Performance of Transportation Systems During the 9/3/2000 Yountville Earthquake

by Mark Yashinsky, Caltrans Office of Earthquake Engineering

Scientists and engineers usually study the impacts of large earthquakes. However, the moderate Yountville, California quake of September 3, 2000 caused significant damage and deserves closer study. This earthquake had a local magnitude of 5.2 (M_w = 5.0), the rupture occurred at a depth of 9 km, and lasted for about 10 seconds (Figure 1). The earthquake occurred at 1:36 am (PDT) on an unknown fault with a strike-slip motion at latitude 38.377N and longitude 122.414W in mountainous terrain on the west side of the Napa Valley (Figure 2). This is a rural (and agricultural) setting and most of the damage occurred 12 km to the south in the City of Napa where there was more infrastructure, thicker alluvial deposits, and perhaps due to the fault rupturing to the south.

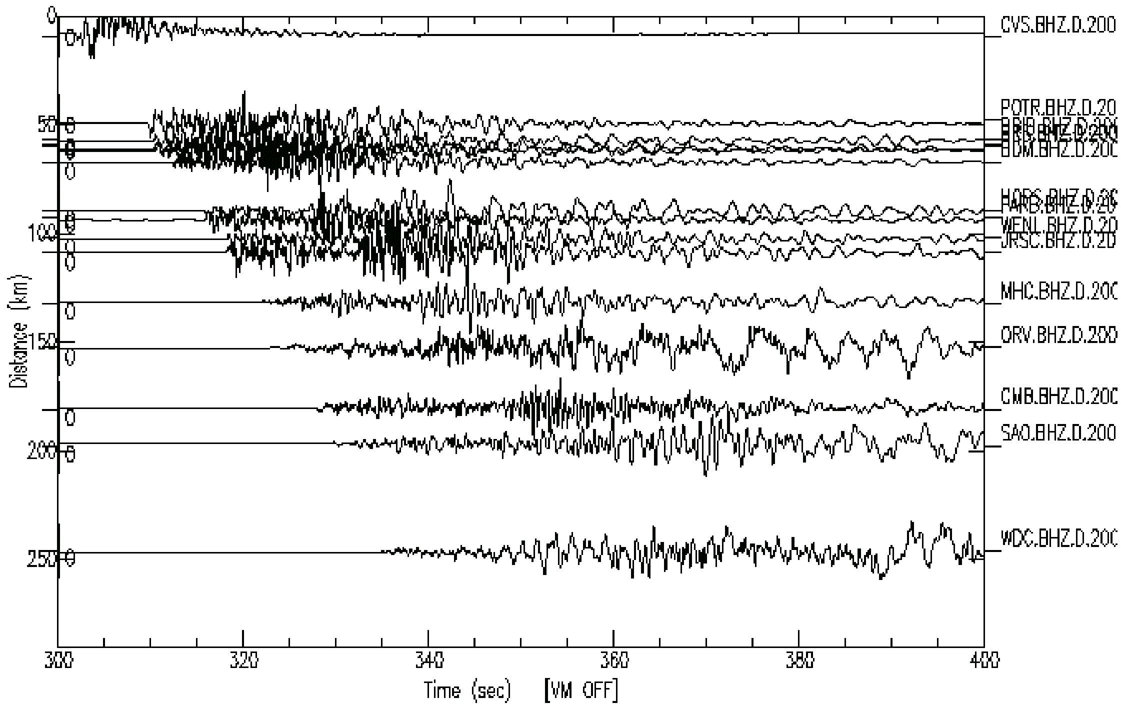

Figure 1 USGS/UCB Ground Motion Records.

The closest strong motion accelerometer was 3 km west of the epicenter, but only recorded a PGA of 0.06*g* (Figure 1). One recorded PGA was 0.337*g* at Napa College, 16 km to the south. Two other instruments recorded PGA values of 0.49g and 0.18g. There was no indication of liquefaction, surface rupture or landslides. Estimates of the cost are still sketchy but public officials are suggesting between $50 to $100 million dollars, largely based on a HAZUS, computer-generated risk analysis. Fortunately, there were no fatalities, only one serious injury, and 40 people were treated as outpatients immediately after the quake. However, the Red Cross was busy providing temporary shelters to families, surveying the damage, and providing counseling as well as food, clothing and medicine.

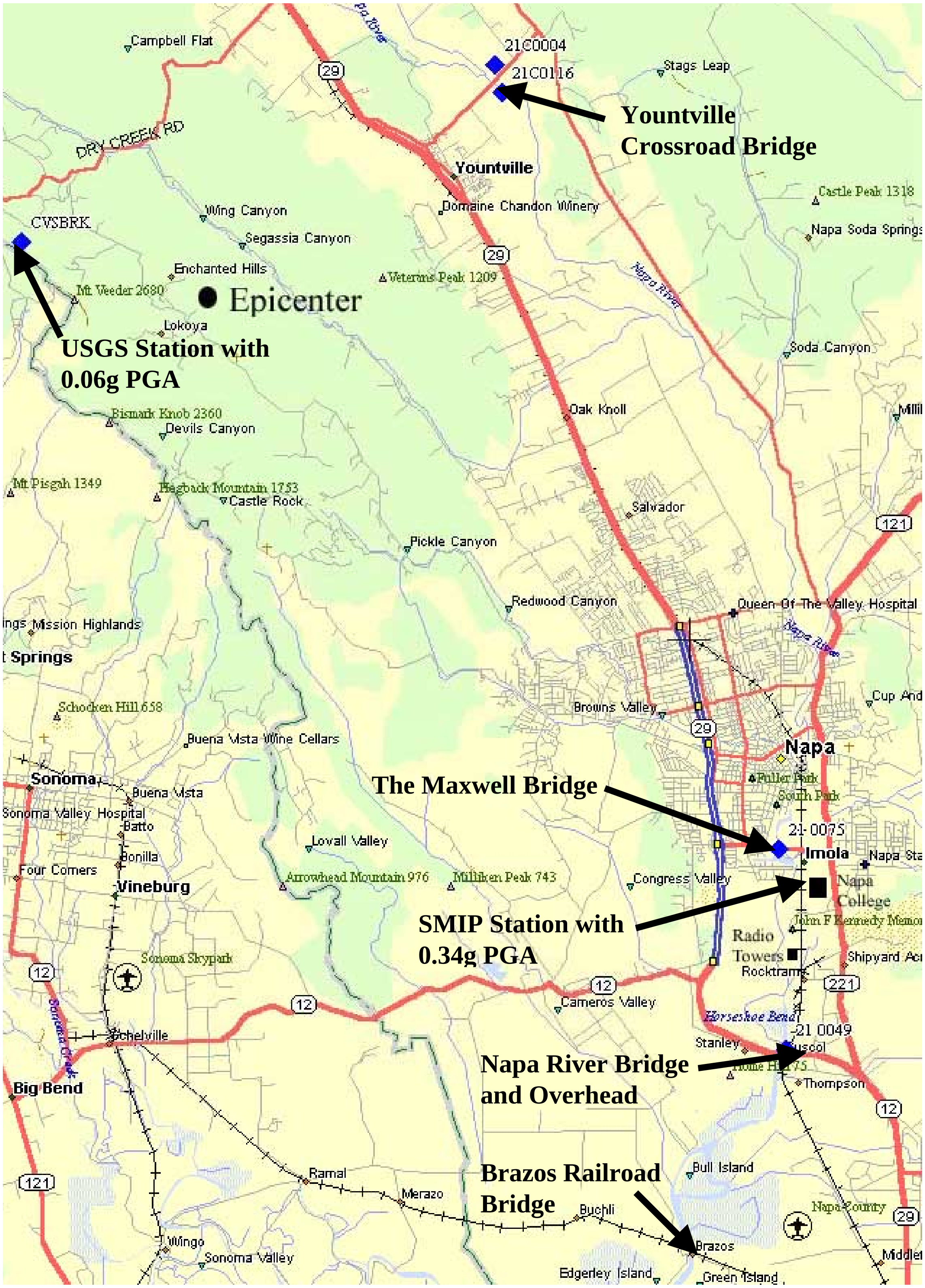

Figure 2. Map of Epicenter and Region.

After talking with city engineers, county firefighters, and surveying the area, we estimate that there were hundreds of residences with broken chimneys (Fig. 3 & 4), damaged plumbing, broken gas lines (due to toppled water heaters), and other damage. There was one small fire in a hotel, twenty damaged water pipes, and a disruption in electric power resulted in 10,000 customers without power and had serious repercussions to the local emergency broadcast radio station. The following describes the performance of transportation systems.

Figure 3. Broken Chimney.

Figure 4. Fallen Chimney.

Transportation Systems

The Napa Valley has two closely related industries, wine and tourism. The greatest demand on the transportation system is in the fall when both of these industries are most active. The Napa Valley has the following transportation facilities:

- a small airport just south of the City of Napa,
- two railroads are currently in operation in Napa Valley. The biggest railway is the California Northern Railroad with trains running between Suisin City, Napa, and Vallejo. The Napa Valley Railroad goes from the City of Napa to St. Helena and carries the popular 'Wine Train' several times a day. A third railroad with tracks running west of Napa, the Northwestern Pacific Railroad, is not currently in service.
- The Napa River carries barges that supply sand and gravel to Syart Construction in the City of Napa. A 200 foot cruise ship and a variety of pleasure craft travel along the Napa River between San Pablo Bay and the City of Napa. There are dolphins, marinas, and even dry docks for these vessels in the City of Napa.
- State Route 29 is the largest capacity road running north and south through the Valley, becoming a four lane limited access expressway in the city of Napa. Routes 121, 128, and a local road, the Silverado Trail provide some redundancy; running parallel to SR 29 in Napa. State Route 12 goes across the Valley and connects Interstate 80 to 101. Because the Napa Valley is surrounded by steep mountains, all of the two-lane State Routes become steep and winding as they climb out of the Valley.

There was no significant damage to any transportation facility during this earthquake. The airport sustained no significant damage: there was no structural or mechanical damage to the runway, the administrative building, or to the control tower. Only a few minor items (radios) fell off shelves, but remained undamaged. The airport was not operational at the time of the earthquake (normal operational hours from 7 am to 8 pm), and it is unknown if PG&E power was temporarily lost to the airport or if the two backup diesel generators worked as intended. The control tower was reported to have suffered slight cracking of a non-structural wall.

Both the California Northern Railroad and the Napa Valley Railroad immediately dispatched inspection crews after the earthquake and reported no damage had occurred. In fact, the Napa Valley Railroad ran a 'Wine Train' several hours after the earthquake. The Northwestern Pacific Railroad has a handsome vertical lift railway bridge over the Napa River just south of the City of Napa. This bridge remains raised to allow boat traffic since the railroad is currently out of service. An inspection crew went out on Monday, September11th and reported that no damage had occurred (Figures 5 and 6).

Figure 5. Brazos Railroad Bridge.

Fig. 6. Counterweight, Vertical Guide, and Marking.

We contacted ports and marinas from Mare Island in Vallejo to the City of Napa and they all reported no damage from the earthquake.

There was some interesting (but very minor) damage to three highway bridges:

- **The Napa River Bridge and Overhead** (Br. #21-0049) was built in 1977. It is a 13 span precast, segmentally constructed, concrete box girder bridge that carries State Route 29 over the Napa River (see Figure 7). The bridge is supported on tall single-column bents and end-diaphragm abutments; all on pile caps that were retrofitted in the 1990's. The structure is composed of four frames separated by three unusual hinges. Instead of a bench for the longer cantilevered span to rest on, they are supported by concrete pistons with steel stoppers. The earthquake widened the hinge openings (and moved the bearings) an inch or two, but the very large gaps (Figure 8) are a pre-existing condition (Figures 9 and 10).

Figure 7. The Napa River Bridge and OH.

Figure 8. Hinge Opening at Napa River BOH.

Figure 9. Hinge.

Figure 10. Bearing.

– **The Maxwell Bridge** (Br. #21-0075) is a two-lane vertical lift bridge (with a main span of 132 ft) that was.built in 1949 (Figures 11 and 12). It was recently retrofitted to provide greater seismic resistance for the maximum credible earthquake. This retrofit included some work to the towers that carry large concrete counterweights to lift the bridge. The main vertical tower members are 'double (back-to-back) angle sections from which small squares were (almost completely) gas-cut out to allow the counterweight to move freely both transversely and longitudinally after knocking out the cut pieces (instead of banging against the tower legs during the earthquake). The metal squares were left in so the guides on the counterweight wouldn't bind against the holes. During the earthquake, the retrofit worked perfectly, with the guides knocking out the cut metal squares, thus allowing it to swing without hitting the tower legs (Figure 13 and 14). However, the metal squares fell onto the roadway, which could have banged up a vehicle or even endangered a driver if the earthquake had occurred when someone was on the road. Therefore, the designer has asked that the plates be tack-welded back onto the channels (to help guide the counterweight) and that little chains should be attached to keep the plates from falling onto the roadway during the next earthquake.

–

Figure 11. The Maxwell Bridge.

Fig. 12 Counterweight and Tower.

Figure 13. Retrofit for Longitudinal Movement.

Figure 14. Retrofit for Transverse Movement.

- **The Yountville Crossroad Bridge** (Br. ##21C-0116) is a two-lane, locally owned bridge that crosses over the Napa River and Conn Creek just east of Yountville. The superstructure is six simple spans of five precast concrete I-girders on elastomeric rubber pads and with a continuous deck (Figure 14). The substructure is pier walls and seat-type abutments. There was a pre-existing problem at this bridge. The elastomeric bearings had delaminated, allowing the deck to settle onto the exterior shear keys of the eastern abutment and causing the concrete to spall and expose some reinforcement. The spall was patched however, the bearings were never replaced and during the earthquake, the precast I-girders of the eastern span moved sufficiently to spall the exterior shear keys again (Figure 15). Otherwise, the bridge was in good condition.

Figure 14. Yountville Crossroads Bridge.

Figure 15. Spalled Abutment.

There was no other bridge damage. All of the bridge damage was on longer river crossings. There are many other bridges in the area including several old stone arch structures that had absolutely no damage. There was no damage to any road from landslide or settlement (except a slight bit of settlement at a few bridge approaches).

Earthquake Recovery

Based on field observations, the bulk of the direct damage could be attributed to chimney failures (200 to 400 of these), a few structural failures, various non-structural failures and lifeline damages; this would suggest (roughly) total direct losses in the \$15,000,000 range. Repairs or maintenance for cosmetic or other non-structural damage (cracks in paint, repair of water heaters, etc.) may amount to substantially higher total losses. There were no fatalities and few injuries, however the Red Cross was busy providing temporary shelters, surveying the damage, and providing counseling, food, clothing and medicine. City inspectors were also busy due to the estimated 3,000 to 5,000 buildings that are thought to be damaged. Inspecting and recording damage is important to the City because they need to document the damage to receive assistance from the federal government. Governor Davis has asked the President to declare Napa a federal disaster area. If Napa qualifies, FEMA would come in and provide grants and loans to people impacted by the earthquake.

Although a M_w 5.0 earthquake would seem too low to cause more than light damage, our survey suggests that the damage is more widespread and more diverse. Research should be done to explain the high level of recorded motions from those expected from a M_w 5.0 earthquake; to establish maps of the community with observed levels of amplified ground motions; to explain the large variation in damage to two buried pipe systems (water and gas); to validate loss models (such as those in HAZUS) for wood frame construction with brick chimneys. If a relatively small earthquake can cause this level of damage in Napa Valley, the community should be concerned about the expected M_w 7.0 earthquake on the Rogers Creek Fault and how it will affect the City of Napa.