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

Date: December 16, 2014

File: 01-HUM-101-R91.99
59-93034-N
0000001016- 6SSCN
Hiller Rd OC
Bridge No. 04-0173

Attention: Mr. Mark Yashinsky

From: K. Douglas Cook, CEG
Office of Geotechnical Design South 2
Division Of Engineering Services

Subject: Evaluation of Fault Rupture Potential, Hiller Road Overcrossing, Bridge No. 04-0173, Post Mile 91.99, Route 101, Humboldt County, California

SUMMARY

The Hiller Road Overcrossing is situated within the Alquist-Priolo Earthquake Fault Zone for the Mad River Fault. The trace of the fault is mapped as crossing under the bridge between Bent 2 and Bent 3. The fault trace is concealed and was not located during a site reconnaissance conducted for this evaluation. A fault rupture analysis was performed and design values for a net dip slip probabilistic displacement of 52 inches (1.31m) was estimated for the bridge site, broken into 26 inches (0.66m) of vertical and 45 inches (1.13m) of horizontal movement for the bridge site. Locally, the fault has a heading of 340° and the bridge has a heading of 090°.

The bridge has been and will be subject to high levels of ground motion during a local seismic event which also may cause a minor amount of secondary offset. Additional field work is recommended to accurately locate the fault if it is determined that the bridge structure cannot accommodate the reported amounts of displacement.

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, 2013). 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 (MTD 20-10). Hiller Road Overcrossing, Bridge No. 04-0173 (01-HUM-101-91.99) is located on the US Route 101 (the Redwood Highway) in the City of

Mckinleyville, Humboldt County (Figure 1). It is situated within the Alquist-Priolo Earthquake Fault Zone for the Mad River Fault as depicted on the Arcata North Quadrangle map (CGS, 1983), Figure 2. Therefore, an evaluation of the fault rupture potential for this bridge is required.

Hiller Road OC was constructed in 1964 as a four span, six continuous T-Beam, reinforced concrete (RC) structure, on diaphragm abutments supported Class II driven piles, and a two - 2 column (RC) bents supported spread foundations. The structure is 186 feet long by 40 feet wide. The overcrossing bridge spans the center median, north and south bound lanes of US 101(Figure 3). The centerline trend of the bridge has an azimuth of 090° and that of the Mad River fault in the vicinity of the bridge site has an azimuth of 340°.

REVIEW OF EXISTING DATA

The Mad River fault (MRF) is a broad (~10 km wide) zone of northeast dipping thrust faults and folds being developed as a part of the accretionary wedge above the Cascadia subduction zone of northern California. From Trinidad Head (9 miles NW of the bridge site), the fault and fold zone extends northwest about 15–20 km into the offshore, and onshore about 43 km to the southeast. The MFR is the comprised of five principal splay faults and other minor faults in the zone one of which passes under the subject bridge.

As a part of a regional geologic fault investigation of the MRF (Carver and Burke, 1988) a fault trench was excavated across a low fault scarp at the School Rd. site, located about 2000 feet southeast of the bridge site. Evidence of 7 displacement events occurring within the past 83k.y. was observed in the excavation. The most recent event was in the Holocene with a radiocarbon date of 10,170 ± 60 yrs B.P was reported. Other more recent fault investigations (Carver, et al, 1992) reported two additional uplift events at Clam Beach near the mouth of the Mad River that were C14 dated at 1,100 yrs B.P. and 300 yrs B.P., which were interpreted as evidence of the most recent events on the MRF.

The expected maximum magnitude earthquake for the Mad River fault is Mw 7.1 (USGS, 2008). Recent paleoseismic studies indicate an averaged Holocene slip rate of 5 mm/yr (Dawson and Weldon, 2012).

A Fault Evaluation Report (FER 138) was prepared by the Division of Mines and Geology (predecessor of the California Geological Survey) for the Alquist-Priolo Special Studies Zone (now Earthquake Fault Zone) for the Mad River Fault (Smith 1982). The fault zone is depicted on the Arcata North Quadrangle Map (CGS, 1983). In the area of the subject bridge the fault is mapped as several splays, of which passes under the bridge is mapped. The general mapped trend of the Mad River fault in the immediate vicinity of the bridge site has an azimuth of 340°.

REVIEW OF SELECTED AERIAL PHOTOGRAPHY AND LIDAR IMAGES

Selected aerial photographs taken prior to or after the construction of the Hiller Road OC were unavailable for review at this time. Nor was any LIDAR imagery available from Open

Topography (2014). However, proprietary LIDAR imagery reported in a master thesis (Sundberg, 2013) shows a topographic scarp over the trace of the MRF at the bridge site. Google Earth imagery for the area reviewed for this does not clearly show any of the Mad River Fault splay in developed areas in the vicinity of the bridge.

FIELD RECONNAISSANCE

A field reconnaissance was conducted of the Hiller OC site and vicinity on August 13, 2013 by Martha K. Merriam, CEG (then with the Office of Geotechnical Support - Instrumentation Branch) and K. Douglas Cook, CEG (Office of Geotechnical Design South 2). The topography, geomorphology and road cut exposures of the area were observed at that time. No direct evidence an exposed fault trace was observed. However, a subtle break in slope in an alley way at the end of Thiel Avenue in the proximity of the fault scarp was observed.

POTENTIAL FOR FAULT RUPTURE

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 Wells and Coppersmith (1994), Abrahamson (2008), and Petersen, et al (2011). For reverse-slip faults such as the MRF a probabilistic fault displacement analysis was used (Moss and Ross, 2011). Input parameters included:

- Slip rate of 5 mm/yr (Dawson and Weldon, 2012)
- Mmax of 7.1 (USGS, 2012)
- Reverse slip 30° NE
- Bridge-to-fault distance of 0 m (crossing under the bridge)
- A net 80% of the slip would occur on the trace under the fault and the other 20% on the next nearest fault splay located 1640 feet (500m) away.
- b-value of 0.8 (USGS, 2008)

Both a deterministic fault displacement hazard analysis (DFDHA) and a probabilistic fault displacement hazard analysis (PFDHA) of 5% in 50 years (975 year mean recurrence interval) were performed using magnitude, slip rate (for PFDHA), mapping and base map errors, and likelihood of secondary fault traces. **A probability of surface slip occurring was calculated at 0.50. A deterministic fault displacement of 4 feet (1.21 m) (Wells and Coppersmith, 1994) and a probabilistic fault displacement of 5.5 feet (1.68 m) (Moss and Ross, 2011) were calculated.** The expected 80 % net fault rupture at the bridge is estimated as shown in Table 1.

Table 1- Estimated Fault Displacement at Bridge

Analysis	Net 80% Displacement	Vertical Displacement	Horizontal Displacement
Deterministic	37in (0.95m)	19in (0.48m)	19in (.82m)
Probabilistic	**52 in (1.31m)**	**26in (0.66m)**	**45in (1.13m)**

At the bridge site the expected probabilistic displacement would be about 26 inches vertical and 45 inches horizontal. The resultant graphs of these analyses are respectively shown on Figures 4 and 5.

RECOMMENDATIONS FOR ADDITIONAL INVESTIGATIONS

Additional work to accurately locate the fault in the field is recommended if it is determined that the bridge structure cannot accommodated the reported amounts of lateral displacement**.** Please contact Douglas Cook at (916) 227-4514 if you have any questions.

Prepared by: Date: December 16, 2014

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Geotechnical Design West – Anna Sojourner

Attachments: Figures 1 through 5

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Figure 1. Hiller Road Overcrossing, with fault trace and EFZ boundaries (after USGS/Google Earth Faults, 2014).

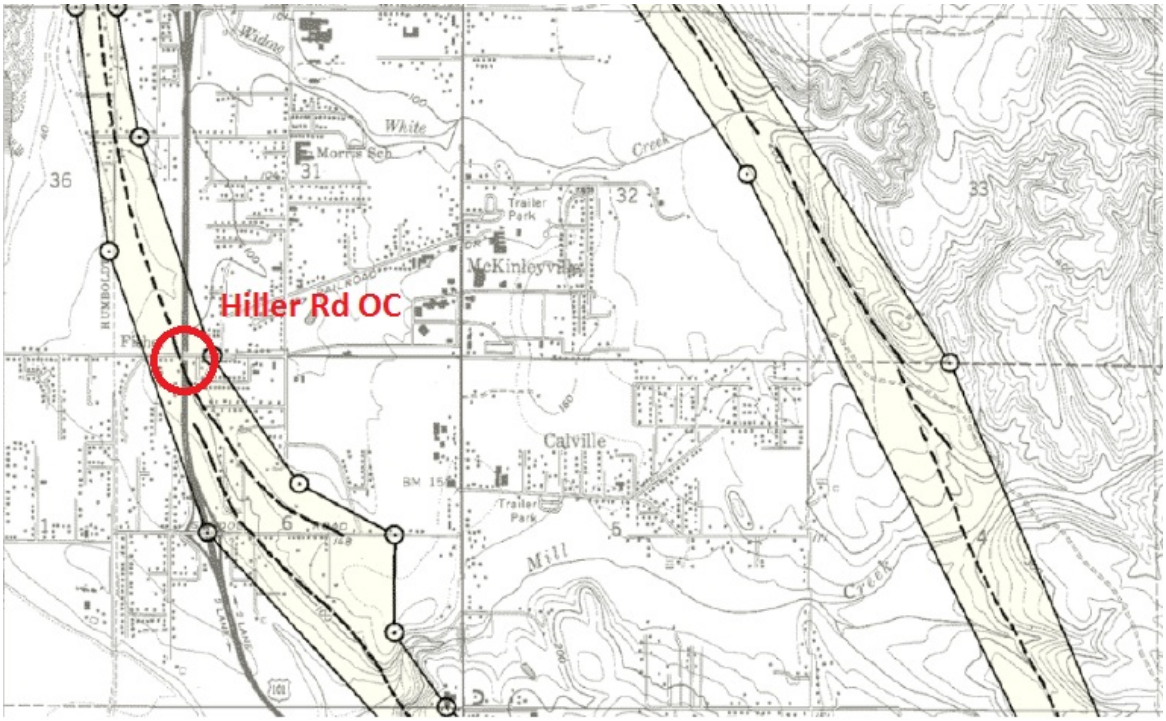

Figure 2. After Arcata North Quadrangle Earthquake Fault Zone Map (CGS, 1983).

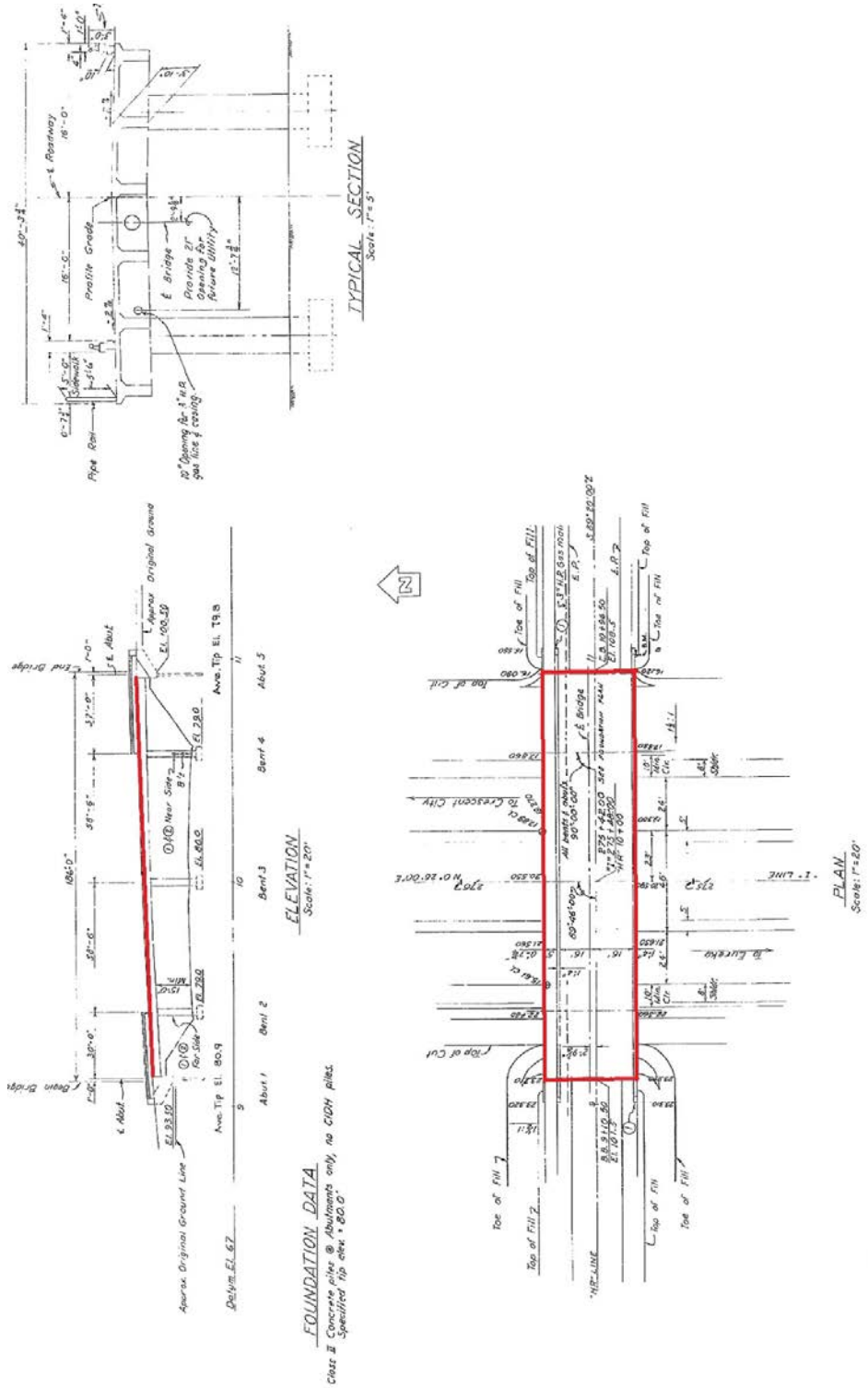

Figure 3: Hiller Road Overcrossing Elevation and General Plan, After As-Built General Plans, 1965.

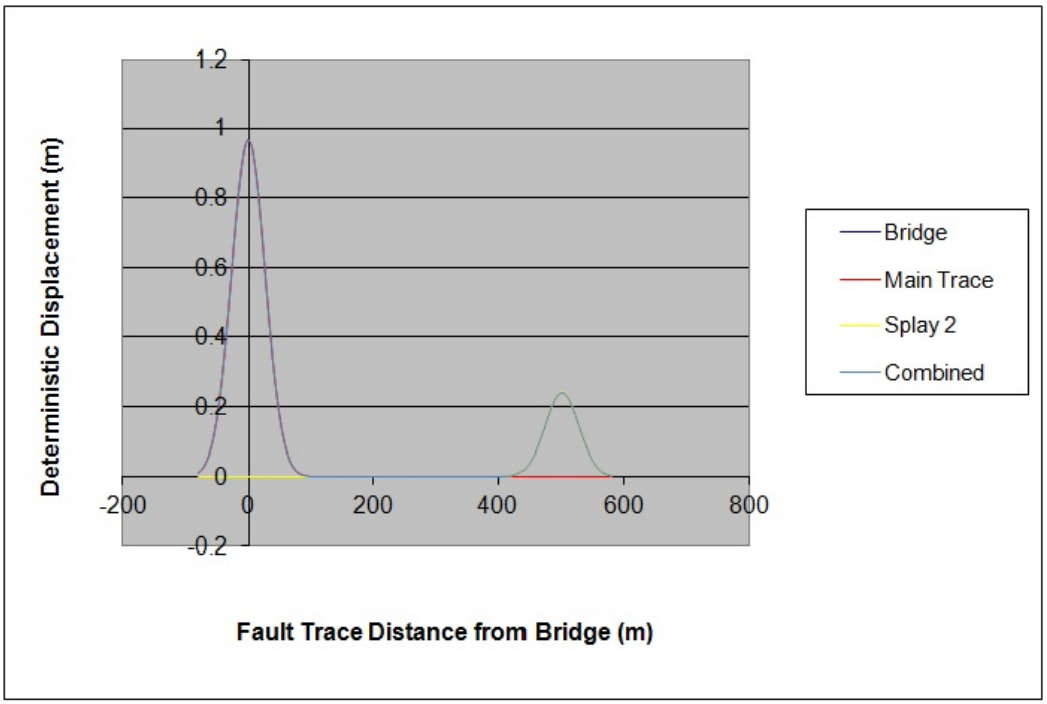

Figure 4: 37 inches (0.95m) of Deterministic displacement at the bridge

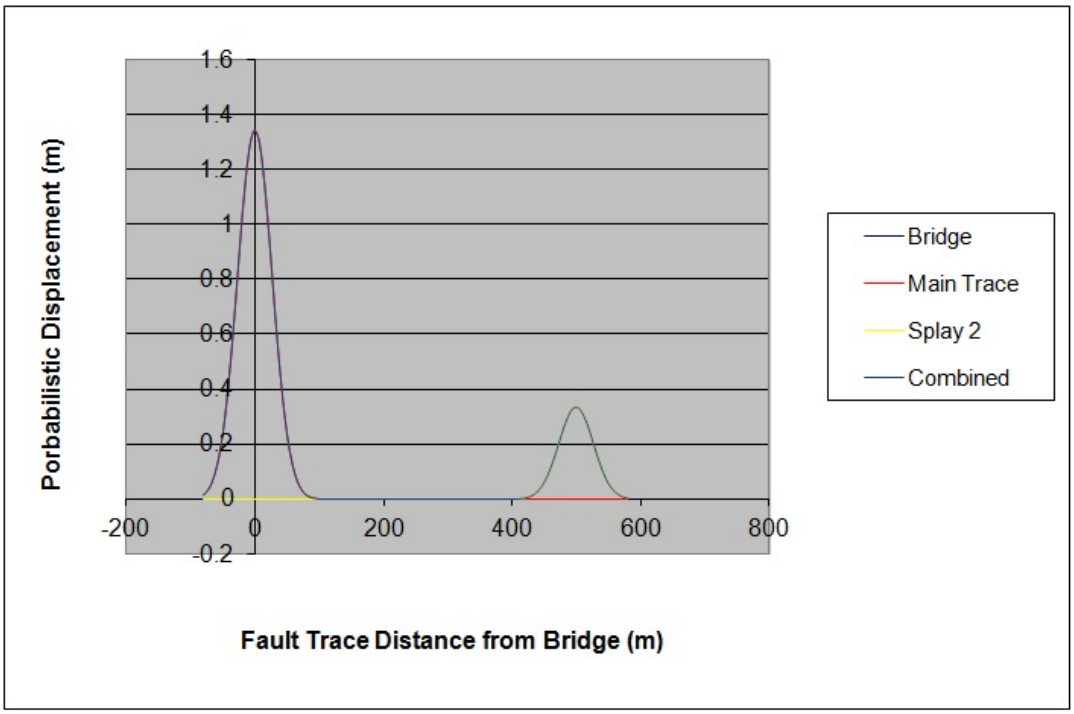

Figure 5: 45 inches (1.31m) of Probabilistic displacement at the bridge