24 August 2014
South Napa M_w 6 Earthquake

Reconnaissance Report

26 September 2014

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Abstract

A magnitude Mw 6.0 affected the northern portion of the San Francisco Bay Area at 3:20 AM on 24 August 2014. While the epicenter was in agricultural farmland, the surface rupture extended for approximately 12 km – at its northern end, the surface rupture was within the Brown's Valley neighborhood of the City of Napa. Ground motions were relatively high in Napa, with MMI VIII and PGA of 0.6 being observed. The earthquake caused one fatality and about 13 hospital admittances in Napa, with several hundred people requiring medical assistance. In the historic city of Napa, it caused substantial damage to ordinary buildings, and very heavy damage to a number of historic masonry buildings, although some retrofitted masonry buildings had very little or no damage. Approximately 116 buildings were red-tagged (unsafe to enter or occupy) and over five hundred yellow-tagged (limited entry), meaning that 2% of the Napa building stock was impaired by this not-very-rare earthquake. Infrastructure was variously affected, with perhaps the water system having the most damage, with approximately 160 water main breaks. One water main break impaired firefighting efforts at the largest of six fires that occurred due to the earthquake. A number of wineries sustained (probably avoidable) broken wine barrels, with the total spillage of wine estimated to be as high as five to six thousand barrels (representing a loss of \$10~20 million, as compared with a total Napa Valley wine gross sales revenue of \$10 billion in 2006). Other affected communities included the cities of American Canyon and Vallejo. Within several days, the City of Napa had largely returned to normal.

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Introduction

A magnitude Mw 6.0 affected the northern portion of the San Francisco Bay Area at 3:20 AM on 24 August 2014. While the epicenter was in agricultural farmland, the surface rupture extended approximately 12 km – at its northern end, the surface rupture was within the Brown's Valley neighborhood of the City of Napa. Ground motions were relatively high in Napa, with MMI VIII[1] and PGA of 0.6 being observed. The earthquake caused one fatality and about 13 hospital admittances in Napa, with several hundred people requiring medical assistance. The fatality was a 65-year-old woman who was struck on the head by a falling television. (Nonstructural damage and overturned contents are common in earthquakes at fairly low levels of shaking, and can usually be mitigated fairly inexpensively.) In the historic city of Napa, the earthquake caused substantial damage to ordinary buildings, and very heavy damage to a number of historic masonry buildings, although some retrofitted masonry buildings had very little or no damage. Infrastructure was variously affected, with the water system having perhaps the most damage, with approximately 160 water main breaks. One water main break impaired firefighting efforts at the largest of six fires that occurred due to the earthquake. A number of wineries sustained broken wine barrels, with the total spillage of wine estimated to be as high as five to six thousand barrels (representing a loss of $10~20 million, as compared with a total Napa Valley wine gross sales revenue of $10 billion in 2006[2]). Other affected communities included the cities of American Canyon and Vallejo. Within several days, the City of Napa had largely returned to normal.

This report provides a summary of the event and reconnaissance performed by SPA, beginning the day after the event and continuing for a month. This report is not intended to be exhaustive, but rather to provide a useful overview of the event, with special attention to infrastructure (termed "lifelines" within the earthquake community) and fire following earthquake. Some aspects, such as the performance of bridges, are not treated.

For more information, the reader is referred to detailed reports by others, especially (Bray et al. 2014; PEER 2014; TCLEE 2014) (EERI, 2014 forthcoming) as well as a video of a two hour briefing (http://www.youtube.com/watch?v=R1A7zAi8_lE).

Affected area

Figure 1 and Figure 2 show the epicentral area of the earthquake, with Figure 2 showing Modified Mercalli intensities (MMI[3]) overlaid on population density. Initial estimates of affected population are shown in Table 1, while current estimates of total population within MMI VI (the threshold for building damage) are about 200,000, with approximately 36,000 subjected to MMI VIII, Table 2. Three significant population centers are located within the MMI VI

[1] MMI VI is the threshold for building damage; MMI IX is the strongest observed in the 1989 Loma Prieta earthquake, so MMI VIII is fairly strong

[2] Gross sales revenue data from http://www.napanow.com/wine.statistics.html . Unsecured wine barrels have overturned in past earthquakes. Like residential contents, this kind of damage is avoidable.

[3] MMI is one measure of shaking at a site. It varies with earthquake magnitude, the site's distance from the rupture, the soil beneath the site, and other parameters. It is different from magnitude, which measures the total energy released by the rupture. The beachball-like object in Figure 1 is called a fault-plane solution. It tells seismologists how the two sides of the fault moved relative to each other. This one says that the motion was mostly horizontal, like earthquakes on much of the San Andreas, Hayward, and other Bay Area faults.

isoseismal, being the cities of Napa, American Canyon and Vallejo. The location of the event relative to these and other nearby cities are:

- 6 km (3 mi) NW of American Canyon, California
- 10 km (6 mi) SSW of Napa, California
- 12 km (7 mi) NNW of Vallejo, California
- 14 km (8 mi) SE of Sonoma, California
- 83 km (51 mi) WSW of Sacramento, California

The Earthquake

Event and Tectonics

The event is designated as USGS event ID *nc 72282711* and has the following parameters:

- Magnitude: 6.0
- Epicenter: 38.22N, 122.313W
- Depth: 11.3 km
- Universal Time (UTC): 24 Aug 2014 10:20:44
- Local time: 24 Aug 2014 03:20:44

The earthquake lies within a set of major faults of the San Andreas Fault system that forms the boundary between the Pacific and North American tectonic plates, and was located just north of San Pablo Bay between the Hayward-Rodgers Creek Fault and the Concord-Green Valley Fault. The earthquake occurred near the well-known West Napa Fault, which is known from trenching and aerial evidence to have ruptured at the earth's surface within in the last 11,000 years.

Historic events in the region include the M6.8 1868 Hayward, the M7.8 1906 San Andreas, and the M6.3 1898 Mare Island earthquakes. The 1898 earthquake may have occurred about 20 km (12 miles) to the northwest on the southern Rodgers Creek Fault. The Concord-Green Valley Fault system, which is 12 km (7 miles) east of the site, produced a M5.5 earthquake in 1954; while it has not generated a large historical event, there is strong evidence for recent pre-historic activity.

Strong Motion

Figure 3 shows the location of strong ground motion instruments in the affected area, while Table 3 lists peak strong motion data from those instruments with epicentral distance less than 25 km. Figure 4 shows the waveform for station N016 located in the City of Napa, which recorded a PGA of 0.61g. The largest PGA was 0.995 g recorded at station CGS 68206 – this record is relatively anomalous and so far is unexplained. Figure 5 taken from (Bray et al. 2014) plots these and more distant data's horizontal Peak Ground Acceleration (PGA) and 5% damped Pseudo-Spectral Acceleration (PSA) (RotD50) versus ground motion prediction equations (GMPEs) against distance to the rupture surface (Rrup), with reasonable agreement particularly in the near field.

(Bray et al. 2014) compared recorded ground motions to code-based design spectra, Figure 6, finding that the pseudo-spectral accelerations recorded there (and at some other locations) exceeded the maximum considered earthquake (MCE) and 2/3·MCE (design) spectra at a period around 1.5 s near the fault, observing that "this observation is related to near-fault velocity pulses."

To explain: the black lines in Figure 6 are what engineers design for. A shorter building (less than 5 stories or so) is designed for accelerations near the flat part of the solid black line. A taller building is designed for downward-curving solid black line. The dashed black line corresponds to very rare (MCE) motion, with somewhat higher than 2% probability of being exceeded in 50 years, or in other words somewhat higher than shaking that is only expected to occur once in 2,500 years. The three jagged lines show shaking at Napa Fire Station 3 measured in two different directions and a geometric mean, which approximates the strongest motion a building would have experienced. Different x-values in the plot correspond to the motions that buildings of different heights would have experienced or would be designed for. The plot shows that motions in not-very-rare earthquakes can produce very rare shaking in some locations, reaching or substantially exceeding life-safety and even collapse-prevention motions.

Figure 7 plots similar information but reformatted to focus on how observed motions differed from what one would calculate for an earthquake of this magnitude (as opposed to design-level motions). Figure 7a shows that observed motions were much higher than median where it mattered most, close to the epicenter. Triangles above the diagonal line are higher than would be calculated. Some motions reached life-safety design-level shaking of 1.3 g, in locations where the median calculated motion would have been 0.28 g. Figure 7b shows the ratio of observed to median motions plotted against distance from the rupture. Motions within 20 km of the epicenter were on average double the median calculated value, and in some cases 3 to 5 times higher. Circles and error bars show averages and ±1 standard deviations in 5-km distance bins. This not-very-unusual, not-very-large earthquake produced life-safety design-level shaking in locations where the median for their distance in this magnitude was 1/5th the design-level shaking.

Ground rupture and geotechnical effects

Ground rupture and geotechnical effects are covered extensively in (Bray et al. 2014), who concluded "The rupture mechanism was primarily strike-slip and surface fault rupture and was expressed along much of the ruptured fault plane trending NNW and extending for a distance of 12-14 km from the hypocenter…. Surface faulting damaged homes, underground utilities, and other infrastructure when it traversed developed areas, such as the Browns Valley area in western Napa…. There was a lack of liquefaction and liquefaction-induced ground failure in this event, even in areas previously identified as being susceptible to liquefaction hazard." Observed traces of the fault are shown in Figure 8, taken from a presentation by T. Dawson.

Change in seismic hazard

Contrary to popular misconception, a Mw 6.0 earthquake like this does not significantly relieve stress on nearby faults. In the short term it increases the probability of a strong earthquake. The probability of a Mw 7 or larger earthquake in the San Francisco Bay Area is still 70% in the next 30 years, and 4% (about a 1 in 25 chance) in the coming 12 months.

Building Effects

Tags

A total of 752 buildings in the City of Napa were tagged red, yellow or green according to the ATC-20 process, as of 1 pm on 27 August 2014. Of these, 116 (15%) were red (unsafe to enter or occupy), 515 (68%) were yellow (limited entry, such as safe enough to remove property or safe enough only in a portion of the building), and 121 (16%) were green (inspected, and deemed safe for normal, pre-earthquake use). These are shown in Figure 9.

The total count of county assessed parcels in Napa County's files within the City of Napa is 22,872; the total number of addresses is 27,661; and the total number of building footprints (i.e., individual structures) in the City of Napa is 28,004.

Thus, if 28,004 is taken as the number of structures, red tagged buildings are approximately 0.41% of all buildings, and yellow tagged buildings 1.84%. So this not-very-large earthquake impaired 2% of the building stock. A larger earthquake probably would have impaired a larger fraction of the building stock.

<u>General Building Performance</u>

A variety of buildings were affected by the event, as follows:

- Wood-framed single family dwellings performed relatively well, except in the areas of highest intensity, where significant damage was observed among some but not all such buildings, Figure 10. The kind of damage shown in Figure 10 is fairly common, predictable, and straightforward to mitigate. Chimney damage was more widespread, Figure 11, and is also very common.
- Manufactured homes are of at least two kinds in the affected area – older "trailers" no longer on wheels but rather on blocks of some sort, and newer actual manufactured homes. Performance of both kinds was observed on a limited basis at the relatively large Napa Valley Mobile Home Park on Orchard Road in northern City of Napa, and at a smaller group of such buildings on Lincoln Road in more central City of Napa. The older type of home generally did much more poorly, with a number of instances of what is probably total loss. The newer type of home generally did well, with few observations of significant structural damage, Figure 12. This kind of damage has been repeatedly observed in California earthquakes. Mobile homes and other manufactured buildings such as temporary buildings at schools commonly suffer damage like this at low levels of shaking if they are not properly secured. Earthquake resistant bracing systems and engineered tie-down systems are fairly inexpensive methods to prevent this kind of damage. For more information, see http://www.sparisk.com/pubs/SPA-2014-Mobile-Homes-in-Earthquakes.pdf.
- Unreinforced masonry (URM) buildings were probably the most extensively damaged larger class of buildings in this event. Based on a limited survey, URMs may be grouped into several categories:
    - Extensively and probably more recently retrofitted, which appear to have done very well in this event, Figure 13 to Figure 16;
    - Less, perhaps marginally, and perhaps older retrofits, which appear to have, at least some instances, sustained major damage, Figure 17;
    - Un-retrofitted, which may be further subdivided:
        - Damaged, Figure 18 to Figure 22;
        - Undamaged – no undamaged un-retrofitted URMs were observed.

Figure 19 highlights the fact that a fragile building next door can imperil a modern, well designed building and can potentially kill or injure building occupants and cause business interruption.

Other damaged buildings including the Old Courthouse, Figure 23, and a modern (built 1984) three story 40,000 sq. ft. office building, Figure 24. Several of these buildings were historic structures, listed on the National Register of Historic Places.

Lifeline Effects

The section reports on lifelines serving the affected area – these included the following utilities: potable water, wastewater, electric power, natural gas and communications. There are no petroleum refineries or major pipelines within MMI VI, but there are several major facilities within MMI V. Transportation lifelines serving the affected area include roads and highways, rail, airports, marine ports and ferry.

Potable Water

This section focuses on impacts to the City of Napa's water system, which serves approximately 80,000 persons. The system is shown in Figure 2 and has three sources:

- Lake Hennessy (31,000 acre-feet, A-ft), Water Treatment Plant (WTP, 20 million gallons per day, mgd, built in 1982)
- SWP / Barwick Jamison WTP (21,900 A-ft pa entitlement, WTP 20 mgd, built in 1967)
- Milliken reservoir, a seasonal backup source, 1400 A-ft.

The distribution system includes 12 tanks and 337 miles of distribution pipe, which is made up of several types and vintages of pipe as shown in Table 4. Table 5 and Figure 26 show the breakdown and locations of breaks in the system caused by the 24 Aug. event – there were a total of 163 breaks, 75% of which were in cast iron pipe.

In some ways, the most significant break was in the main transmission pipe from the Milliken source, which was broken by a rock slide, Figure 28.

Of the 12 tanks in the system, one (termed Montana "B") sustained significant damage, Figure 29. The tank is an unanchored 67-foot diameter, 37-ft high circular welded steel tank with corrugated iron (CGI) roof supported by redwood beams on steel columns. The water sloshed with approximately 6 ft amplitude, damaging the roof. No buckling of the walls occurred, but some rocking occurred as evidenced by motion at the outtake slip joint. The tank drained immediately following the event due to a nearby pipe break.

While there were a relatively large number of breaks, and loss of pressure at some locations, service was maintained for much of the service area due to a decision by the City to continue to maintain flow from both Lake Hennessy and Barwick-Jamieson sources. It was later estimated that the total loss of water due to this policy was approximately 100 acre-feet.

Pipe breaks were repaired relatively quickly, with half completed in less than five days, Figure 30. The City of Napa was aided in making repairs by regional utilities through the CalWARN (www.calwarn.org) system, as follows:

- Alameda County Water District– 1 truck/crew
- City of Fairfield – 1 truck/ 2 crews
- Contra Costa Water District (CCWD) – 1 truck/crew
- East Bay Municipal Utility District (EBMUD) – 5 truck/crews

These crews arrived with their own trucks and equipment, fully stocked with spare parts. All were released by 29 Aug. The City estimates it spent about $200,000 on spare parts for repairs.

In other cities, American Canyon reported no damage to its system, while City of Vallejo sustained approximately 20 distribution pipe breaks.

Napa Sanitation District

Napa Sanitation District (NSD) which provides sewer service for 75,000 people over 23 square miles with a system of 270 miles of sewer lines (Table 6), 5,651 manholes and 3 lift stations. NSD reported 11 breaks in its sewer mains, all in asbestos cement pipes. Nine of these breaks are believed to have occurred along the fault trace, while two were due to water main breaks (causing soil erosion and loss of support to the sewer line).

Napa's wastewater is treated at the 7 mgd (dry weather) Soscol Water Recycling Facility (SWRF), Figure 31. SWRF) experienced sloshing and spillage at the sand filters. Additionally, minor cracking was observed in the several reinforced concrete structures at the plant.

SWRF did not lose PG&E service but wastewater treatment operations were however significantly disrupted due to an inflow of an estimated[4] 334,000 gallons of wine spilled from damaged barrels that flowed to the sewers and then SWRF. The wine is acid and disrupted normal anaerobic bacterial processes in the digester, increasing biochemical oxygen demand (BOD, an operational measure for wastewater treatment) to as high as 15,000 mg/l (normal is 175 mg/l), and resulted in the usual treatment operations upset for about 48 hours. Remediation was to blow air into the digester for 24 hours (using normal blowers), and the process recovered. No untreated water or solids were released to the environment.

Electric Power

The affected region contains several 60 kV – 230 kV transmission lines and 30 substations, Figure 32, as well as some relatively unique structures such as the Carquinez Straits crossing structures, Figure 33.

Damage to the distribution system (12-21 kV), included damage to 12 pole-mounted transformers, 15 cross arms, 63 spans of conductors, and 28 downed overhead wires (though no poles were damaged). Initial investigations have estimated that more than 90% of all outages are related to wire-wire contact of the electrified lines (lines swayed into each other), which caused the fuses to blow and the power outage.

Approximately 70,000 PG&E customers experienced one or more power outages during and after the earthquake, with a peak in the number of people experiencing power outage around 3.75 hours after the quake. Over 99% of these customers who experienced power supply interruption had power restored within 24 hours, Figure 34. A standard electrical system measure for outages

[4] This is an upper bound estimate, and is equivalent to 6,800 standard wine barrels (taken as 49 gallons).

(CAIDI, Customer Average Interruption Duration Index) had a value of 315.2 minutes for this event.

Natural Gas

Figure 35 shows the affected region, which is traversed by two natural gas transmission lines (shown dashed green in the figure). PG&E reported two non-hazardous leaks were detected on these lines, with however no rupture of line.

In the distribution system, PG&E reported no loss of service to customers due to damage to PG&E facilities. A total of 160 customers lost service due to damage to customer facilities. PG&E responded to 5,810 service "tags" (report of gas odor, leak, safety check…) and performed a total of 2,818 relights (with 926 in Napa and 110 in Vallejo), which were all completed by 4 AM 25 August (about 24 hrs following the mainshock). PG&E also reported 26 priority-zero leaks (blowing gas, immediate response), 425 non-hazardous leaks, 886 non-hazardous meter reset leaks. PG&E inspected 76 gas regulators in the impacted area, finding no damage.

There is no information currently available regarding the presence or performance or effect of seismic shut-off valves.

While there was no leak or apparent damage, PG&E is replacing abt 7,000 ft of line 121A due to ground movements possibly affecting the line.

Telecommunications

Telecommunications generally performed well in this event. The AT&T building in downtown Napa sustained damage to a concrete wall panel, attached to the building using 8 bolted angles and which fell due to connection failure during the earthquake and disrupted PG&E supply to the building, Figure 36. Emergency generators did not work, but the equipment and operations were sustained by battery systems. It is not unusual for emergency generators to fail to start, especially if they are not regularly tested, or if they or any of their ancillary equipment such as day tanks, starter batteries, fuel lines, and fuel tanks, are not seismically secured.

Verizon reported no loss of service; however they had to bring in backup power for several cell towers

No disruption of 911 service was reported.

Rail

Figure 37 shows rail lines within the affected area. California OESS reported that the Union Pacific inspected its lines and found no issues; BNSF opened most tracks; and Cal Northern Railroad reported no damage; and Sonoma-Marin Area Rail Transit (SMART) stopped trains running until 26 August. The Napa Valley Railroad reported heavy damage to its Napa Station. Amtrak reported its *Capitol Corridor* was suspended for "a time;" its Los Angeles–Seattle *Coast Starlight* was held while track and bridges inspected; its Northbound train No. 14 was stopped near Emeryville and the southbound No. 11 stopped near Chico for several hours; and its *California Zephyrs* were also significantly delayed[5].

[5] Some of this information was taken from http://trn.trains.com.

Air

Figure 38 shows Napa airport relative to the fault trace. Napa airport reported no damage to any of its own facilities, although minor cracking was reported on one runway. Operations were suspended from normal opening time (7am) for 30 minutes to allow inspection, and then were resumed with air traffic control (ATC, see below). The airport lost normal commercial power, but backup power functioned satisfactorily.

The ATC tower at Napa airport is owned and operated by the FAA, and sustained no structural damage but did sustain glass breakage of its main control room windows. Local ATC was not available for four days until a temporary tower was brought in, Figure 39. The temporary tower is anticipated to be required for several weeks, pending delivery of replacement glass. Operations continued without ATC, based on pilots communicating directly via radio, which is the normal procedure at airports that normally do not have ATC.

Other transportation

No damage was reported at Napa Marina (on the Napa river), nor at marine terminals in Vallejo, Martinez or Benicia, nor at the ferry in Vallejo.

Fire following earthquake

Fire Protection

There are a total of nine fire agencies in Napa County: American Canyon Fire, Calistoga Fire, City of Napa Fire, Napa County LRA, Napa County SRA, Napa State Hospital Fire, St Helena Fire, Veterans Home Fire, Yountville Fire, with a total of 28 fire stations, Figure 40.

The Napa City Fire Department was established in 1906 and protects 75,000 from four fire stations covering 18 square miles within the City limits of Napa, Figure 40 and Figure 42:

- Station 1 930 Seminary Street Napa 94559
- Station 2 1501 Park Avenue Napa 94558
- Station 3 2000 Trower Ave Napa 94558
- Station 4 251 Gasser Drive Napa 94558

Each station provides an Advanced Life Support (Paramedic) Engine company staffed with a minimum of three personnel. In addition, Fire Station One provides an Aerial Ladder Truck Company and a Heavy Rescue Unit for special operations and technical rescues. The department staffing consists of 56 suppression, six fire prevention and three full time administration personnel. Annual call volume is about 7,000 responses per year of which 70% are medical in nature. Approximately 5% are fire related and another 5% hazardous material related with the remaining 20% in various "other categories. The department participates in Interagency Hazardous Materials and Urban Search and Rescue Teams, maintaining a Heavy Rescue Unit and three rescue boats. NFD works closely with CAL FIRE, and Napa County Fire Department and maintains mutual and automatic aid agreements with those agencies as well as with the cities of American Canyon and Vallejo. NFD also participates in a Statewide Mutual Aid system as part of the California State Emergency Management Authority (EMA) by housing and staffing a State fire engine (EMA 365) that can respond to large emergency incidents throughout the state.

Stn. 1 is 1970s vintage (apparatus bays RC and CMU construction with Lin dbl T roofing) which had been seismically retrofitted (steel plates securing Ts to walls). Stn. 2 was retrofitted following the 1999 earthquake. Stns. 3 and 4 are newer construction. Engines carry 1000 ft. of 5" LDH, and at least some of the municipal water tanks have manifolds for supplying fire engines.

Actions at time of Earthquake:

NFD Battalion Chief (BC) Steve Stewart was on duty at Stn. 1 at the time of the earthquake. Upon start of shaking he and other firefighters sought safe shelter, then opened the doors and moved the apparatus to the exterior aprons, called other stations and confirmed they were operational. For approximately two minutes, there was quiet, then numerous calls began arriving.

Normal NFD dispatch is computer-aided – however, this was disrupted by the earthquake. That is, the 911 dispatch center was able to receive telephone calls, but their computer aided dispatch (CAD) was not accessible, and they reverted to calling BC Stewart by radio with reports. In this situation, he set up an initial NFD operations center at his Chief's vehicle ("buggy") on the apron of Stn. 1 and kept a handwritten list of the incoming reports, then dispatched resources by priority, by radio.

Overview of NFD Response

A partial list of incidents NFD responded to on 24 August was received on 10 September, Table 7. There were a total of 54 incidents responded to – breakdown of type of incidents is shown in Table 8 and Figure 43. It should be noted while this incident list is partial and incomplete, it is the best available at the point in the City's recovery.

Earthquake-related ignitions

A survey of fire sites was conducted on the day following the earthquake (i.e., 25 Aug), and data obtained from an interview with senior officers of Napa City Fire Department (NFD). Fires attributable to the main shock are summarized in Table 1 and shown in Figure 44.

Orchard Ave Fire: This was the largest fire in the earthquake. First dispatch was of T1 to a report of gas odor but en route T1 observed a fire in the Napa Valley Mobile Home Park (NVMHP) off of Hwy 29 at Orchard Road, and diverted to this incident. T1 encountered a broken water main spewing water at the entrance to the NVMHP on Orchard Road, Figure 27, and proceeded to enter the NVMHP. T1 then encountered a single structure fire at 313 Mark Way – the structure was 50% involved; they also observed a second fire at 317 Patty Way, which was 100% involved and impinging on neighboring buildings, see Figure 45 to Figure 51. Wind conditions were calm.

Approximately 20 minutes into the incident (i.e., about 0400) Water Tenders 15 and 25 arrived from Napa County Fire Department. NFD E6 had also arrived and took water from one of the WT 15 and suppressed the Mark Way fire. T1 and WT 25 similarly suppressed the Patty Way fire. Overhauling continued until about 10 am.

An alternative source of water for firefighting was a swimming pool approximately 200 ft. from the foreground, Figure 46. The timely arrival of the water tenders made use of this alternative source unnecessary.

1990 Trower: This was a report of smoke inside a structure. Scawthorn visited this site, which is a restaurant – employees reported some equipment had fallen onto other equipment in the kitchen, causing a call to the fire department. No significant damage occurred.

Rohlffs Way: This was a report of smoke in a kitchen area of a senior citizens residence

Mutual Aid: As reported above, Napa County FD responded quickly with water tenders. By noon, two OES strike teams had arrived in Napa.

Earthquake Early Warning and Rapid Loss Estimation

New roles of technology emerged in two ways in this earthquake: Earthquake Early Warning (EEW), and Rapid Loss Estimation – in this case the PAGER system.

Earthquake Early Warning

EEW is notification of an earthquake's occurrence in real time, that is, after the earthquake has begun (Scawthorn and Kanamori 2008). EEW can provide up to 30 seconds or more warning of the onset of strong motion. Even a few seconds can be enough to give building occupants time to take self-protective actions and for building managers to warn others to do so. It can also be sufficient to stop an elevator door from closing or for a driver to slow a car, as well as other potentially life-saving actions. EEW systems are operational in Japan, Mexico and Turkey. In California, there is one operational system and one prototype system.

The operational system is a relatively small system operated by the private sector firm of Seismic Warning Systems (SWS). SWS has five operational stations in Vallejo (in fire stations), Figure 52, one in an Albany fire station, and one at the Lawrence Berkeley National Laboratory. SWS reported their performance as follows[6]:

- *Vallejo Fire Station 22: 2.4s, doors disconnected*
- *Vallejo Fire Station 23: 2.0s, doors began to open, but power then failed.*
- *Vallejo Fire Station 24: 2.3s*
- *Vallejo Fire Station 25: 1.7s, 1 door under maintenance*
- *Vallejo Fire Station 27: 2.1s*
- *Albany Fire Station: Did not activate, below threshold*
- *Berkeley Lab: Did not activate, below threshold*

All the above were correct actions. Unless otherwise noted, activation includes audio alarm and bay doors opening.

The other California system is ShakeAlert[7], which currently operates but messages are only disseminated among the research community and a few operational users, such as BART. The

[6] Personal communication 30 Aug 2014 et seq, Gilead Wurman, Chief Seismologist, Seismic Warning Systems. See http://www.seismicwarning.com/ for further information.

[7] ShakeAlert is developed by a consortium of universities (California Institute of Technology University of California Berkeley University of Washington Eidgenossische Technische Hochschule Zurich Southern California Earthquake Center) working with the United States Geological Survey. See http://www.shakealert.org/ for further information

system functioned well in the South Napa event, providing about two seconds warning for recipients in the strongly shaken epicentral area – in Berkeley, which was not heavily shaken, the warning was about eight seconds, Figure 53.

PAGER

A second technology, which has been operational for several years, is **PAGER** (Prompt Assessment of Global Earthquakes for Response) (Wald et al. 2008). PAGER is an automated system that produces content concerning the impact of significant earthquakes around the world, informing emergency responders, government and aid agencies, and the media of the scope of the potential disaster. It rapidly assesses earthquake impacts by comparing the population exposed to each level of shaking intensity with models of economic and fatality losses based on past earthquakes in each country or region of the world. Earthquake alerts – which were formerly sent based only on event magnitude and location, or population exposure to shaking – now will also be generated based on the estimated range of fatalities and economic losses.

While the PAGER system has been operational for several years and has provided rapid assessments of earthquake impacts, there has not been a significantly damaging earthquake in the western US since PAGER became operational, so that the South Napa earthquake was its first significant application in the western US. Figure 54 shows the assessment that PAGER provided within minutes of the event – its assessment of single digit fatalities is relatively accurate, compared with the actual figures of one fatality and thirteen hospital admittances. Financial estimates of the damage are not available, but the PAGER estimate appears somewhat higher (although not unreasonably so) than what may be the actual financial costs.

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TABLES

Table 1 Initial PAGER MMI and affected population centers
http://comcat.cr.usgs.gov/earthquakes/eventpage/nc72282711#pager

MMI	City	Population
VIII	Napa	77k
VII	Yountville	3k
VII	American Canyon	19k
VI	El Verano	4k
VI	Sonoma	11k
VI	Temelec	1k
IV	Oakland	391k
IV	San Francisco	805k

Table 2 Estimated population with MMI isoseismals

≥ MMI	Population
VI	199,000
VII	90,000
VIII	36,000

Table 3 Peak Strong Motion Data for S Napa Earthquake, epicentral distance less than 25 km
(Source: http://www.strongmotioncenter.org)

Peak Ground Motion Data (Distance Order) for
South Napa Earthquake of 24 Aug 2014, 03:20:44 PDT, 6.0MW
38.22N 122.31W, 11.3 km depth Event Id: 72282711NC
CESMD Engineering Strong Motion Data Center
Table Last Updated: 2014-09-25 15:34:50

Network Id	Name	Statn Nmbr	Station Name	N.Lat	W.Long	Distance Epic Fault	PGAv1 (g)	PGAv2 (g)	PGV (cm/s)	PGD (cm)	---- Sa (g) ----- .3sec	1sec	3sec	Struct Apk(g)
NC	NCSN	NHC	Huichica Creek	38.217	122.358	3.5(4.4)	.403	.396	57.70	24.4	1.044	.315	.101	- -
CE	CGS	68150	Napa - Napa College	38.270	122.277	7.1(4.5)	.375	.370	54.77	16.5	.817	.525	.101	- -
NC	NCSN	N016	Main St, Napa, CA	38.299	122.285	9.1(--)	.611	.611	47.10	15.0	1.247	.405	.137	- -
CE	CGS	68310	Vallejo - Hwy 37/Napa River E Geo. Array	38.122	122.275	11.0(--)	.198	.198	19.00	2.2	.518	.138	.015	- -
CE	CGS	68065	Vallejo - Hwy 37/Napa River Bridge	38.120	122.280	11.1(--)	- -	- -	-	-	- -	- -	- -	.657
NC	NCSN	NGVB	Green Valley Road	38.280	122.216	11.5(9.7)	.110	.114	12.10	6.5	.249	.083	.022	- -
CE	CGS	68294	Vallejo - Broadway & Sereno	38.125	122.249	11.7(12.1)	.469	.466	16.74	1.2	.644	.106	.009	- -
NC	NCSN	N019B	Lovall Valley Loop Rd	38.301	122.402	12.0(6.4)	.342	.340	62.50	25.0	1.168	.548	.089	- -
NP	USGS	1765	Napa; Fire Station No. 3	38.330	122.318	12.3(--)	.427	.427	92.56	33.9	.645	1.030	.233	- -
NC	NCSN	NSP	Sears Point	38.200	122.464	13.3(--)	.051	.051	10.19	4.3	.145	.068	.029	- -
NP	USGS	1759	Vallejo; Fire Station	38.108	122.256	13.4(--)	.329	.329	21.11	2.3	.706	.177	.016	- -
NC	NCSN	NTO	Tolay Creek	38.144	122.450	14.0(14.8)	.038	.038	5.60	2.7	.054	.070	.013	- -
NC	NCSN	N002	Lynbrook Dr, Fairfield, CA	38.183	122.141	15.9(15.8)	.093	.093	6.80	2.7	.229	.080	.016	- -
NC	NCSN	NMI	Mare Island	38.076	122.258	16.7(--)	.369	.369	19.19	1.8	.909	.093	.017	- -
NC	NCSN	NLH	Lake Herman	38.123	122.149	18.0(18.1)	.094	.093	6.90	1.7	.232	.092	.005	- -
CE	CGS	68184	Vallejo - Carquinez/I80 East Bridge	38.061	122.225	18.9(--)	.149	.150	9.42	1.1	.340	.102	.010	1.085
CE	CGS	68185	Vallejo - Carquinez/I80 West Bridge	38.061	122.227	18.9(--)	.085	.085	9.20	1.1	- -	- -	- -	.790
CE	CGS	68259	Crockett - Carquinez Br Geotech Array #2	38.055	122.226	19.5(--)	.436	.424	19.78	1.8	.948	.123	.012	- -
CE	CGS	68206	Crockett - Carquinez Br Geotech Array #1	38.054	122.225	19.6(--)	.995	.980	22.20	1.5	1.322	.115	.010	- -
CE	CGS	68778	Novato - Hwy37/Petaluma River Bridge	38.116	122.505	19.7(--)	.024	.024	1.67	.8	.032	.012	.005	.062
NC	NCSN	C032	McCall Drive, Benicia, CA	38.083	122.158	20.3(20.6)	.140	.140	7.59	1.4	.568	.035	.004	- -
NC	NCSN	NBRB	Beebe Ranch	38.260	122.552	20.9(--)	.041	.041	9.61	6.0	.117	.069	.066	- -
NP	USGS	1762	Novato; Fire Station No. 1	38.098	122.566	22.2(--)	.042	.042	2.80	1.3	.131	.021	.006	- -
NC	NCSN	N013	Mesquite Ct, Sonoma, CA	38.299	122.550	22.3(19.1)	.087	.087	6.30	3.8	.168	.071	.026	- -
NP	USGS	1760	Benicia; Fire Station No. 1	38.054	122.157	22.9(--)	.037	.037	3.93	1.5	.095	.068	.005	- -
NC	NCSN	N003	Summers Ave, Novato, CA	38.109	122.554	23.8(24.5)	.017	.017	1.50	1.1	.027	.011	.004	- -
CE	CGS	68367	Hercules - Refugio Vly Rd & Partridge	38.004	122.262	23.9(24.4)	.074	.074	4.90	1.1	.233	.052	.005	- -
CE	CGS	68045	Fairfield - Pennsylvania & Travis	38.261	122.049	24.1(23.6)	.041	.041	6.20	2.7	.106	.044	.011	- -
CE	CGS	68032	Fairfield - 3-story Hospital	38.262	122.048	24.2(--)	.042	.041	5.14	1.9	.115	.045	.014	.172
CE	CGS	68321	Benicia - Martinez Br N Geotech Array	38.051	122.128	24.7(--)	.042	.042	3.24	.7	.094	.075	.004	- -
CE	CGS	68430	Novato - 2-story Hospital	38.099	122.560	24.8(--)	.036	.036	2.30	1.1	.090	.025	.006	.055
CE	CGS	68433	Novato - Hwy 101 & Rowland Way	38.098	122.559	24.8(25.6)	.043	.043	3.20	1.2	.109	.024	.004	- -
NC	NCSN	C040	Flannery Rd, San Pablo, CA	37.990	122.314	25.0(25.6)	.063	.063	4.00	2.1	.156	.054	.010	- -
CE	CGS	68322	Benicia - Martinez/I680 East Bridge	38.044	122.123	25.5(--)	.063	.062	3.30	.7	.057	.029	.004	.122

Table 4 City of Napa distribution piping – length of pipe (% in red) by age and material
Key: C900 = PVC, DIP = Ductile Iron Pipe, CI = Cast Iron, AC = Asbestos Cement, RCCP = Reinforced Concrete Cylinder Pipe, STL = Steel

	C900	DIP	CI	AC	RCCP	STL		
Under 20 years	6,600	225,600				100	232,300	13%
20-40 years	24,300	370,500	83,400	14,100		100	492,400	28%
40-60 years		12,300	466,700	167,200	9,900	59,800	715,900	40%
60-80 years			173,100			100,400	273,500	15%
80-100 years			55,100				55,100	3%
Over 100 years			10,300				10,300	1%
Sum	30,900	608,400	788,600	181,300	9,900	160,400	1,779,500	100%
	2%	34%	44%	10%	1%	9%	100%	

Table 5 Number, % and per mile breaks, City of Napa Water Distribution system

Material	Breaks	% Brks	Brks/mile
Asb. Cement	8	5%	0.23
C900 (PVC)	2	1%	0.34
Cast Iron	123	75%	0.82
Concrete	1	1%	0.53
Duct. Iron	18	11%	0.16
Steel	3	2%	0.10
other / unk	7	4%	
Tot	163	100%	

Table 6 Napa Sanitation District Pipe Material breakdown

Type of Pipe	Miles	% system
ABSPlastic	2	0.7%
Asbestos cement	124	45.9%
Cast iron	1	0.4%
Concrete	3	1.1%
Polyvinyl chloride	61	22.6%
Reinf. Concrete pipe	7	2.6%
Vitreous clay pipe	70	25.9%
Other	2	0.7%
	270	100.0%

Table 7 Partial List of Incidents Responded to by City of Napa FD
(Partial, as of 10 Sept. 2014, Source: NFD)

Incid. No.	Date	time	Location	Type
5350	08/24	3.40	3456 W ILLI S Dr	553 Public service
5352	08/24	3.43	424 REED Cir	550 Animal problem or rescue
5351	08/24	3.47	118 COTTAGE COVE Ln	311 Medical assist
5353	08/24	3.50	50 NEWELL Cir	611 Dispatched and canceled en route
5354	**08/24**	**3.57**	**1540 LAUREL St**	**111 Building fire.**
5359	08/24	3.60	813 Main St.	351 Extrication ofvictim(s) from building or structure,
5970	08/24	3.62	314 MARK Way	UNK
5355	08/24	3.77	1 000 TRANCAS St	553 Public service
5365	08/24	3.78	206 BETSY PI	UNK
5366	08/24	3.78	500 MA I N St	UNK
5356	08/24	3.85	2320 OAK St	412 Gas leak (natural gas or LPG).
5357	08/24	3.92	2261 EVASt	321 EMS call
5850	08/24	4.27	1709 F St	412 Gas leak (natural gas or LPG).
5360	08/24	4.43	2186 S TERRACE Dr	321 EMS call
5361	**08/24**	**4.97**	587 JEFFERSON St	**111 Building fire.**
5363	**08/24**	**5.07**	**157 Robin St**	**121 Fire in mobile home used as a fixed residence**
5362	08/24	5.12	2360 REDWOOD Rd	UNK
5417	08/24	5.52	1738 Oak St	461 Building or structure weakened or collapsed
5367	08/24	5.68	201 BETSY PI	UNK
5911	08/24	6.17	400 SEYMOUR St	UNK
5372	08/24	6.20	2211 KATHLEEN Dr	UNK
5373	08/24	6.23	1031 CHARLSON Way	UNK
5375	08/24	7.32	2000 TROWER Ave	UNK
5402	08/24	8.00	1201 WALNUT St	UNK
5842	08/24	8.00	2054 RUSSELL St	UNK
5843	08/24	8.00	467 SEYMOUR St	UNK
5847	08/24	8.00	430 MONROE St	UNK
5849	08/24	8.00	1539 ESt	UNK
5852	08/24	8.00	1621 ORA Dr	UNK
5855	08/24	8.00	2047 CORONADO Av	UNK
5856	08/24	8.00	1660 E St	UNK
5857	08/24	8.00	1553 ASH St	UNK
5885	08/24	8.00	1406 3RD St	UNK

Incid. No.	Date	time	Location	Type
5890	08/24	8.00	123 LILIENTHAL Av	UNK
5891	08/24	8.00	2060 WILKINS Av	UNK
5914	08/24	8.00	519 MADISON St	UNK
5915	08/24	8.00	473 WALNUT St	UNK
5916	08/24	8.00	2708 PINE St	UNK
5928	08/24	8.00	2359 REDWOOD Rd	UNK
5967	08/24	8.00	1644 F St	UNK
5968	08/24	8.00	2261 EVA St	UNK
5972	08/24	8.00	2073 EUCLID Av	UNK
5382	08/24	15.03	2175 SHURTLEFFAve	UNK
5383	08/24	15.07	150 SILVERADO Trl	UNK
5405	08/24	15.77	On School St at 3rd St	321 EMS call
5425	08/24	15.83	150 Silverado Trl	553 Public service
5438	08/24	16.50	On Laurel St at I st St	UNK
5437	08/24	16.73	2799 Kilburn Av	412 Gas leak (natural gas or LPG).
5448	08/24	20.53	1013 BROADMOOR Dr	UNK
5451	08/24	21.22	1660 B St	UNK
5455	08/24	21.58	2571 HAWTHORNE CT	UNK
5457	08/24	21.88	1767 LAUREL St	UNK
5458	08/24	22.33	214 HOMEWOODAVE	UNK
5460	08/24	23.17	352 JEFFERSON St	UNK

Table 8 Breakdown of Incidents responded to by NFD on 24 August 2014

Type	count	%
111 Building fire.	2	4%
121 Fire in mobile home used as a fixed residence	1	2%
311 Medical assist	1	2%
321 EMS call	3	6%
351 Extrication of victim(s) from building or structure	1	2%
412 Gas leak (natural gas or LPG)	3	6%
461 Building or structure weakened or collapsed	1	2%
550 Animal problem or rescue	1	2%
553 Public service	3	6%
611 Dispatched and canceled en route	1	2%
UNK	37	69%
Total	**54**	**100%**

Table 9 Fires attributed to the 24 August main shock (from handwritten notes)

No.	Time of Report (approx.)	Location	Description (see below)
1	0330	Orchard Ave	Napa Valley Mobile Home Park (NVMHP) – actually two ignitions – see narrative
2	0400	Laurel St. (no. street number)	2 story, 2 unit residence, roof collapse, started fire
3	0500	162 Robin at Solano	Double wide home
4	0630	1990 Trower	Smoke inside structure
5	0730	770 Lincoln x Soscol	Electrical fire in substructure of a mobile home
6	1200	4072 Rohlffs Way x Fair	Kitchen fire in single story multi-unit senior housing complex

FIGURES

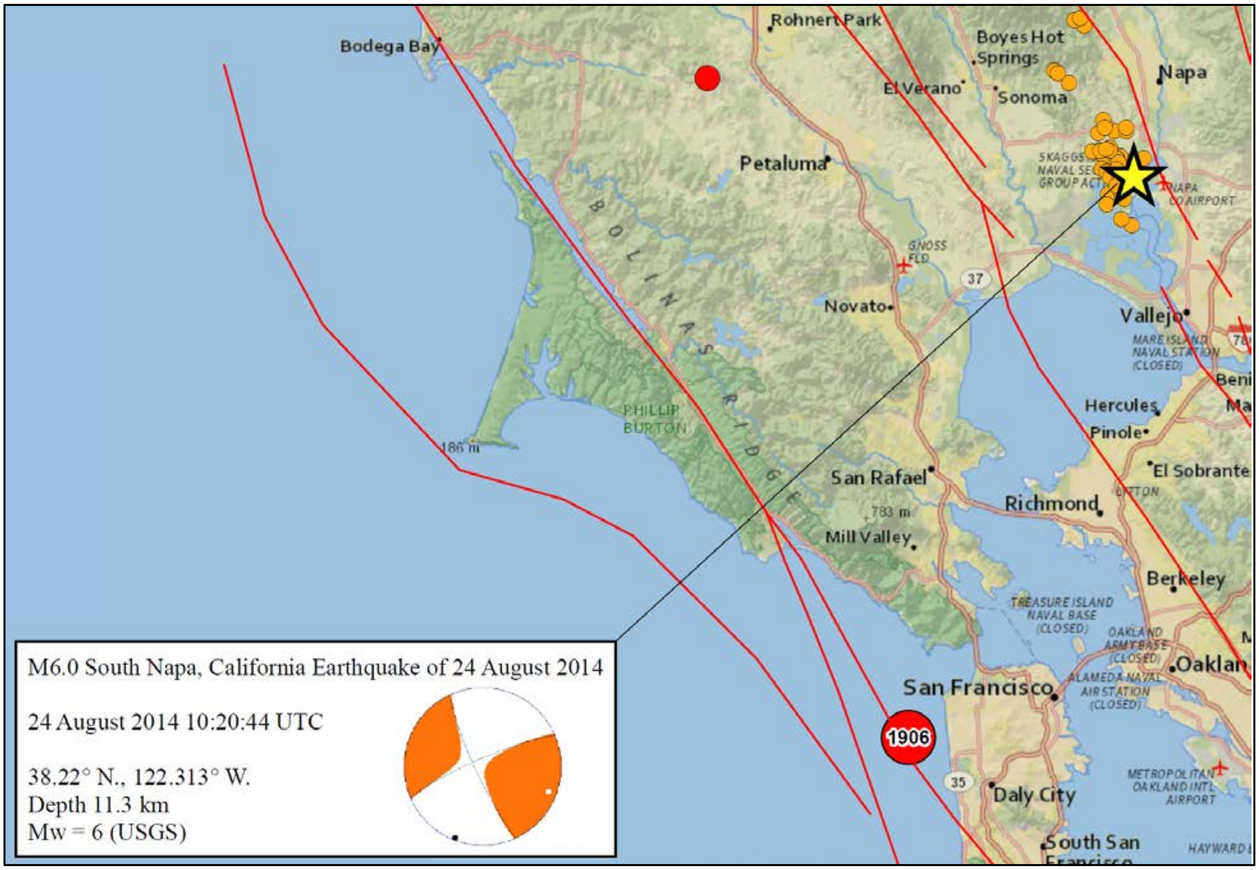


Figure 1 Epicentral location, aftershocks and fault plane solution of 24 August 2014 M_w 6 South Napa earthquake. Source: USGS

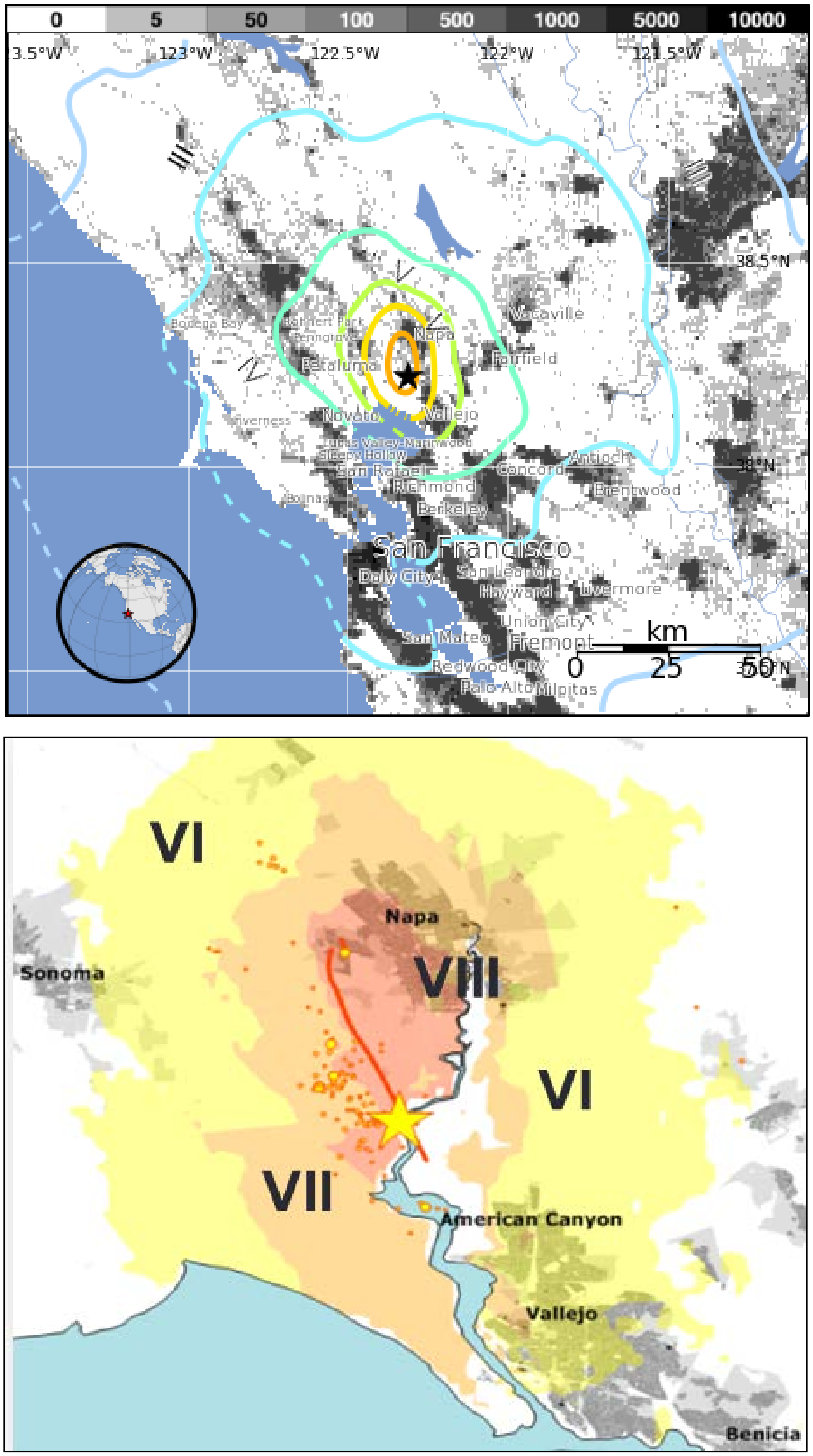


Figure 2 Epicentral area of 24 Aug. 2014 S. Napa earthquake, showing (t) initial USGS instrumental intensity estimates and (b) more refined estimated MMI intensities with fault rupture and aftershocks, overlaid on population density
(Source: (t) USGS PAGER http://comcat.cr.usgs.gov/earthquakes/eventpage/nc72282711#pager ,(b) SPA Risk)

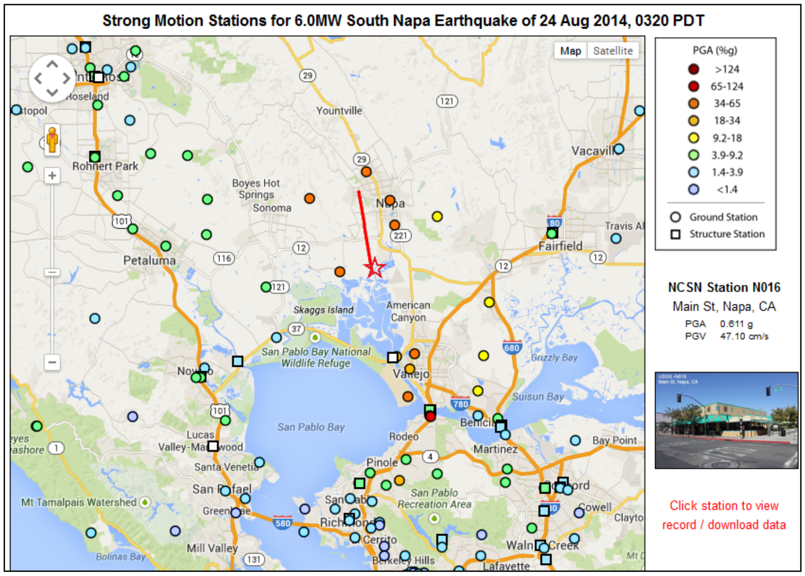


Figure 3 Strong Motion Instrument sites, South Napa Earthquake
http://www.strongmotioncenter.org/cgi-bin/CESMD/iqrStationMap.pl?ID=SouthNapa_24Aug2014_72282711

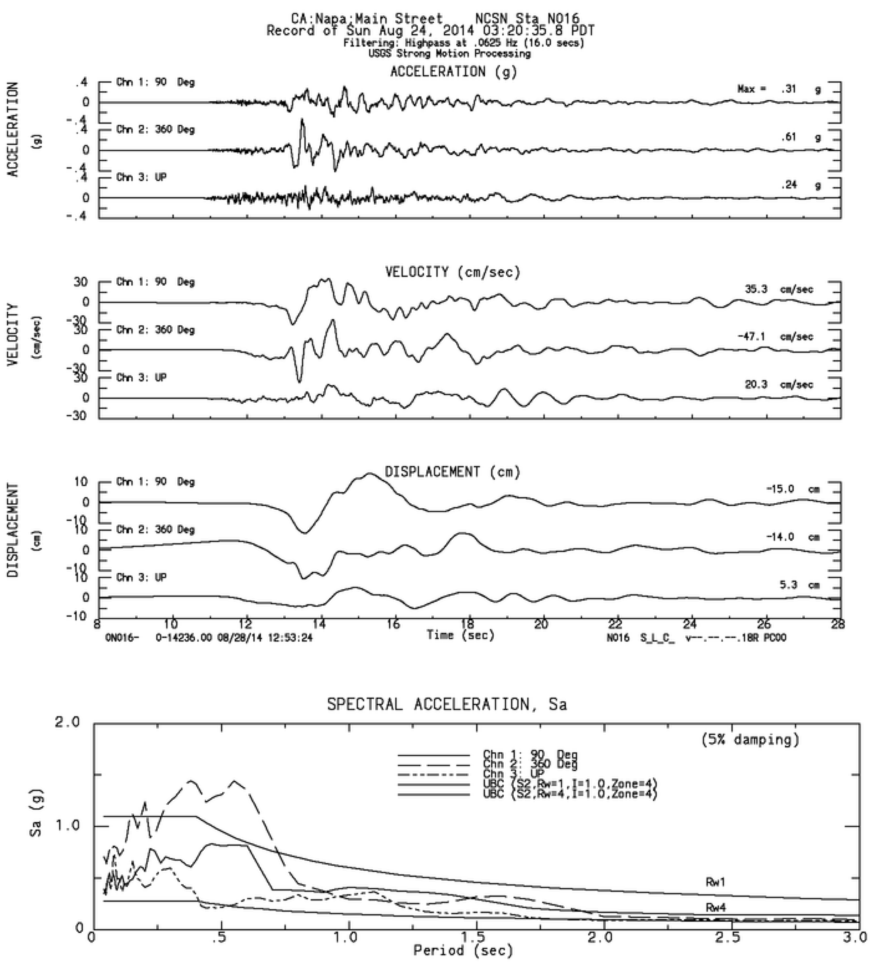


Figure 4 NCSN Station N016 record, South Napa Earthquake
http://www.strongmotioncenter.org/cgi-bin/CESMD/iqrStationMap.pl?ID=SouthNapa_24Aug2014_72282711

Horizontal PSA for all the stations were compared to the predicted median values obtained by taking the geometric mean of ASK14, BSSA14, CB14, and CY14. Figure 9 shows the comparison of PGA, PSA at T=0.2 s (PSA(0.2)), PSA at T=1.0 s (PSA(1.0)), and PSA at T=3.0 s (PSA(3.0)) against R_{rup} where the V_{s30} of 490 m/s is used in the GMPEs. The PSA of the records were adjusted to a reference V_{s30} of 490 m/s by V_{s30} scaling to these records. The figures show that PGA and PSA(0.2) are reasonably predicted within R_{rup} of 10 km whereas PSA(1.0) is underpredicted for this range. At distances greater than about 10 km the median GMPE tends to overpredict PGA and spectral values at 0.2 and 1.0 sec.

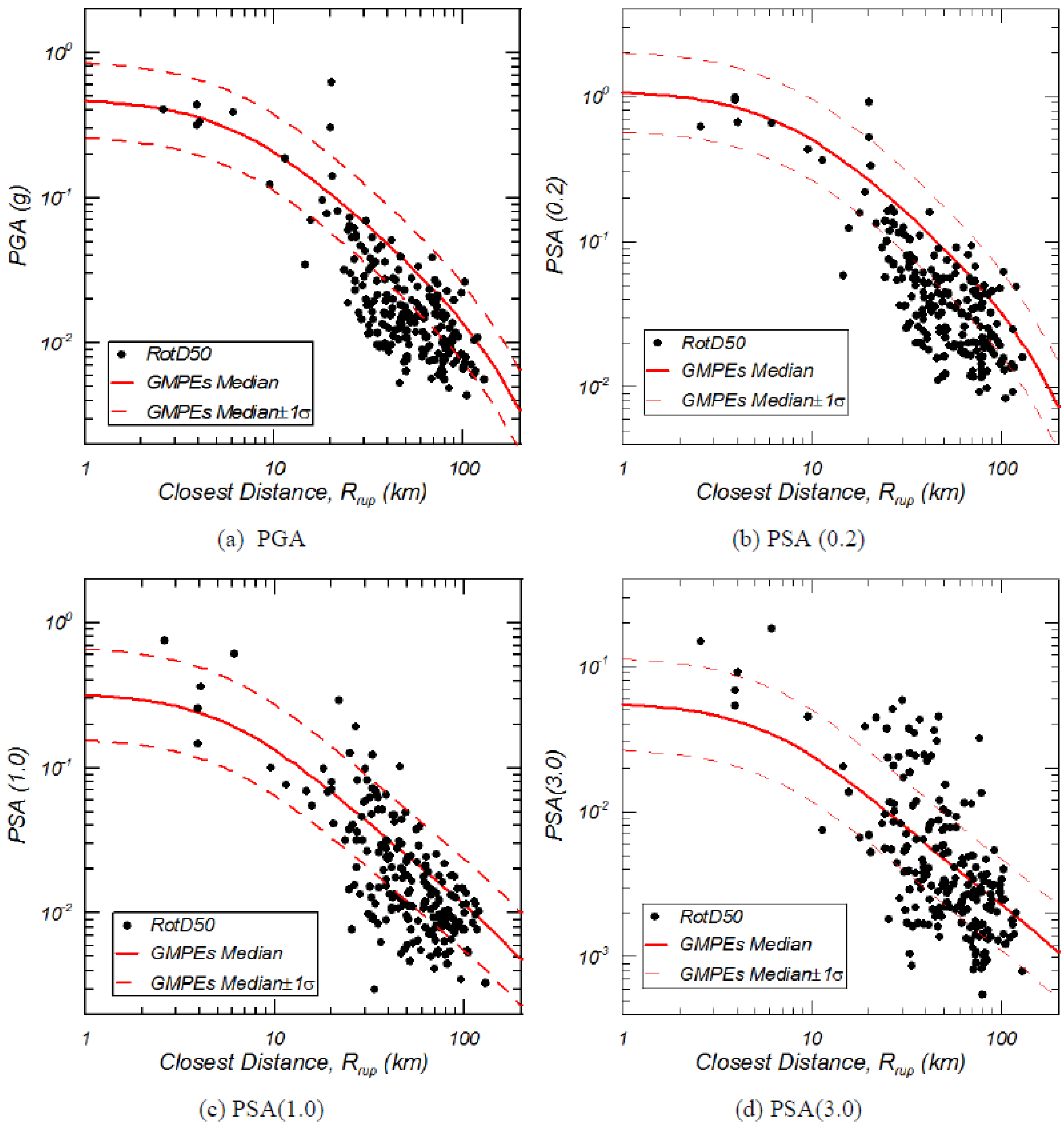


Figure 5 Comparison of horizontal pseudo-spectral acceleration (PSA, RotD50) with ground motion prediction equations against rupture distance. Dots outside of the dashed lines are generally more than a factor of 2 higher or lower than the median (Bray et al. 2014)

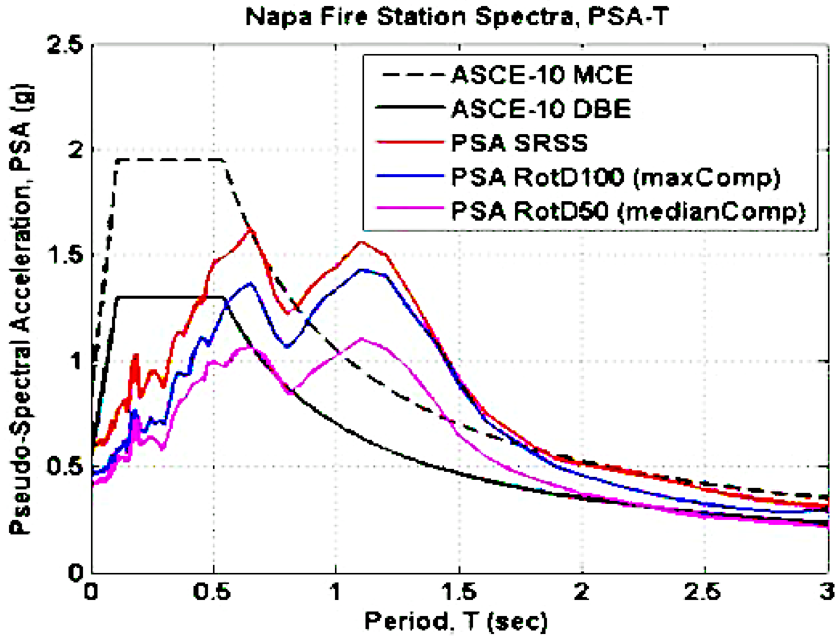


Figure 6 Spectra comparison for Napa; Fire Station No. 3
(Bray et al. 2014)

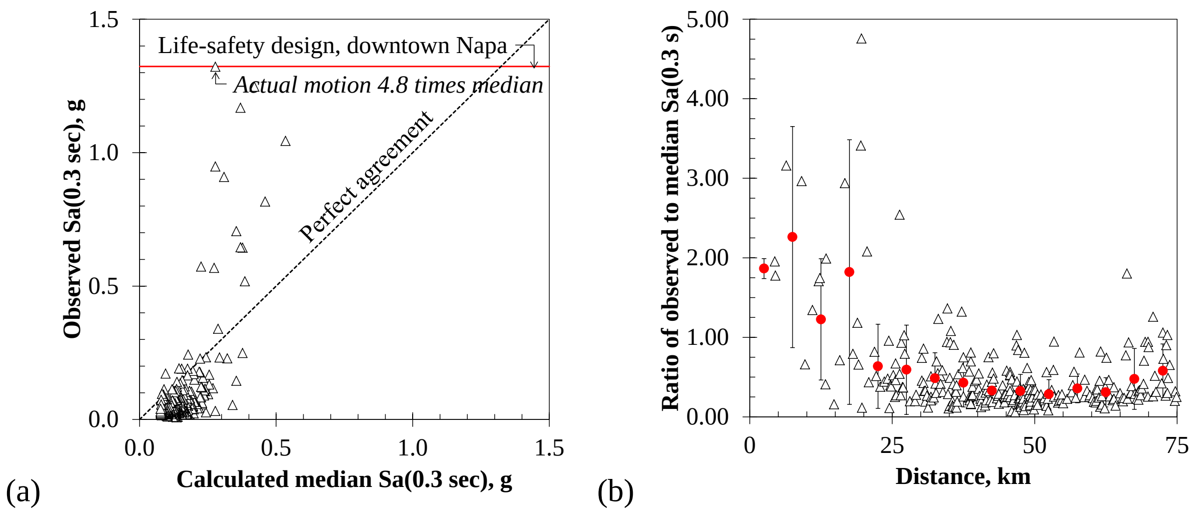


Figure 7 Comparison of observed short-period (0.3-second) spectral acceleration response with median calculation. Circles and error bars in (b) show differences when averaged over all instruments in 5-km-distance bins.

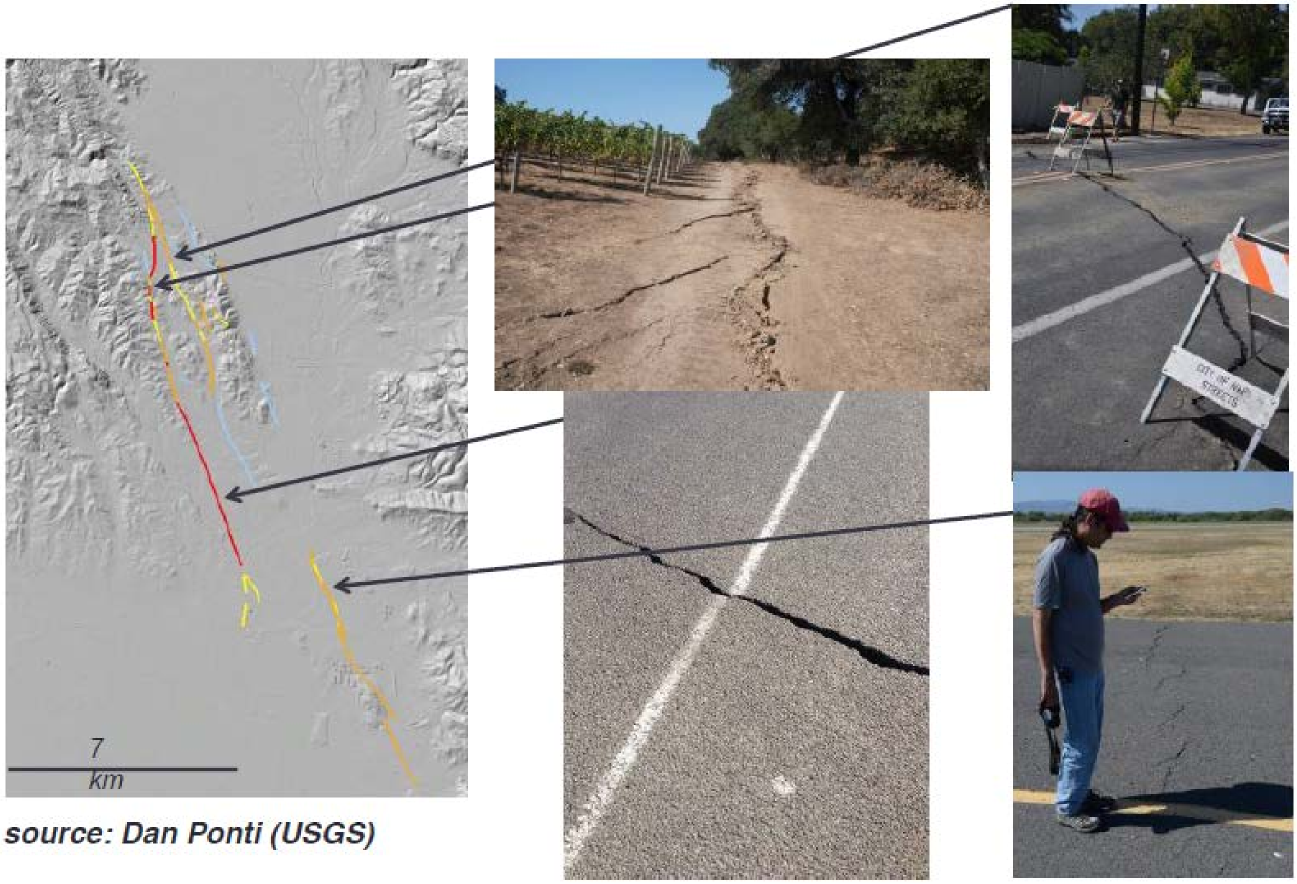


Figure 8 Observed surface faulting
Source: from T. Dawson presentation at PEER-EERI S. Napa Earthquake briefing, 15 Sept. 2014
(lower right is runway cracking at Napa County airport)

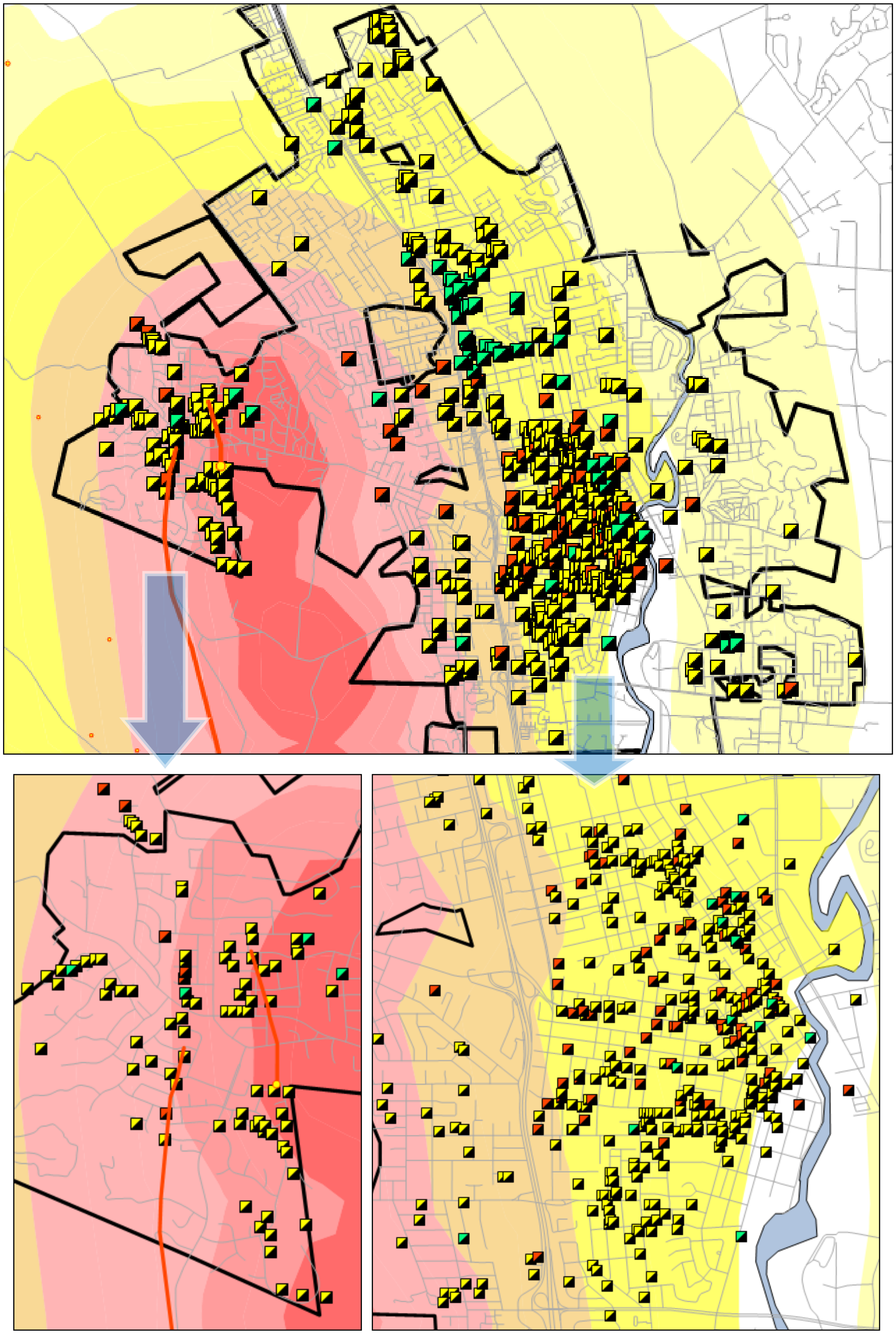


Figure 9 ATC-20 Tags, City of Napa (t) entire city;
(b) detail for Brown's Valley on left, for downtown on right

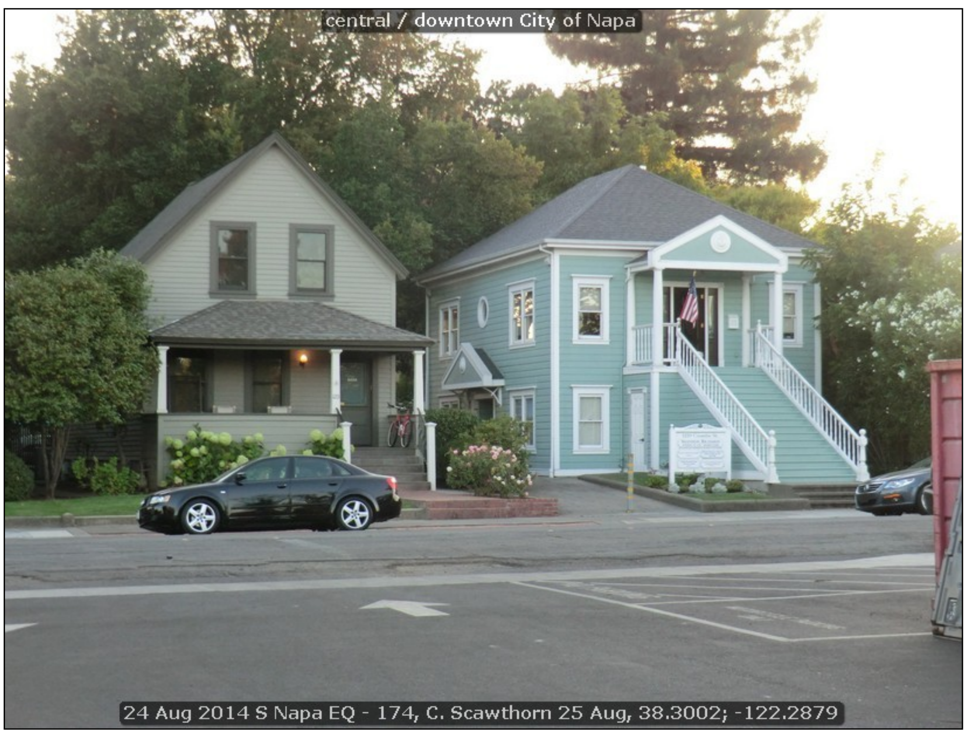


Figure 10 Single family wood framed dwellings – (t) damaged, photo by J. Maffei; (b) undamaged, central Napa (photo by author)

Figure 11 Approximately 1900 era house with chimney damage, Mare Island

Figure 12 Manufactured home (t) racking of substructure; (b) undamaged

Figure 13 Napa Valley Opera House and adjoining buildings, East side of 1000 block of Main Street, City of Napa: (t) entire block, photo looking NE; (b) north end of block

Figure 14 Napa Valley Opera House and adjoining buildings Main Street Napa (cont.): (top) north building and Opera House facades; (b) south building façade and bracing (interior of café).

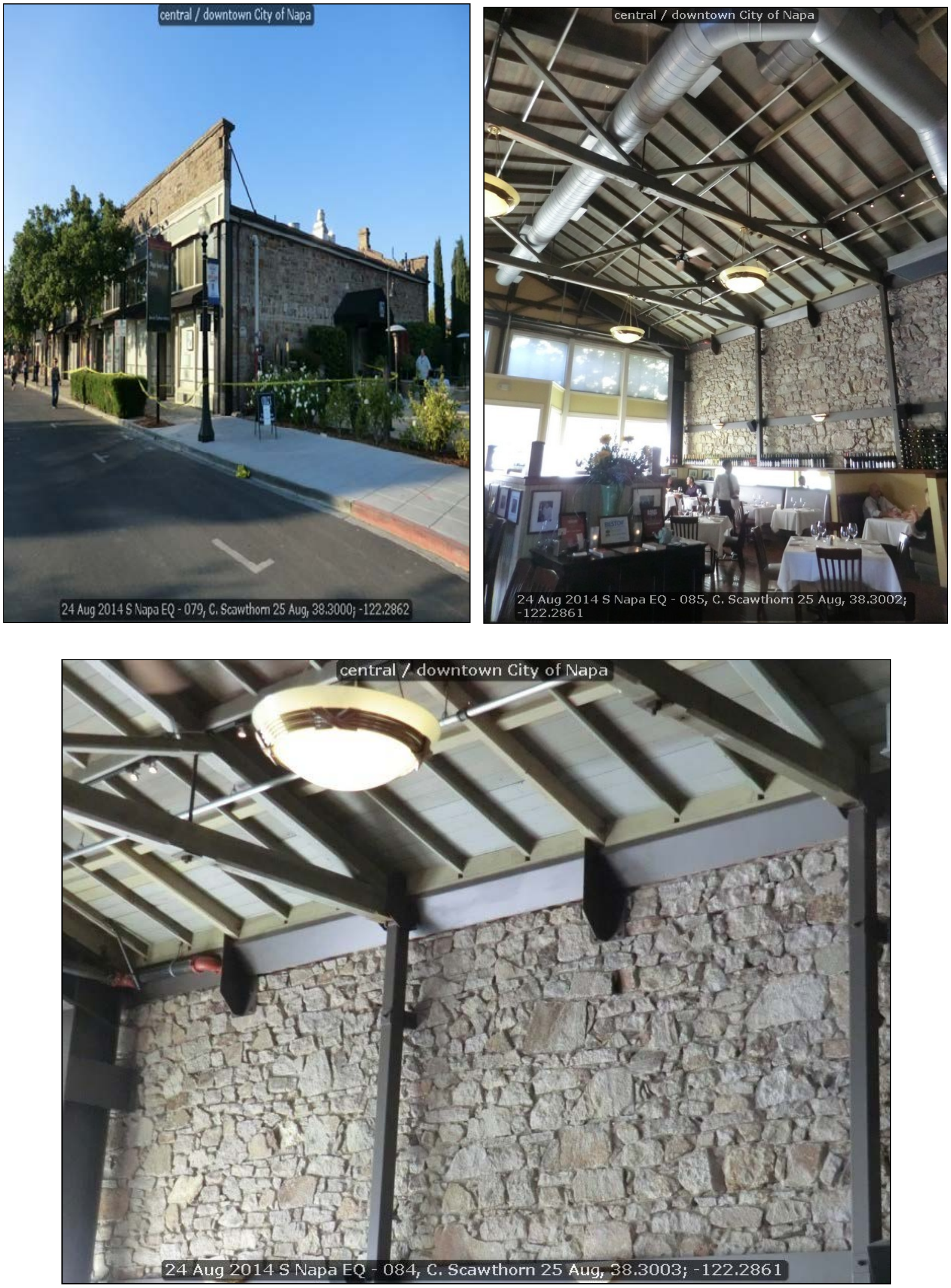


Figure 15 Restaurant building Main Street Napa, field stone URM retrofitted, with only minor damage – building was yellow tagged with notation “Guests allowed.”

Figure 16 (t) block of URM buildings on Main Street Napa with little to no damage; (b) restaurant building in interior of the block in upper photo, retrofitted URM with no damage – note heavy steel columns also serving as wall bracing on interior.

Figure 17 Heavily damaged URM building, Main Street Napa – note light horizontal member used in retrofitting, with clean pull out of masonry anchors.

Figure 18 Building directly across Main Street from buildings in Figure 16 with no apparent retrofitting and partial loss of second story wall.

Figure 19 URM building, Georgia Street, Vallejo, (t) façade, with little apparent damage, note unbroken windows; (b) interior, showing ground floor on left and second floor on right, where parapet fell through to ground floor.

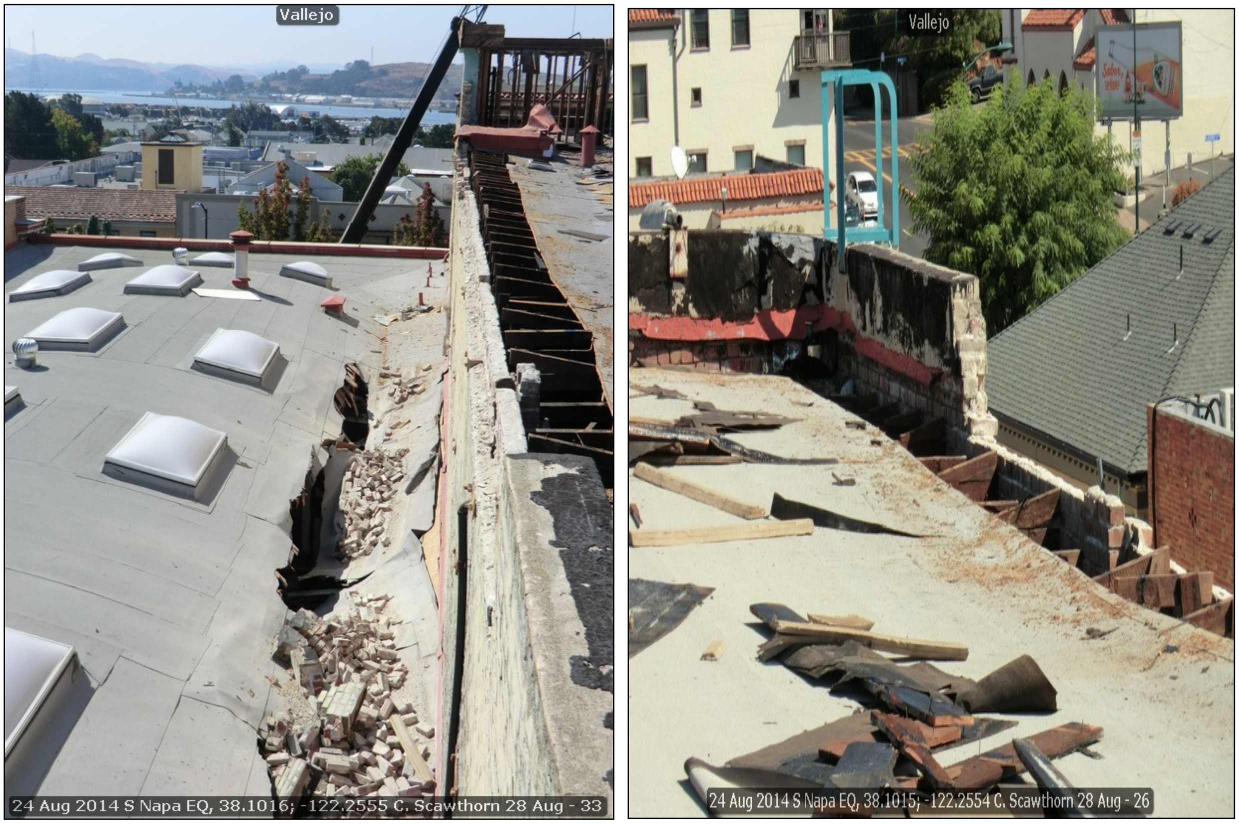


Figure 20 Roof of URM building shown in Figure 19, showing approximately 3 ft. by 40 ft. long section of parapet, which fell approximately 15 ft. onto and through neighboring building roof.

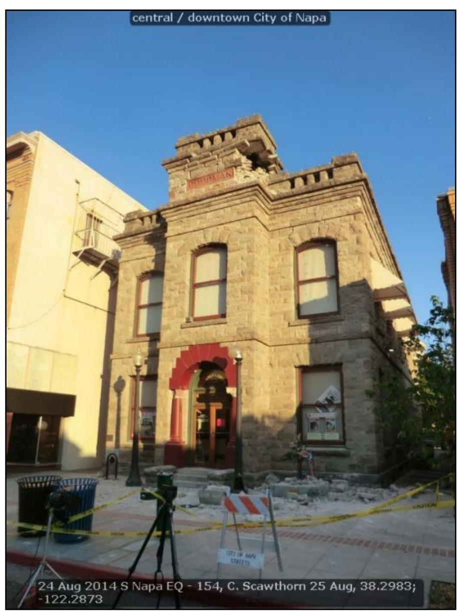


Figure 21 Goodman library – URM built 1901, longest continuously operating library in California, National Register #74000539, retrofit unclear, damaged.

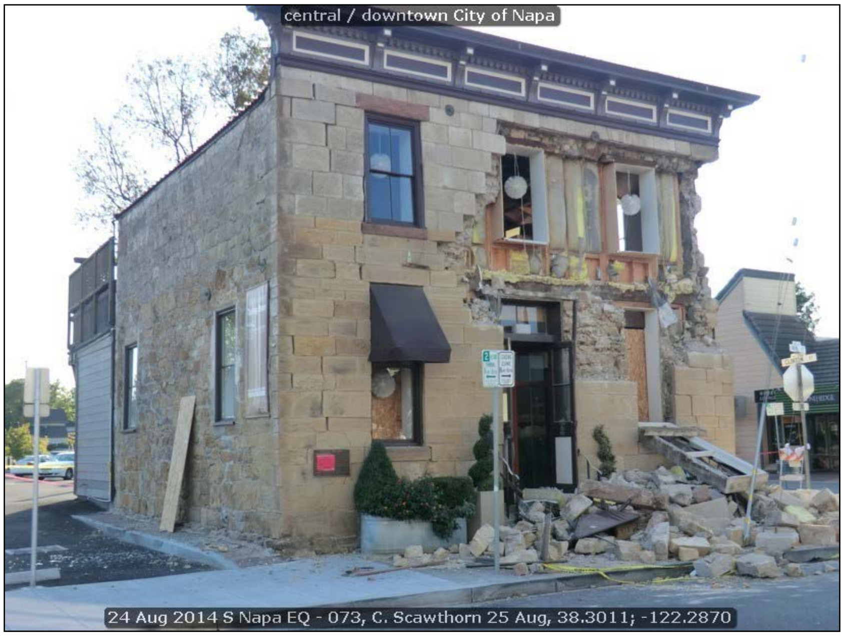


Figure 22 Sam Kee Laundry Building, also known as the Pfeiffer Building, 1245 Main St. Napa, built 1875, is the oldest stone building and commercial building in Napa, National Register #74000540, unretrofitted and damaged.

Figure 23 Napa County Courthouse, built 1870

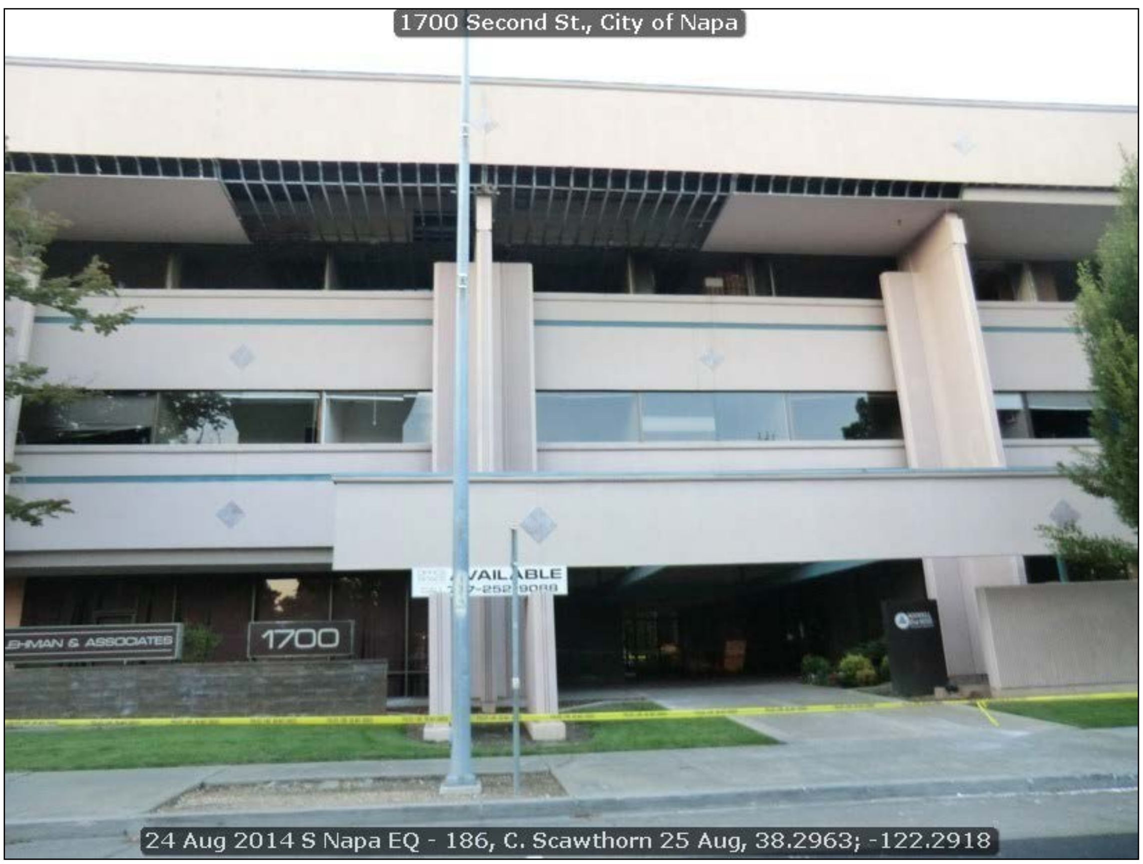


Figure 24 Office building 1700 Second Street, built 1984, damage to third floor exterior soffit

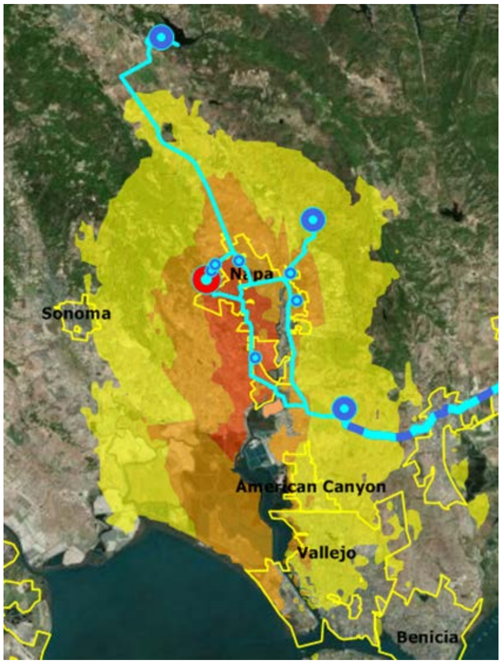


Figure 25 Schematic of City of Napa water system overlaid on MMI and showing three sources (large dark blue circles) and main transmission lines, locations of distribution tanks (smaller circles) and damaged Montana "B" tank. The California Water Project's North Bay Aqueduct, which feeds Barwick Jamison WTP, is shown as dashed light-dark blue.

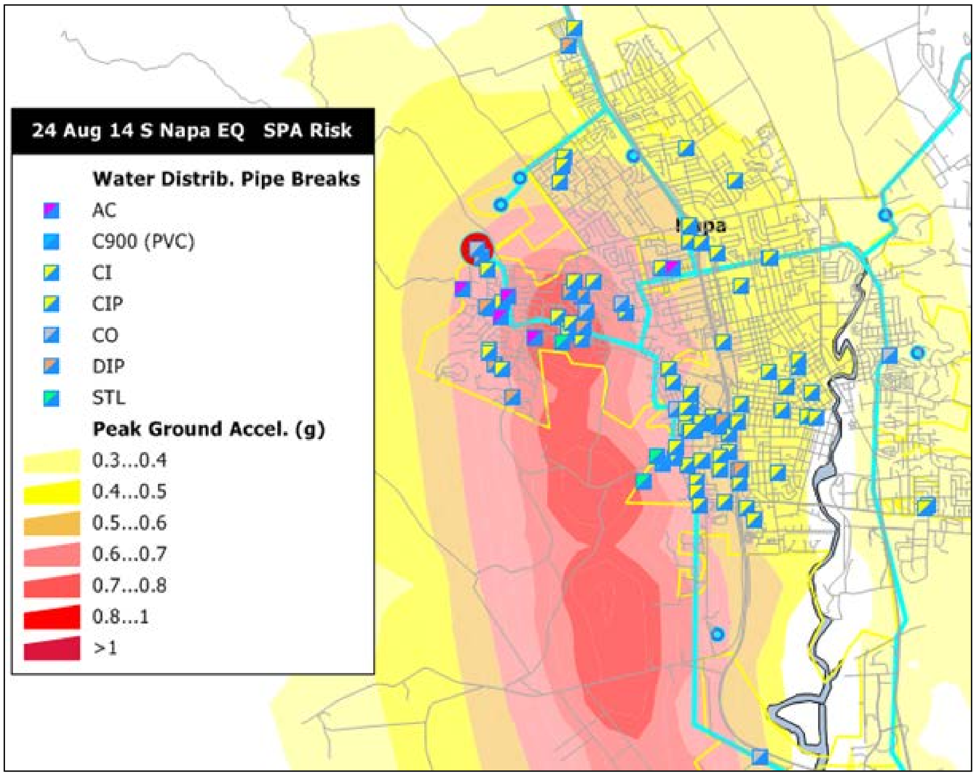


Figure 26 City of Napa water system overlaid on PGA and showing locations of breaks and Montana "B" tank.

Figure 27 Water main break, Orchard Road.

Figure 28 Milliken line, broken by rock slide.

Figure 29 Montana "B" tank – roof damaged by sloshing and outtake exhibiting evidence of motion at slip joint.

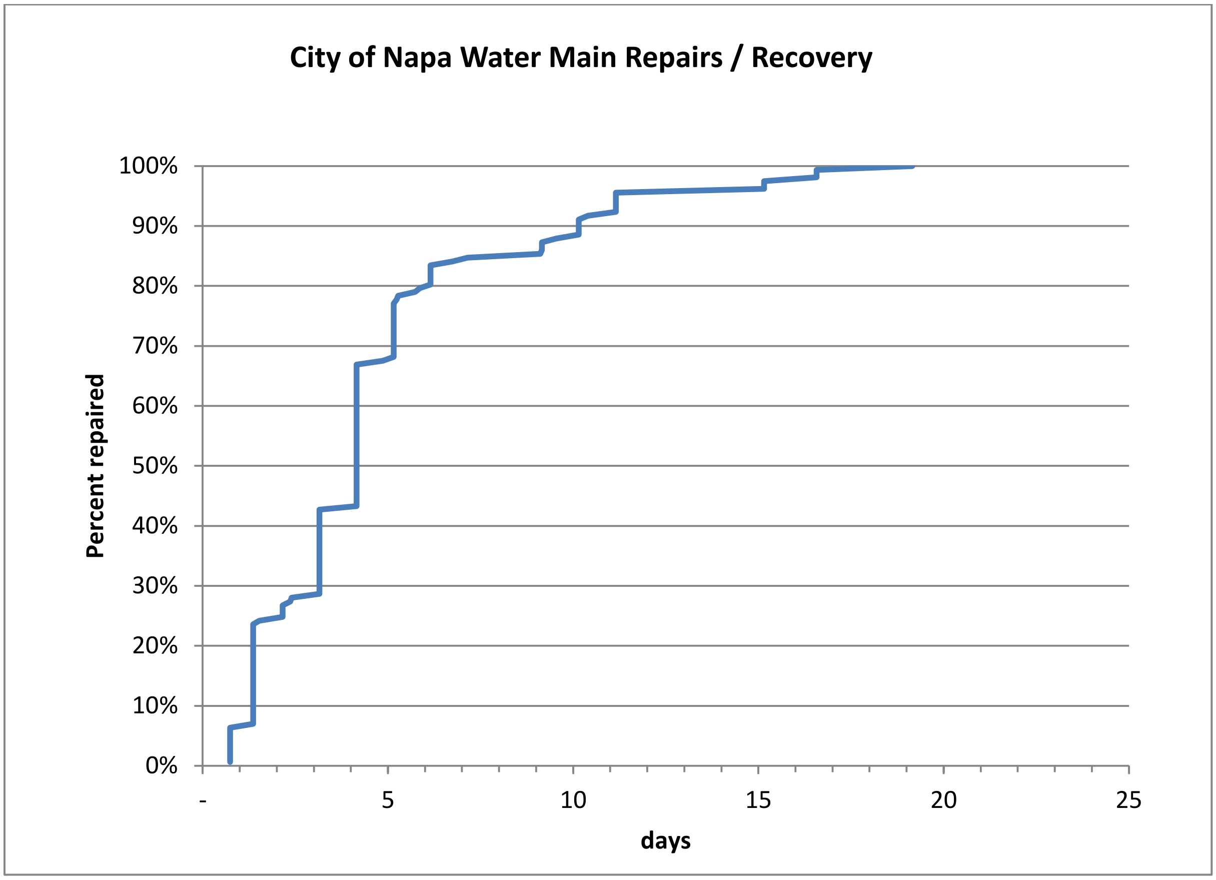


Figure 30 Water distribution pipe break repairs (%) vs. number of days following the earthquake.

Figure 31 Napa Sanitation District (NSD) Soscol Water Recycling Facility (SWRF)

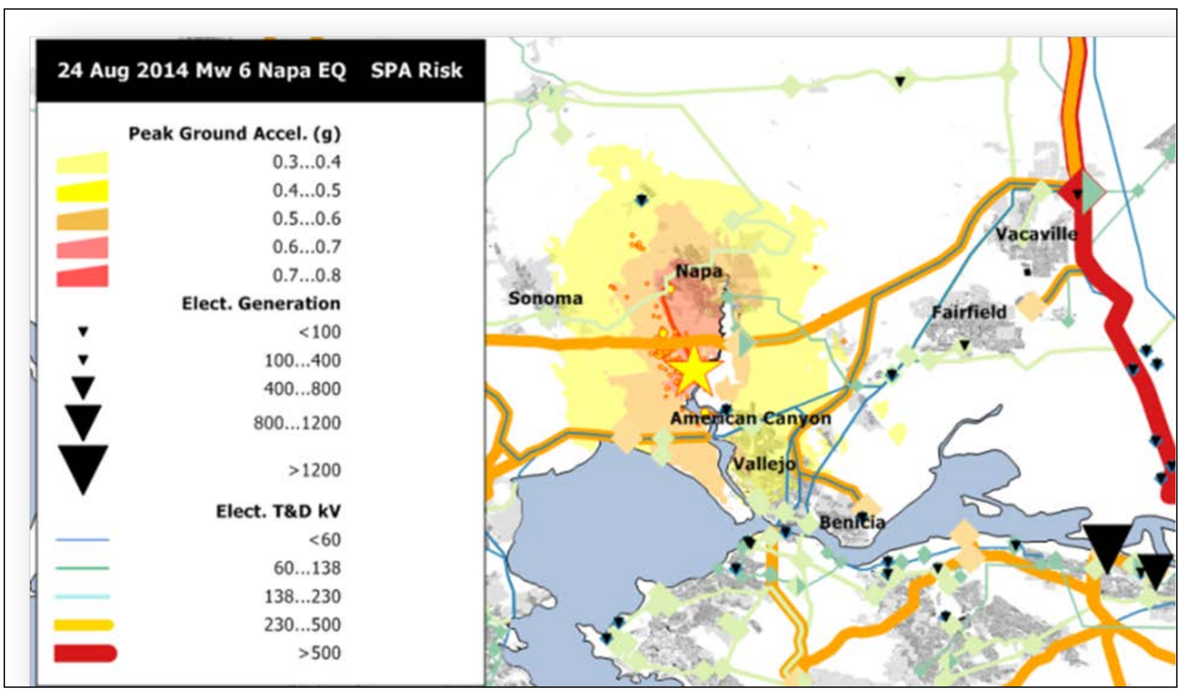


Figure 32 Affected region EHV electric system

Figure 33 Carquinez Straits EHC Crossing structures (at left)

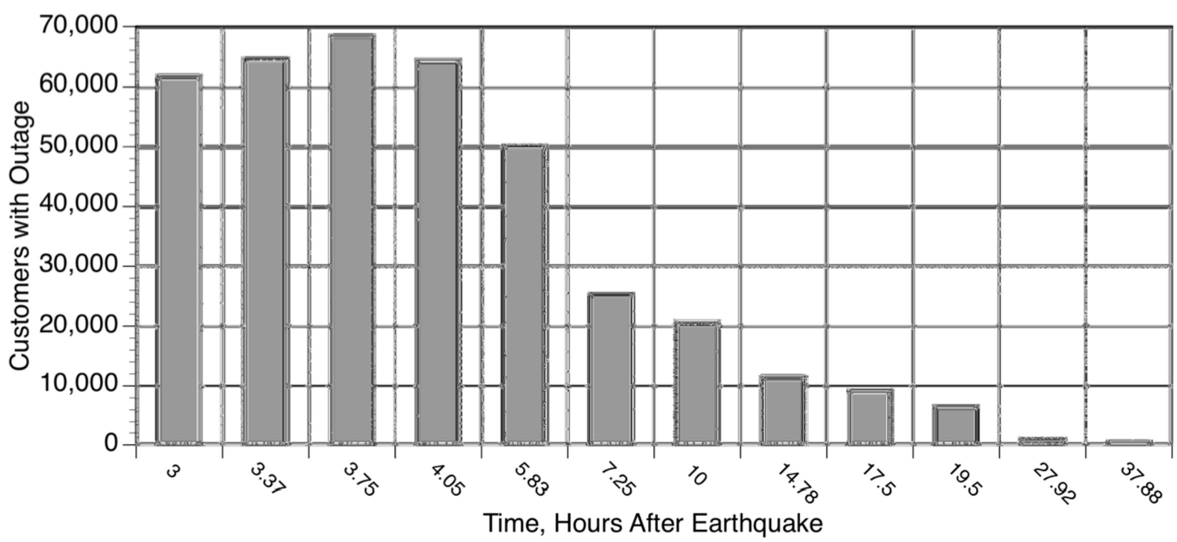


Figure 34 Number of customers without power, versus hours after the earthquake (TCLEE)

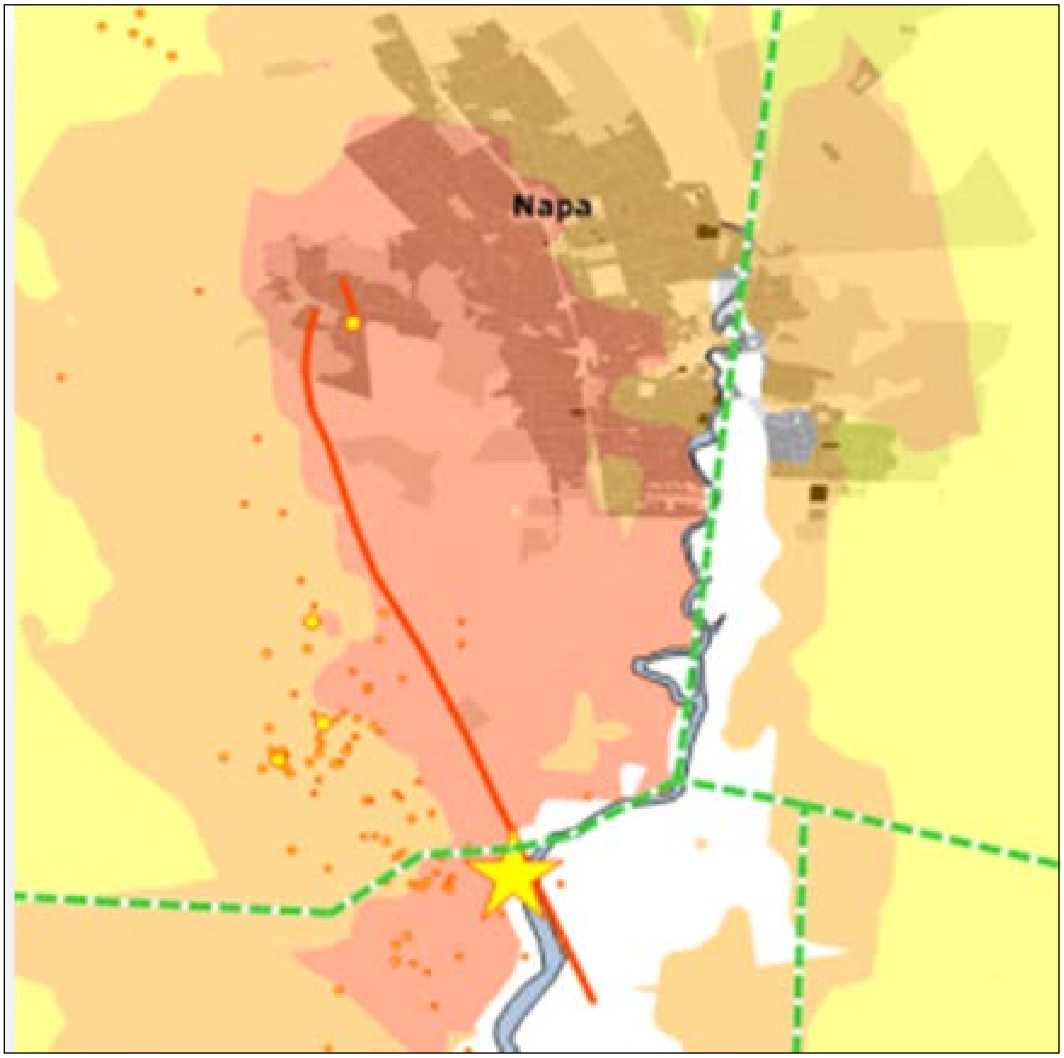


Figure 35 Affected region and natural gas transmission lines (dashed green) overlaid on PGA

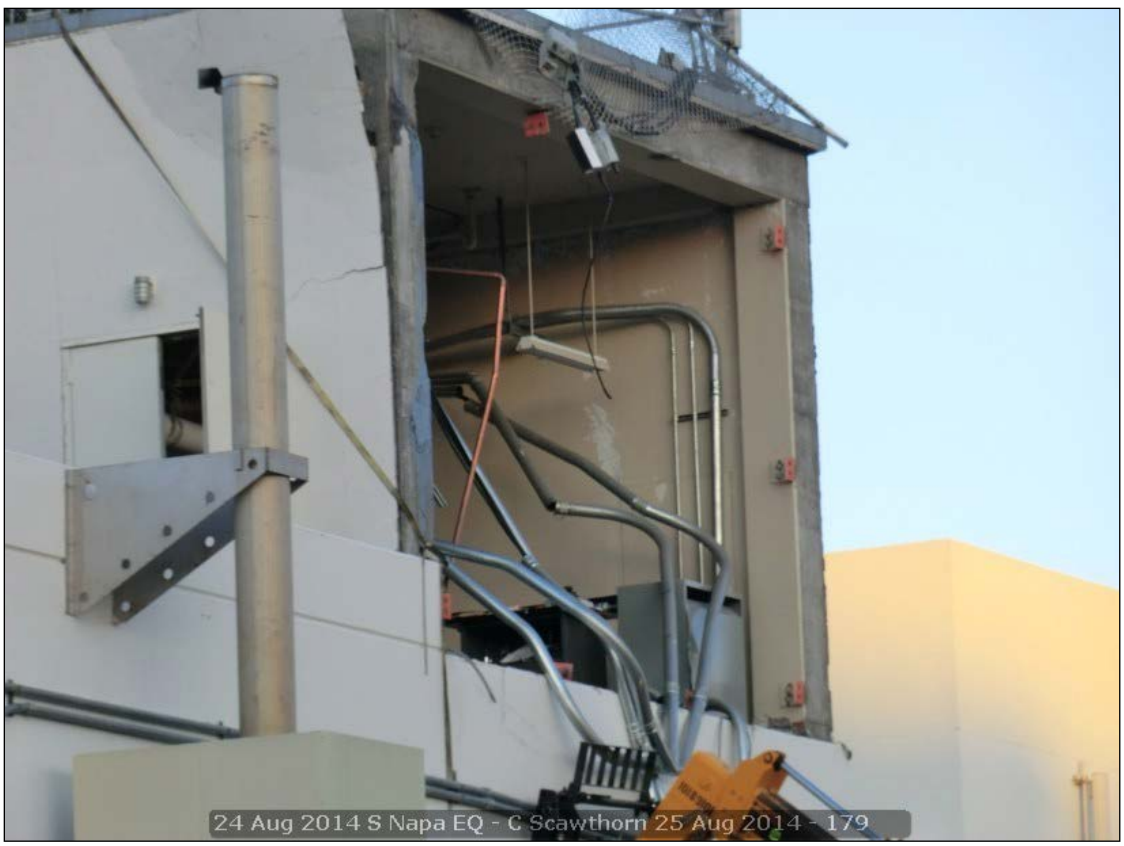


Figure 36 Damage to AT&T building, Napa

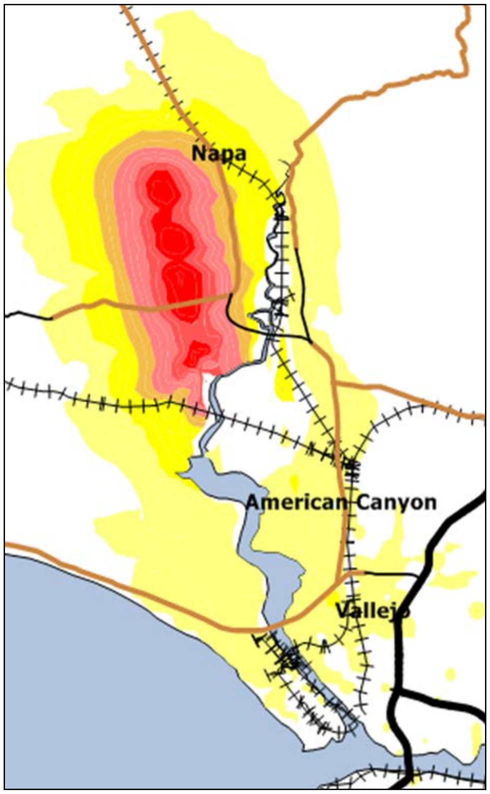


Figure 37 Railroad within the affected area, overlaid on PGA

Figure 38 Napa airport with inferred fault trace in red (epicenter star), and mapped trace of W. Napa fault in black.

Figure 39 Napa airport ATC tower with broken glass (above) and temporary tower (below)

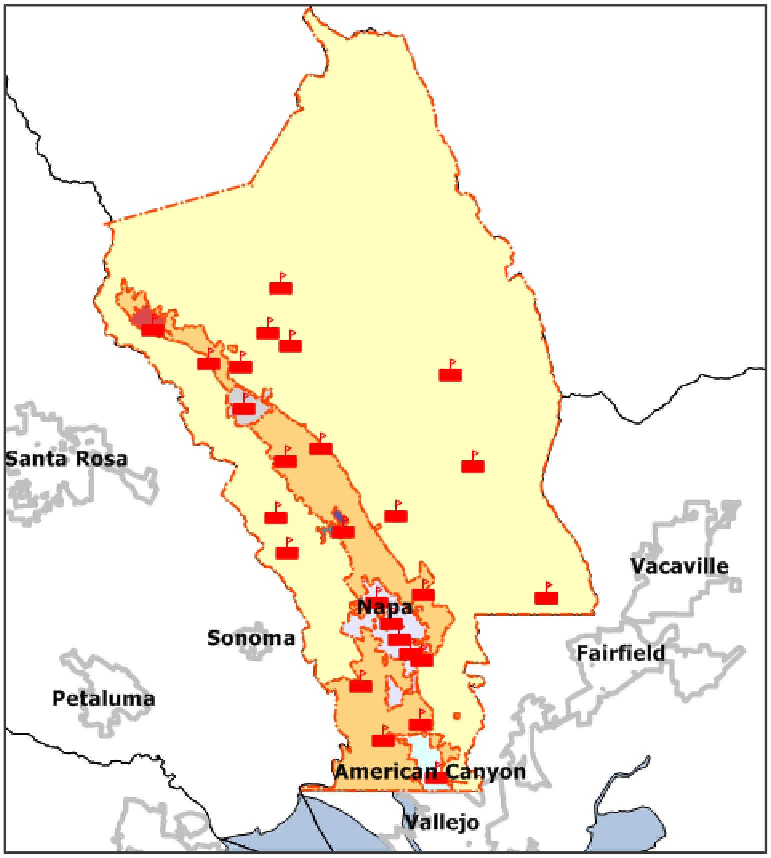


Figure 40 Napa County fire agency boundaries and fire stations

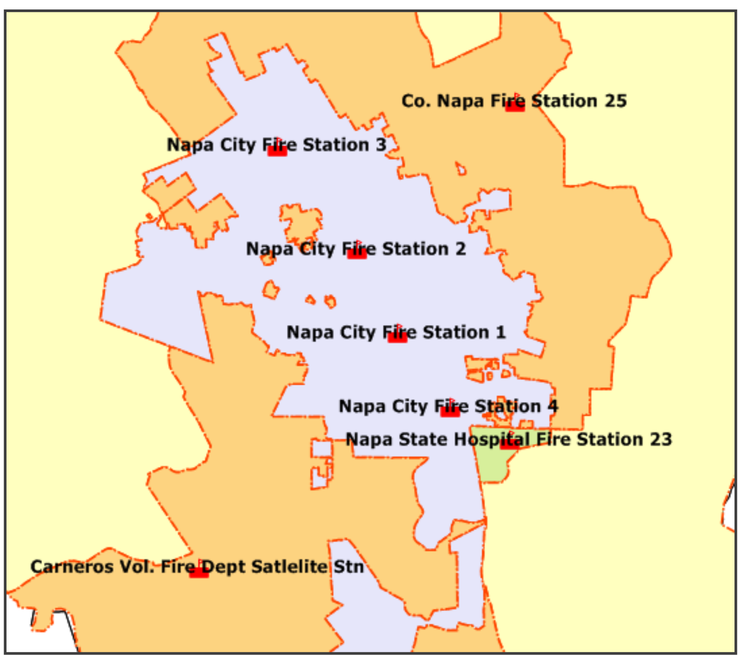


Figure 41 City of Napa Fire Department and nearby fire station locations

Fire Station #1: 707-257-9589 (x7370)
Located at 930 Seminary Street, Fire Station #1 was built in 1962. Station #1 houses a Paramedic Engine Company, a 110 foot Aerial Ladder Truck, the Battalion Chief, a Heavy Rescue Unit (for building and trench collapse, air supply, and Hazardous Materials rescue) and one Reserve Fire Engine.

Fire Station #2: 707-257-6222 (x7380)
Located at 1501 Park Avenue, Fire Station #2 is our oldest existing station and was built in 1950. Fire Station #2 also houses a Paramedic Engine Company as well as a Fire Patrol Unit (pickup with water tank for small grass fires) and a State Emergency Management Authority Engine (EMA 365 for our use and for large incidents throughout the state). In addition, Station #2 is the

Fire Station #3: 707-252-0986 (x7791)
Located at 2000 Trower Avenue, Fire Station #3, was built in 1987 and also provides a Paramedic Engine company. In addition, Station #3 houses a Type 3 Fire Engine (for off road vegetation fire attack).

Fire Station #4: 707-257-9612 (x7612)
Located at 251 Gasser Drive, behind Target, Fire Station #4 is our newest station completed on Feb. 17, 2004. It houses a Paramedic Engine Company, a Reserve Engine, and a Fire Patrol Unit.

Figure 42 Napa City Fire Dept. (NFD) Stations
(Source: http://www.cityofnapa.org/index.php?option=com_content&task=view&id=395&Itemid=508)

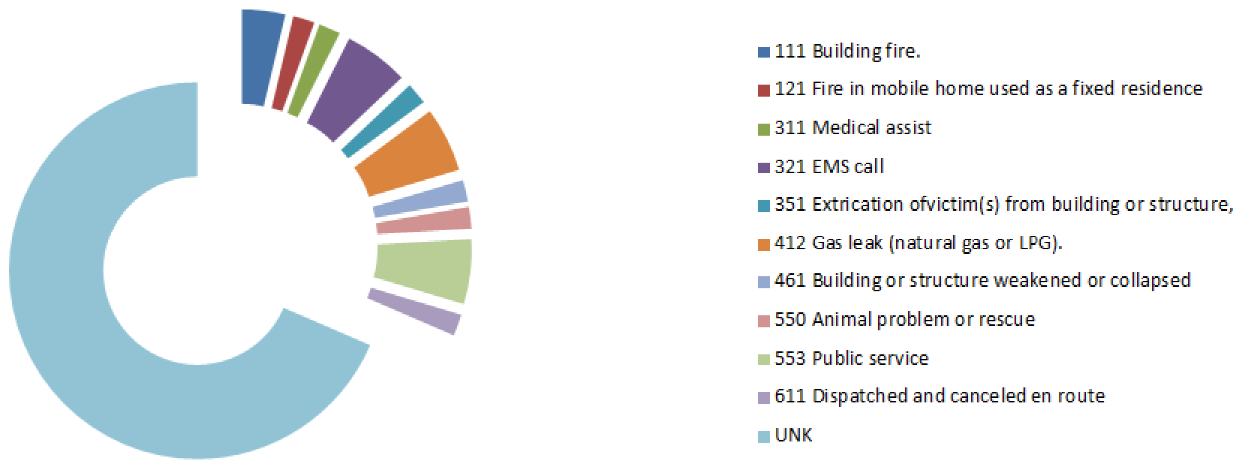
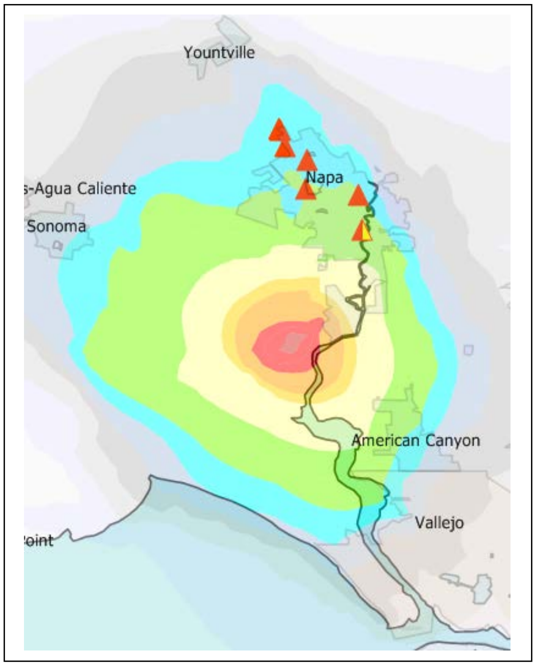


Figure 43 Breakdown of Incidents responded to by NFD on 24 August 2014



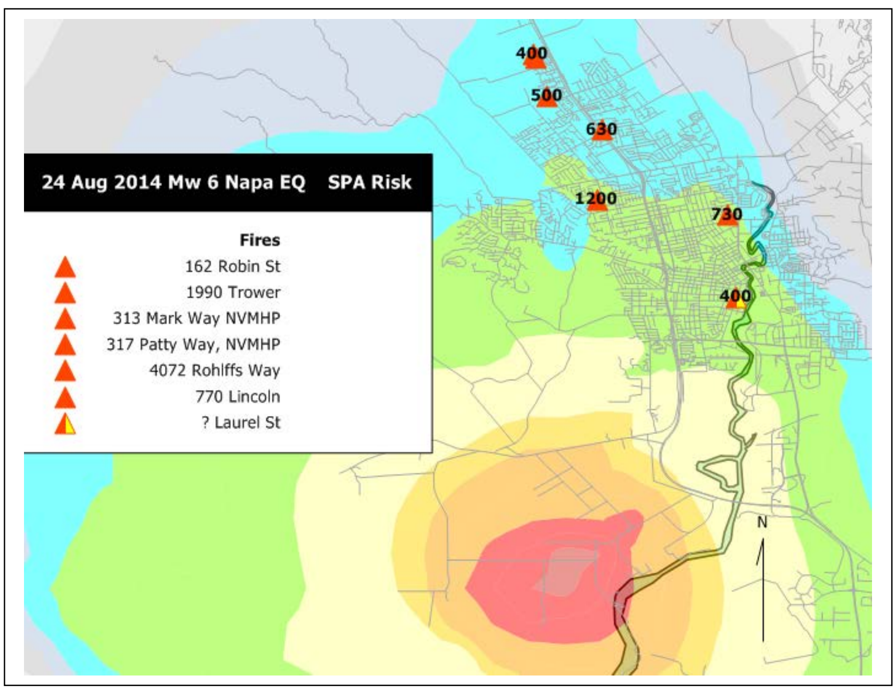


Figure 44 Fires and approx. times overlaid on PGA, 24 Aug 2014 S. Napa M_w 6.0 Earthquake (half shaded triangle indicates street number unknown)

Figure 45 Map of Napa Valley Mobile Home Park (NVMHP Park)

Figure 46 Swimming pool on Pattie Way, NVMHP

Figure 47 (l) NVMHP Park and locations of fires, 24 Aug 2014 S. Napa M_w 6.0 Earthquake; (r) 317 Patty Way fireground, showing locations of photos 31, 33, 38 in Figs. 3 and 4 (damaged buildings outlined in red)

Figure 48 Fireground 317 Patty Way, NVMHP Park, 24 Aug 2014 S. Napa M_w 6.0 Earthquake

Figure 49 Views from NE, Fireground 317 Patty Way, NVMHP Park, 24 Aug 2014 S. Napa M_w 6.0 Earthquake

Figure 50 Views looking N from Stacey Way, Fireground 317 Patty Way, NVMHP Park, 24 Aug 2014 S. Napa M_w 6.0 Earthquake

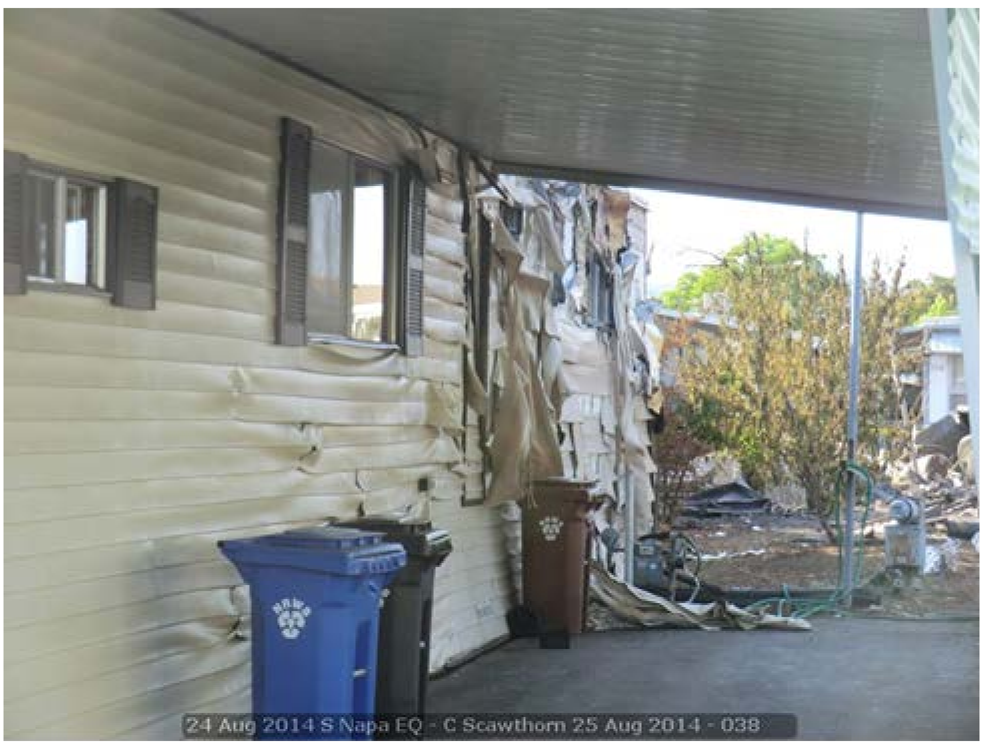


Figure 51 Damage to exposure structures, 317 Patty Way, NVMHP Park, 24 Aug 2014 S. Napa M_w 6.0 Earthquake, structure to south of fireground

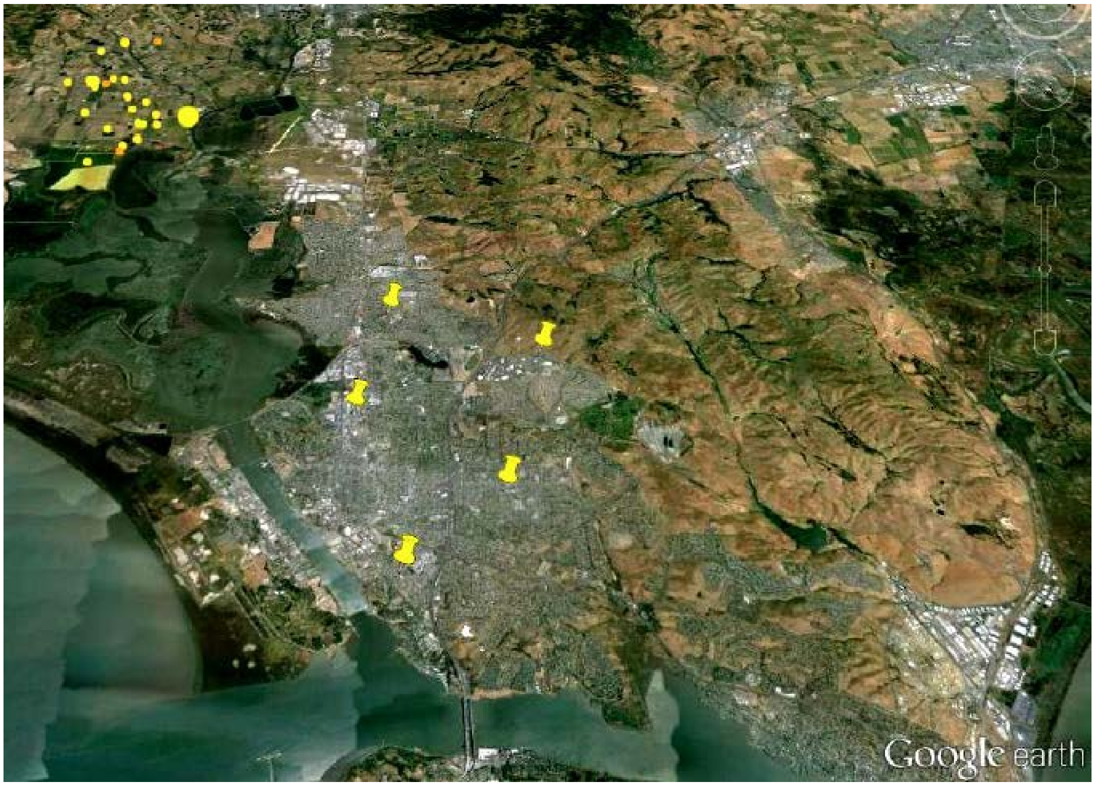
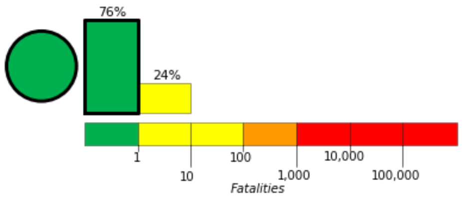


Figure 52 SWS stations in Vallejo (yellow pins). Yellow dots are mainshock and aftershocks of 24 Aug. 2014 South Napa Earthquake

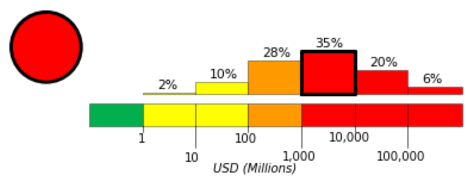
Figure 53 ShakeAlert Early Earthquake Warning, 24 Aug. 2014 South Napa Earthquake

Estimated Fatalities



Green alert level for shaking-related fatalities. There is a low likelihood of casualties.

Estimated Economic Losses



Red alert level for economic losses. Extensive damage is probable and the disaster is likely widespread. Estimated economic losses are less than 1% of GDP of the United States. Past events with this alert level have required a national or international level response.

Estimated Population Exposure to Earthquake Shaking

Estimated Modified Mercalli Intensity		I	II-III	IV	V	VI	VII	VIII	IX	X
Est. Population Exposure		--*	4,881k*	3,281k	370k	145k	52k	82k	0k	0k
Perceived Shaking		Not Felt	Weak	Light	Moderate	Strong	Very Strong	Severe	Violent	Extreme
Potential Structure Damage	Resistant	none	none	none	V.Light	Light	Moderate	Moderate/Heavy	Heavy	V.Heavy
	Vulnerable	none	none	none	Light	Moderate	Moderate/Heavy	Heavy	V.Heavy	V.Heavy

*Estimated exposure only includes population within calculated shake map area. (k = x1,000)

Figure 54 Initial PAGER estimates of impacts (http://comcat.cr.usgs.gov/earthquakes/eventpage/nc72282711#pager)