located 400 feet south.