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To: MR. TOM OSTROM, CHIEF
OFFICE OF EARTHQUAKE ENGINEERING

Date: August 2, 2013

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LA Aqueduct Penstock
Bridge No. 53-1012

From: DEPARTMENT OF TRANSPORTATION
DIVISION OF ENGINEERING SERVICES
Materials Engineering and Testing Services and Geotechnical Services
Office of Geotechnical Support – Geotechnical Instrumentation

Subject: Evaluation of Fault Rupture Potential, Los Angeles Aqueduct Penstock, Los Angeles County

SUMMARY

LA Aqueduct Penstock Bridge, No. 53-1012, is crossed by the Sierra Madre (Santa Susana fault) fault zone, a Caltrans-active fault. Vertical offsets of 0.63 m (2 ft) north side up, horizontal sliding toward the north of 0.44 m (1.4 ft), and 0.3 m (1 ft) of lateral offset perpendicular to the bridge centerline should all be considered in design. No further work is recommended.

INTRODUCTION

This evaluation was prepared as part of the statewide evaluation of fault rupture potential at Caltrans bridges. Caltrans' policies regarding fault rupture at bridges are described in [Memo to Designers \(MTD\) 20-10](#). Caltrans requires a fault rupture evaluation if a bridge is located within an Alquist-Priolo (AP) Earthquake Fault Zone (EFZ) or within 1,000 feet of an un-zoned fault 15,000 years or younger. LA Aqueduct Penstock Bridge (Bridge) is situated within the EFZ established for the Sierra Madre fault (Santa Susana section) in 1979 in the San Fernando 7-1/2' Quadrangle; therefore a fault evaluation was required.

An initial estimate of potential offset was based on an analysis developed by Division of Research and Innovation in collaboration with Geotechnical Services, using methods presented in Abrahamson (2008) and Moss and Ross (2011). Both a probabilistic (5% in 50 yr) fault displacement analysis (PFDHA) and a deterministic fault displacement analysis (DFDHA) were performed based on the maximum magnitude earthquake, slip rate (for PFDHA), assumed mapping and base map errors, and likelihood of secondary fault traces. If the Santa Susana fault crosses beneath the Bridge, about 2 feet of displacement (probabilistic or larger value) would be expected. Mark Yashinsky and Fadel Alameddine reviewed the bridge plans and determined the

bridge could not withstand the displacement without modification. Therefore additional work, documented herein, was undertaken to better define the fault location and estimate offset.

LA Aqueduct Penstock Bridge was built in 1970, and repaired in 1974 for earthquake damage after spalling and cracking in abutment walls (Elliott and Nagai, 1973) during the February 9, 1971 **M**6.6 San Fernando Earthquake (Figures 1 and 2). The bridge is 70 feet long and 319 feet wide. The bridge is not a top grade structure, and is a single span RC T-beam structure with RC closed end backfilled strutted abutments, all supported on concrete and steel piles. A “rigid inclusion” effect was noted in surveys along the freeway alignment (Figure 3).

FAULT RUPTURE EVALUATION

This evaluation consisted of review of data gathered shortly after the 1971 San Fernando Earthquake, literature, and air photos of the area near the Bridge. The magnitude of the 1971 event (**M**6.6) is the same as the **M**Max value for the fault given by the USGS (USGS, 2008); therefore the damage from that event would be similar to what would be expected from the **M**Max event. Note that the original Bridge was reportedly damaged by shaking from that event and not by fault rupture.

The nearest fault to the Bridge is the Sierra Madre Fault Zone (Santa Susana fault), shown in Figures 4-7. At the latitude of the Bridge, the Santa Susana fault consists of north and south branches (the branch nearest the Bridge) and continues as two branches westward. During the 1971 San Fernando Earthquake, discontinuous ruptures as shown in figures 6 and 7 occurred both west and east of the Bridge. In particular the east-west trending rupture east of the Bridge was described as a “mole track” and as a fault with thrusting of Saugus formation (Sunshine Ranch member) over younger upper Saugus formation. This feature is not observable on air photos taken two days after the earthquake. What are visible in these photos are cracks in Foothill Blvd east and south of the Bridge which were repaired prior to the photos taken two months later. These cracks however are likely the result of road settlement.

As much as 30 cm (12 inches) of lateral fault displacement was noted west of the Bridge on the south branch (Proctor et al, 1972). Vertical displacement on a single fault trace was not reported but likely the mole trace discussed above had some vertical displacement.

Figure 6, the geologic map, shows a concealed fault trace beneath the Bridge. Locations of concealed traces in this area are based on earlier mapping using oil industry data (Winterer and Durham, 1962). CGS connected the 1971 ruptures east and west of the freeway using this concealed trace. We consider the entire trace of the south branch to be active.

POTENTIAL FOR FAULT RUPTURE

The following parameters were used in a PFDHA to determine fault offset:

50% of offset on the southern branch of the Santa Susana fault crossing the bridge (concealed and complex)
50% of offset on the northern branch of the Santa Susana fault feet north of the Bridge (accurate and complex)
MMax = 6.6 (1971 San Fernando Earthquake magnitude),
slip rate = 6 mm/yr (Dawson and Weldon, 2012) (probabilistic),
Dip slip (reverse) 55 degrees north

Results of the probabilistic analysis are shown in Figure 8. Probability of rupture is 0.38. Expected net fault rupture at the bridge is estimated at 0.775 meter (2.5 ft) probabilistically or 0.42 m (1.4 ft) deterministically. The probabilistic value should be used. The net probabilistic rupture can be separated into **vertical offset north side up of 0.63 m (2 ft) and horizontal movement toward the north of 0.44 m (1.4 ft). 0.3 m (1 ft) of offset in the lateral direction parallel to the bridge centerline should also be included in design.**

RECOMMENDATIONS FOR ADDITIONAL INVESTIGATION

No additional work is recommended at this time. If you have any questions, please contact Martha Merriam at (916) 227-7135 or K. Douglas Cook at 916-227-4514.

Prepared by:

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Figure 1. Looking east from atop Balboa Blvd OC at LA Aqueduct Bridge #53C-316. Penstock is covered and in the center of photo near Doug; Penstock is on the left. See Figure 6 for plan view.



Figure 2. Caltrans air photo taken two days post-earthquake. The Penstock is exposed across the I5 freeway alignment. Surface cracks were observed southeast of the Penstock on Foothill Blvd, and were likely the result of differential settlement.

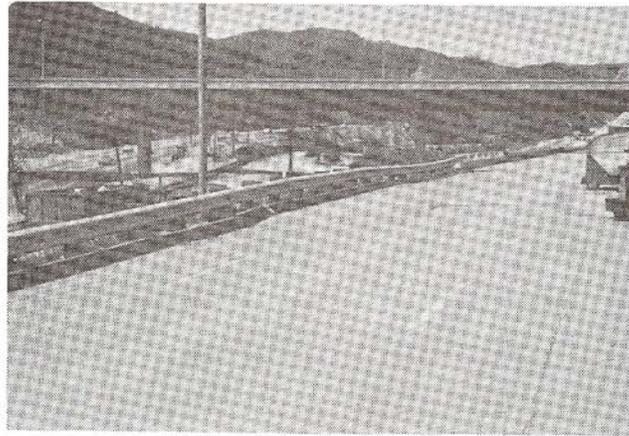
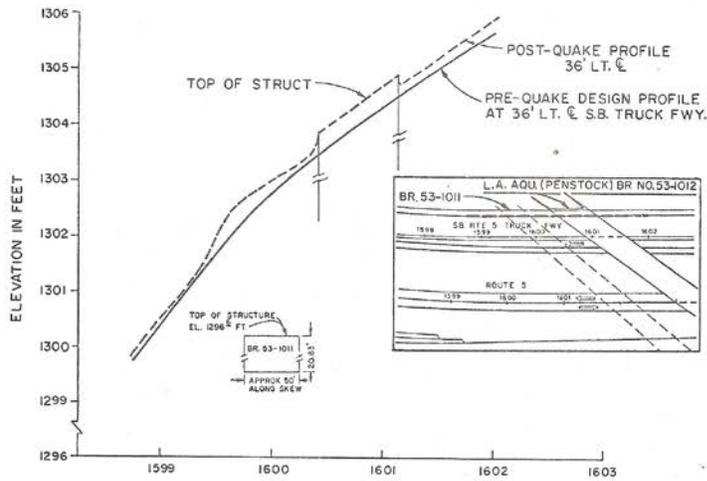


Photo 50. Looking northerly at undulating pavement of Route 5 caused by differential settlement. Balboa Boulevard Overcrossing structure is in background.



BEFORE AND AFTER QUAKE PROFILES
OF PAVEMENT SHOWN IN PHOTO 50.

FIGURE 13

Figure 3. Survey across structure showing rigid structure effect (Prysock and Egan, 1981).

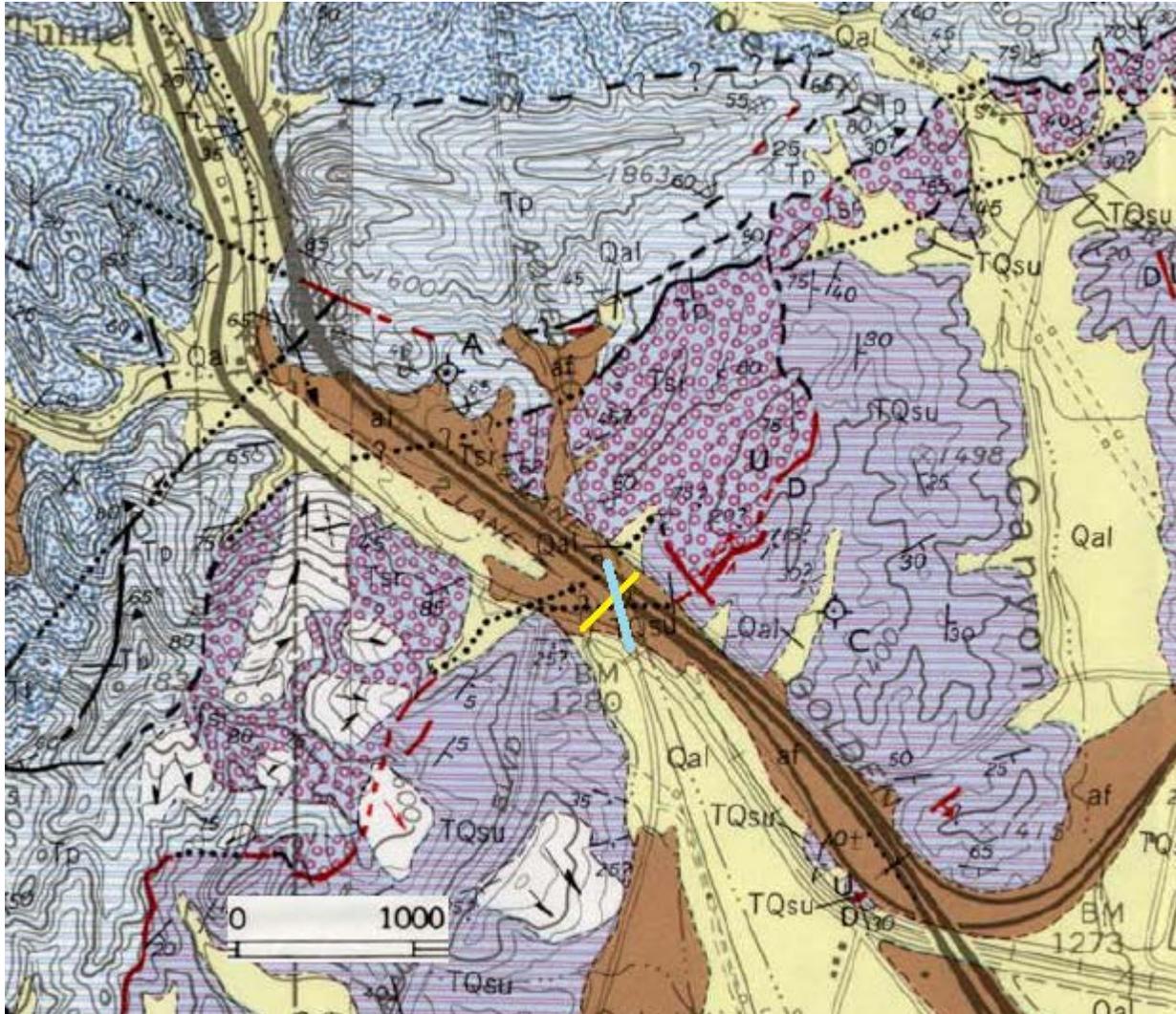


Figure 6. Geologic map of area. Blue line is Bridge and penstock location. Solid red lines represent positively identified/accurately located February 9, 1971 Earthquake fault ruptures. Black dotted lines represent concealed fault traces. U (upthrown block), D (downthrown block) (Barrows, 1975). Fault contact between the Tsr Saugus fm (Sunshine Ranch Member) on the north and the TQsu to the south.

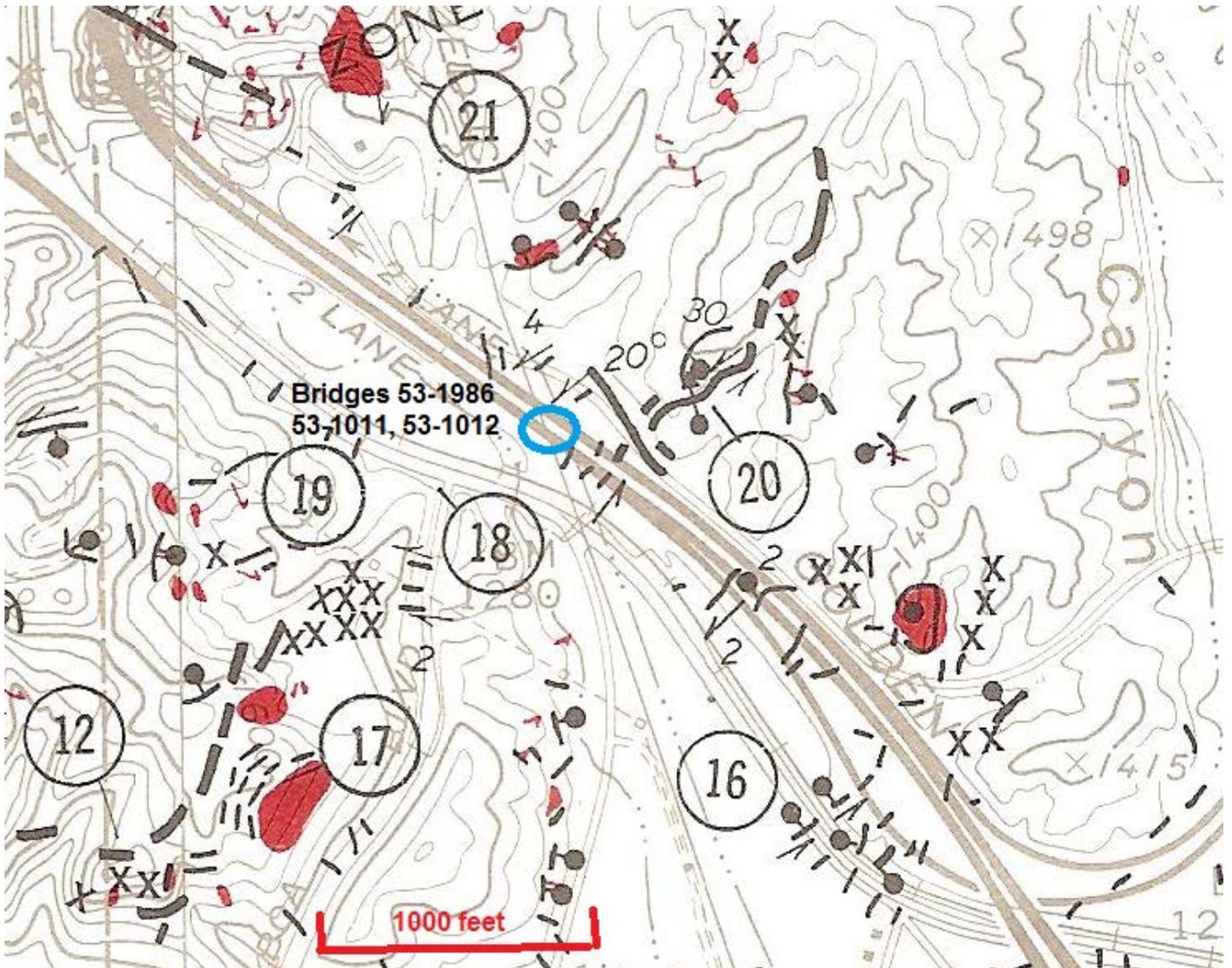


Figure 7. Location of 1971 San Fernando Earthquake surface cracks. (Barrows, 1974).

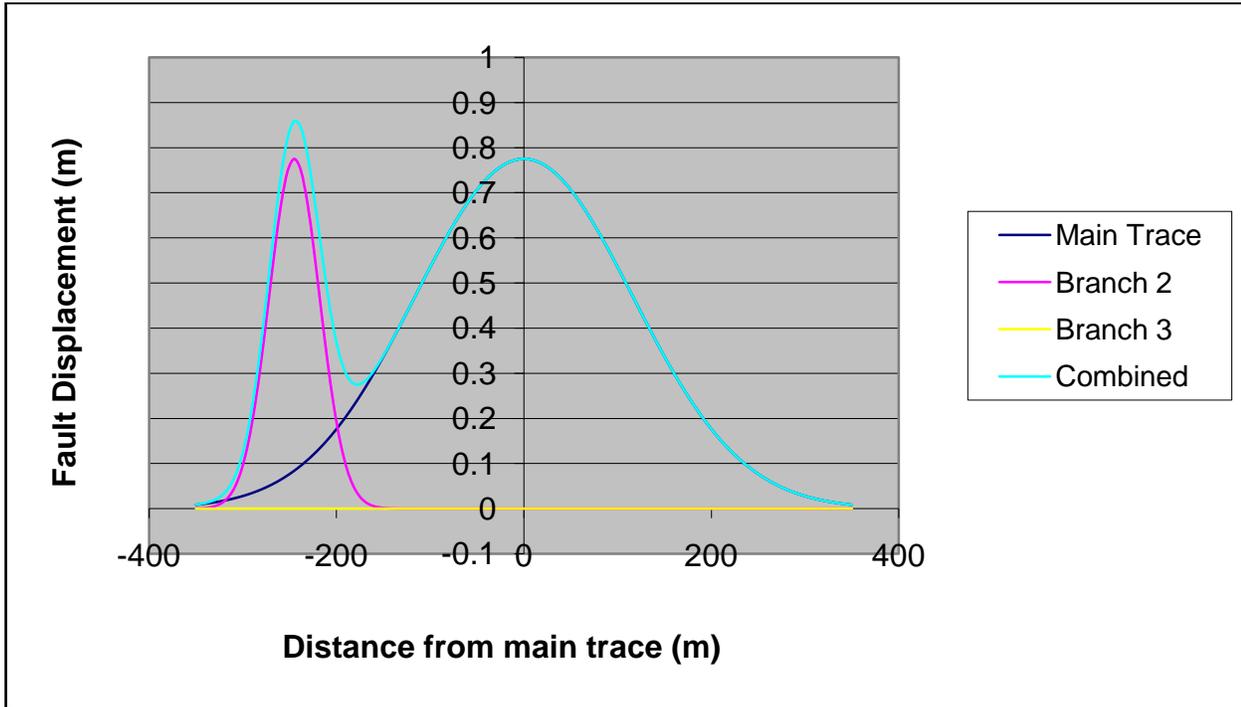


Figure 8. Results of PFDHA. The southern branch of the Santa Susana fault crosses beneath the bridge and is shown here as the “main trace.” That fault is weighted 50%. The northern branch of the Santa Susana fault is 245 m north of the bridge and is weighted 50% as well.