California Seismic Safety Commission

Pacific Earthquake Engineering Research Center (PEER)

The M_w 6.0 South Napa Earthquake of August 24, 2014:

A Wake-up Call for Renewed Investment in Seismic Resilience across California

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FINAL DRAFT

EXECUTIVE SUMMARY

The magnitude 6.0 South Napa Earthquake of August 24, 2014, took the lives of two people, injured 300 others, and caused moderate to severe damage to more than 2,000 structures. It is one of the first damaging earthquakes to strike a major metropolitan area in the State of California in over two decades. During that time period, California's population has grown by over 25%, the state's economy has tripled, and a great many of the state's new residents and businesses have never experienced a major earthquake. It is almost guaranteed that there will be a major damaging earthquake somewhere in the state within the next 30 years, and thus the South Napa earthquake is our "wake-up call" to renew investment and action to enhance the seismic resilience of communities, businesses, and residents across the state.

On October 8, 2014, the Alfred E. Alquist Seismic Safety Commission (Commission) held a hearing in American Canyon, California, to better understand impacts and lessons learned from local, State and federal representatives, and residents and businesses impacted by the South Napa earthquake. The Commission subsequently engaged the Pacific Earthquake Engineering Research Center (PEER), headquartered at the University of California, Berkeley, to synthesize and analyze observations and studies resulting over the first year following the earthquake. As part of its work, PEER was asked to review relevant and transferable lessons from other recent earthquakes and, in addition, to consider how scientific, engineering, and technological advances of the last few decades have affected emergency response and recovery following the 2014 earthquake. PEER presented a set of 20 findings of the study to the Commission at its meeting on January 14, 2016, and then worked with the Commission's staff to incorporate feedback into a revised draft that included 41 recommendations for consideration at the Commission's workshop on March 9, 2016. At that time, the Commission identified the 12 priority recommendations. Both the 20 findings and 12 priority recommendations are organized around the areas of Geosciences, Infrastructure, Buildings, People and Businesses, and Government and Institutions.

1. Geosciences

Finding 1.1: The South Napa earthquake is the first earthquake to produce significant surface rupture in Northern California since 1906, and the first surface fault rupture to impact housing in the 40 years of the Alquist-Priolo Earthquake Fault Zoning Act.

Finding 1.2: Afterslip on the West Napa fault following the 2014 earthquake produced further damage and necessitated a regional-scale geologic investigation, on-going monitoring, and technical guidance for federal, State and local government, utilities, and property owners to better characterize both the short- and long-term risks for buildings and infrastructure due to afterslip.

Finding 1.3: The South Napa earthquake identified some critical gaps in mapping coverage and guidance that affected the abilities of city, county, and State agencies to identify and map seismic

FINAL DRAFT

hazard zones and mitigate seismic hazards to protect public health and safety in accordance with the provisions of the Seismic Hazard Mapping Act of 1990.

Finding 1.4: Investments in strong-motion instrumentation and earthquake alerting systems, applications of advance remote sensing techniques and activation of the California Earthquake Clearinghouse all were demonstrably valuable in assisting damage assessment and emergency response, even in a moderate earthquake.

Priority Recommendation 1.1: Identify the locations of complex and integrated fault zones in the state, like the West Napa fault zone, and prioritize these for evaluation and mapping and potential designation as Alquist-Priolo Earthquake Fault Zones.

Priority Recommendation 1.2: Evaluate the aggregate effects of current amendments and exemptions under the Alquist-Priolo Earthquake Fault Zone Act and accompanying regulations, and study ways to better regulate and fund geologic investigations and structural mitigation in Alquist-Priolo Earthquake Fault Zones.

2. Infrastructure

Finding 2.1: The 2014 South Napa earthquake demonstrated the long-term benefits of the State's $12 billion highway bridge earthquake strengthening program, which has screened and retrofitted (as needed) more than 2,200 structures statewide to prevent collapse during future earthquakes.

Finding 2.2: The South Napa earthquake highlighted the vulnerability of natural gas transmission and distributions systems to earthquake-related ground failure.

Finding 2.3: The South Napa earthquake highlighted the vulnerability of water and wastewater systems to earthquake-related ground failure, the additional fire hazards that earthquake-related water-system failures can pose, and the fiscal challenges that public agencies face in improving the seismic resiliency of these systems, both pre- and post-earthquake.

Priority Recommendation 2.1: Ensure that all State-required gas safety plans address the mitigation of system risks to seismic hazards.[1]

Priority Recommendation 2.2: Convene a State task force that includes local water and wastewater providers as well as fire departments across the state to identify vulnerabilities, mitigation options, and financial mechanisms to enhance the seismic resilience of local

[1] Senate Bill (SB) 705 passed in October 2011 and codified under Public Utilities Code (PUC) §§ 961 and 963(b)(3) mandates that gas operators must develop and implement gas safety plans that are consistent with gas industry best practices. Public Utilities Code § 963(b)(3) specifically requires that the plans identify and minimize hazards and system risks to minimize accidents and dangerous conditions.

FINAL DRAFT

water and wastewater systems, particularly in areas vulnerable to widespread ground failure and that lack alternative water supplies for firefighting.

3. Structures

Finding 3.1: The South Napa earthquake helped to identify important gaps in building safety evaluations and procedures to barricade unsafe areas that should be addressed statewide before the next major earthquakes strikes.

Finding 3.2: The City of Napa's program to seismically retrofit unreinforced masonry buildings was successful in reducing damage and the risk to life safety posed by these buildings.

Finding 3.3: While modern buildings generally met or exceeded code performance standards in the M_w6.0 earthquake, damage to non-structural components was the greatest contributor to property losses.

Finding 3.4: There was generally good performance across a range of wood-frame residential construction vintages and styles. The vast majority of damage was caused by two well-known seismic deficiencies: unbraced chimneys and cripple walls foundations.

Finding 3.5: The significant damage to manufactured housing in the 2014 South Napa earthquake was almost exclusively associated with support systems rather than the homes themselves.

Priority Recommendation 3.1: Work with the Federal Emergency Management Agency, the California Building Officials, and other professional engineering and architectural organizations to: ensure that curricula for training and certification of safety assessors are effective and more widely implemented, particularly for local government personnel; improve protocols for deploying and compensating safety assessors; expand the use of Building Occupancy Resumption Programs; and grant safety assessment authority to the Division of the State Architect for public K-14 schools and State-owned buildings.

Priority Recommendation 3.2: Work with the California Building Officials and professional engineering and architectural organizations, including the American Institute of Architects California Chapter and Structural Engineers Association of California, to develop guidance for local jurisdictions on effective coordination and management of post-earthquake safety assessment processes.

Priority Recommendation 3.3: Develop guidance and training for local fire departments and building owners and operators on alternative procedures to safely turn off damaged sprinkler systems following earthquakes.

FINAL DRAFT

Priority Recommendation 3.4: Evaluate and enhance, as needed, training and inspection materials for school districts and staff to seismically secure non-structural systems, equipment, contents and furnishings in public and private schools.

4. People and Businesses

Finding 4.1: Deaths and injuries sustained in the South Napa earthquake point to continuing gaps in public awareness and education on earthquake safety and preparedness.

Finding 4.2: The 2014 South Napa earthquake highlighted significant gaps in earthquake insurance coverage for both homeowners and businesses, and the need to improve both the affordability and terms of insurance coverage and plan for housing and business recovery funding needs ahead of a major urban earthquake in the state.

Finding 4.3: The delay in authorization of the federal Individual Assistance program hindered community recovery.

Finding 4.4: Insights from the 2014 South Napa earthquake provide an opportunity to consider how State emergency proclamation provisions can accelerate and improve post-earthquake recovery for residents and businesses.

Priority Recommendation 4.1: Establish a State task force to consider the risks posed to the state by the large proportion of uninsured residents and businesses in high-seismic hazard areas, and identify options for improving the take-up, affordability, and terms of earthquake insurance coverage for California residents and businesses, as well as alternative earthquake recovery funding sources for both residents and businesses.

Priority Recommendation 4.2: Evaluate and enhance, as needed, penalties and other consumer protections against post-disaster scamming by contractors and cost inflation.

5. Government and Institutions

Finding 5.1: The state's Standardized Emergency Management System was effective in mobilizing a multi-jurisdictional, multi-level emergency response following the South Napa earthquake but some significant areas for improvement and training, particularly with smaller jurisdictions, have been identified.

Finding 5.2: The 2014 earthquake identified problems with the damage assessment and declaration processes and financing of local government post-disaster assistance that need to be addressed ahead of the next major urban earthquake in the state.

Finding 5.3: The 2014 earthquake highlighted significant gaps in contingency planning at many key government and critical facility operations.

FINAL DRAFT

Finding 5.4: More pre-disaster planning and training for post-disaster recovery is needed at both the State and local levels.

Priority Recommendation 5.1: Strengthen seismic performance standards and contingency planning for all State and local correctional facilities.

Priority Recommendation 5.2: Review and revise, as needed, State regulations guiding the transfer and housing of inmates in county jails during times of emergency.

The Commission's 20 findings and 12 priority recommendations are contained in the main body of this report. Additional recommendations that were identified during the study are provided in the Appendix.

FINAL DRAFT

TABLE OF CONTENTS

Executive Summary i
Introduction 1
Findings and Priority Recommendations 3
1. Geosciences 3
2. Infrastructure 9
3. Structures 15
4. People and Businesses 23
5. Government and Other Institutions 33
Appendix: Additional Recommendations 39
References 49
Acknowledgments 55

FINAL DRAFT

FINAL DRAFT

INTRODUCTION

The magnitude (M_w) 6.0 South Napa earthquake struck at 3:20 A.M. on Sunday, August 24, 2014, approximately four miles [6.4 kilometers (km)] northwest of American Canyon, six miles (9.6 km) south–southwest of Napa, and 51 miles (82 km) west–southwest of Sacramento, California. Two people died and 300 people reported injuries as a result of the earthquake or subsequent clean-up activities.[2]

While the earthquake was felt in many parts of central and northern California, building and infrastructure damage was mostly confined to Napa, Solano, and Sonoma counties in the northwestern reaches of the San Francisco metropolitan area. Nearly 2,000 structures sustained moderate to severe damage, with nine fires erupting post-earthquake. Electricity and water services sustained disruptions, and there was minor damage to roads, water and natural gas lines, and wastewater treatment facilities.

A State Emergency Proclamation was issued for Napa, Solano, and Sonoma Counties on August 24, 2014. On September 2, 2014, Governor Brown requested a Presidential disaster declaration and authorized financial assistance through the California Disaster Assistance Act to local agencies and certain nonprofit organizations. Federal major disaster declarations were granted to portions of Napa and Solano counties on September 11, 2014 (for federal Public Assistance and Hazard Mitigation to qualifying public agencies and non-governmental organizations) and on October 27, 2014 (for federal Individual Assistance). As of May 2016, the federal government has approved approximately $38.3 million of assistance for these programs.[3] Total economic losses have been estimated at $443 million to $800 million.[4]

The M_w 6.0 South Napa earthquake is one of the first damaging earthquakes to strike a major metropolitan area in the State of California in over two decades. The M_w 6.7 Northridge earthquake struck southern California 20 years ago on January 17, 1994, and the M_w 6.9 Loma Prieta earthquake struck the San Francisco Bay Area over 25 years ago on October 17, 1989. These were and remain the two most damaging earthquakes to strike the State's most populous regions in modern times, and a great deal of California's earthquake risk reduction policy was derived and implemented in the aftermath of these two disasters. As a result, there were two decades of research and investment in earthquake hazard characterization, building code development, structural and infrastructure retrofits, insurance reform, and emergency management that were tested, in part, by the 2014 earthquake.

FINAL DRAFT

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[2] K.R. Attfield et al., "Injuries and Traumatic Psychological Exposures Associated with the South Napa Earthquake — California, 2014," *Morbidity and Mortality Weekly Report* 64, no. 35 (September 11, 2015): 975–78.
[3] Federal Emergency Management Agency FEMA, "Financial Assistance," California Earthquake (DR-4193), May 3, 2016, https://www.fema.gov/disaster/4193.
[4] Jennifer Huffman, "Top Stories of 2015, No. 1: Earthquake Aftermath," *Napa Valley Register*, December 30, 2015, http://napavalleyregister.com/news/local/top-stories-of-no-earthquake-aftermath/article_bb832e07-78dc-578a-bbde-10cbfe9c2a95.html.

On October 8, 2014, the Alfred E. Alquist Seismic Safety Commission (Commission) held a hearing on impacts and lessons learned from the South Napa earthquake. Mayors of the cities of American Canyon, Napa, and Vallejo, supervisors from the counties of Napa, Solano and Sonoma, and representatives of State Senator Wolk's office, the California Governor's Office of Emergency Services (Cal OES) and the Federal Emergency Management Agency (FEMA) were among those who testified at the hearing; they identified a number of potential policy considerations and lessons that emerged in the first two months following the earthquake.

The Commission subsequently engaged the Pacific Earthquake Engineering Research Center (PEER), headquartered at the University of California, Berkeley, to synthesize and analyze observations and studies resulting over the first year following the earthquake. The intent of this work has not been to develop a compendium of all information known about the South Napa earthquake but rather to convey priority findings and recommended actions that should be addressed in advance of the next damaging earthquake in California.

As part of its work, PEER was asked to review relevant and transferable lessons from other earthquakes that have occurred in recent years. These include the M_w 7.2 El Mayor Cucapah (Baja, California) earthquake of April 4, 2010, the 2010 M_w 8.8 Maule, Chile earthquake and tsunami, the 2010–2011 earthquake sequence in Canterbury, New Zealand, and the M_w 9.0 Great East Japan earthquake and tsunami of March 2011. In addition, the Commission requested that PEER consider how scientific, engineering and technological advances of the last few decades have affected emergency response and recovery following the 2014 South Napa earthquake, including (but not limited to) earthquake detection and notification, disaster damage assessment, seismic performance standards for structures and infrastructure, and recovery coordination and management.

Over the last two decades, California's population has grown by over 25% to nearly 39 million[5], and as of 2014 the state's economy has tripled with the statewide gross domestic product (GDP) exceeding $2,300 billion.[6] A great many of the state's new residents and businesses have never experienced a major earthquake. Yet, it is almost guaranteed that there will be a major damaging earthquake somewhere in the state within the next 30 years.[7] The South Napa earthquake is our "wake-up call" to renew investment and action to enhance the seismic resilience of communities, businesses, and residents across the state.

FINAL DRAFT

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[5] Regional Economic Analysis Project REAP, "Comparative Trends Analysis: Gross Domestic Product Growth and Change, 1987-2014 and Population Growth and Change, 1958-2014," U.S. Regional Economic Analysis Project, (2015), https://united-states.reaproject.org/analysis/comparative-trends-analysis/.
[6] Ibid.
[7] Edward H. Field et al., "Uniform California Earthquake Rupture Forecast, Version 3 (UCERF3)—The Time-Independent Model," USGS Open-File Report, (2013), http://pubs.usgs.gov/of/2013/1165/.

FINDINGS AND PRIORITY RECOMMENDATIONS

This report's primary purpose is to summarize the new lessons and seismic policy priorities emerging for the M_w 6.0 South Napa earthquake of August 24, 2014, and to identify existing earthquake preparedness, response, and mitigation policies and practices that may need to be improved or revised based on observations from this earthquake—one of the first to inflict damage on a major metropolitan area in the State of California in over two decades. The 20 findings and 10 priority recommendations are organized around five key topical areas: Geosciences, Infrastructure, Buildings, People and Businesses, and Government and Institutions. Additional recommendations that were identified during the study are provided in Appendix A.

1. GEOSCIENCES

The M_w 6.0 earthquake occurred within the West Napa fault zone, which is generally considered to be a relatively minor but active system of faults within the greater and seismically active San Francisco Bay Region. The earthquake originated near the eastern shore of San Pablo Bay and about 1 mile (1.6 km) west of the main mapped surface trace of the West Napa fault system;[8] see Figure 1. Right-lateral rupture propagated mostly northward along the fault zone and up the western edge of Napa Valley, directing the strongest shaking toward the City of Napa. Peak ground accelerations (PGAs) of over 50% *g* were recorded in and near Napa Valley.[9] Post-event analyses of ground motion recordings have also shown evidence of a short-duration, near-fault velocity "pulse" occurring in the Napa Valley.[10] The deep sedimentary basin in the Napa Valley and the alluvial flood deposits in downtown Napa amplified the ground motions.[11]

The earthquake did not produce much liquefaction, landsliding, or other forms of ground failure, even in areas previously identified as susceptible to ground failure.[12] This may partly reflect the low groundwater table caused by drought and late summer timing as well as the short duration of strong shaking.[13] There were relatively few aftershocks—an anomaly for earthquakes of this size.[14]

FINAL DRAFT

[8] T.M. Brocher et al., "The M_w 6.0 24 August 2014 South Napa Earthquake," *Seismological Research Letters* 86, no. 2A (April 2015): 309–26, doi:10.1785/0220150004.
[9] A.S. Baltay and J. Boatwright, "Ground-Motion Observations of the 2014 South Napa Earthquake," *Seismological Research Letters* 86, no. 2A (April 2015): 355–60, doi:10.1785/0220140232.
[10] Grace S. Kang and Stephen A. Mahin, eds., "PEER Preliminary Notes and Observation on the August 24, 2014 South Napa Earthquake" (PEER, University of California, Berkeley, September 17, 2014), http://peer.berkeley.edu/publications/peer_reports/reports_2014/webPEER-2014-13-Napa.pdf.
[11] Brocher et al., "The M_w 6.0 24 August 2014 South Napa Earthquake."
[12] Jonathan Bray et al., eds., "Geotechnical Engineering Reconnaissance of the August 24, 2014 M6 South Napa Earthquake, GEER Report GEER-037" (Geotechnical Extreme Event Reconnaissance Association, January 8, 2015), http://www.geerassociation.org/GEER_Post%20EQ%20Reports/SouthNapa_2014/index.html.
[13] Brocher et al., "The M_w 6.0 24 August 2014 South Napa Earthquake."
[14] Ibid.

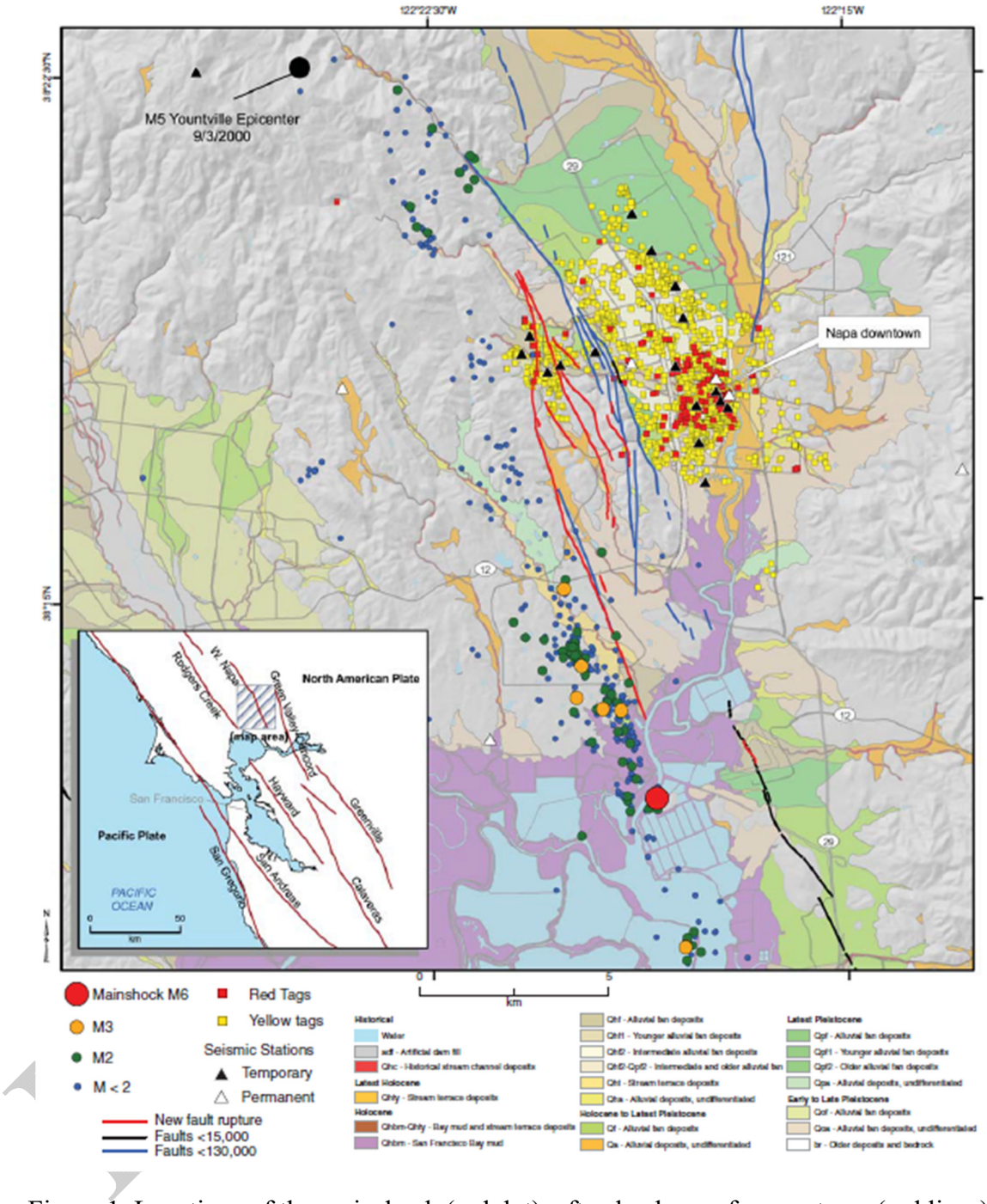

Figure 1. Locations of the mainshock (red dot), aftershocks, surface ruptures (red lines), and locations of permanent (unfilled triangles) and temporary (filled triangles) seismic stations. Locations of red- and yellow-tagged structures are from Boatwright et al. (2015). Surficial geology is from Witter et al. (2006). The inset map shows the location of the major strike–slip faults in the San Francisco Bay Area. Source: Brocher et al. (2015).

The M_w 6.0 earthquake did produce an unusually large amount of surface rupture, co-seismic displacement, and afterslip.[15] Average co-seismic displacements of 20 inches [50 centimeters (cm)] occurred along up to 9.3 miles (15 km) of the northward surface rupture and another 1.25 miles (2 km) of surface rupture occurred to the southeast in American Canyon.[16] In the first three months following the earthquake, up to 14 inches (35 cm) of afterslip occurred along some portions of the fault, and afterslip is forecast to continue for many months or possibly years.[17]

Findings: Geosciences

Finding 1.1: The South Napa earthquake is the first earthquake to produce significant surface rupture in Northern California since 1906, and the first surface fault rupture to impact housing in the 40 years of the Alquist-Priolo Earthquake Fault Zoning Act.

Pre-earthquake investigations of the West Napa fault zone had deemed that a short 5-mile (8 km) segment extending south from the Napa County Airport was sufficiently active and well-defined to be included as an Alquist-Priolo (A-P) Earthquake Fault Zone. However, nearly all of the 2014 surface rupture occurred northward of the mapped A-P Fault Zone—either on fault traces within the West Napa fault zone that had not been deemed sufficiently active (within the last 11,000 years) or where no faults had previously been mapped.

The California Geological Survey (CGS) was conducting additional studies on the West Napa fault zone when the South Napa earthquake struck. The CGS is now working to include all those traces that had surface rupture in the 2014 earthquake as A-P Fault Zones. At the same time, repairs and reconstruction of structures impacted by the 2014 surface rupture are proceeding. The City of Napa has required site-specific geologic investigations before issuing repair permits. It has also been advising that new structural foundations be located away from the fault, when feasible, or it is requiring much stronger, enhanced foundations that can survive some movement.[18]

Finding 1.2: Afterslip on the West Napa fault following the 2014 earthquake produced further damage and necessitated a regional-scale geologic investigation, on-going monitoring, and technical guidance for federal, State and local governments, utilities, and property owners to better characterize both the short- and long-term risks for buildings and infrastructure due to afterslip.

Within the first week following the South Napa earthquake, a multi-agency, State–federal, cost-sharing agreement was reached to acquire airborne LiDAR of the affected region, which was

[15] Ibid.
[16] Bray et al., "Geotechnical Engineering Reconnaissance of the August 24, 2014 M6 South Napa Earthquake, GEER Report GEER-037."
[17] K.W. Hudnut et al., "Key Recovery Factors for the August 24, 2014, South Napa Earthquake," Open-File Report (Ontario, CA: U.S. Geological Survey, October 1, 2014), http://pubs.usgs.gov/of/2014/1249/.
[18] Rong-Gong Lin II and Rosanna Xia, "Napa's Surprise Fault Line Triggers Earthquake Study of the Region," *Los Angeles Times*, December 26, 2014, http://www.latimes.com/local/california/la-me-quake-napa-fault-20141226-story.html.

FINAL DRAFT

utilized by State and federal agencies to assess ground deformation and its potential impacts and risks to buildings and infrastructure in the most critical areas of interest;[19] however, sufficient funding was not available to complete a comprehensive survey of the region. In contrast, following the 2010–2011 Canterbury earthquake sequence in New Zealand, liquefaction, rockfalls, and other ground failure across the metropolitan region necessitated large-scale geologic investigations, which was funded by the national government, to better characterize future risks and mitigation options for buildings and infrastructure in these areas.[20]

Future earthquakes, especially in more urbanized areas of the state, may cause large-scale ground failure that extend across many jurisdictions. As was experienced in the Santa Cruz Mountains following the 1989 Loma Prieta earthquake, the pace of recovery can be impeded as individual jurisdictions struggle to fund the necessary post-earthquake investigations and develop appropriate policies for repairs and rebuilding.[21]

Finding 1.3: The South Napa earthquake identified critical gaps in mapping coverage and guidance that affected the abilities of city, county and State agencies to identify and map State Seismic Hazard Zones and mitigate seismic hazards to protect public health and safety in accordance with the provisions of the Seismic Hazard Mapping Act of 1990.

In the San Francisco Bay Area, the CGS has prepared State Seismic Hazard Zone maps for liquefaction and earthquake-induced landslide hazards in San Francisco and parts of Alameda, Santa Clara, and San Mateo counties. Gaps remain in portions of Alameda, Santa Clara, Marin, Sonoma, Napa, and Solano counties. Hazard zone maps for tsunami and seiche (also called for by the Act when appropriate hazard information and funding are available) have not yet been developed. The CGS is in the process of developing appropriate information that will make it possible to map tsunami hazards across the state in the near future.

The Seismic Hazard Mapping Act recommends that the criteria for delineating State Seismic Hazard Zones be updated as and when the understanding of seismic phenomena and the methods used to assess their likelihood and potential impacts on the built environment improve. The publication was last updated in 2004. The State's guidance for the site-specific investigations and analysis of hazards, mitigation of hazards, and review of site-specific investigation reports for State seismic hazard zones was last updated in 2008. Updates of these documents should include insights gained from ground failure hazard mapping, evaluation, and mitigation efforts following the 2014 South Napa earthquake, the 2010–2011 Canterbury, New Zealand, earthquake sequence, and other recent earthquakes.

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[19] Hudnut et al., "Key Recovery Factors for the August 24, 2014, South Napa Earthquake."
[20] Nick Rogers et al., "Geotechnical Aspects of Disaster Recovery Planning in Residential Christchurch and Surrounding Districts Affected by Liquefaction," *Earthquake Spectra* 30, no. 1 (February 2014): 493–512, doi:http://dx.doi.org/10.1193/021513EQS029M.
[21] William Spangle and Associates, *Rebuilding After Earthquakes: Lessons from Planners* (Portola Valley, CA: William Spangle and Associates, Inc., 1991).

FINAL DRAFT

Finding 1.4: Investments in strong-motion instrumentation and earthquake alerting systems, applications of advance remote sensing techniques and activation of the California Earthquake Clearinghouse all were demonstrably valuable in assisting damage assessment and emergency response, even in a moderate magnitude earthquake.

The prototype earthquake early warning system developed by the U.S. Geological Survey (USGS), University of California, Berkeley (UCB), Caltech, and its partners successfully delivered the first ShakeAlert to prototype users in Berkeley and San Francisco in 5.1 seconds after the earthquake's origination; thus it provided about 10 seconds of warning prior to the onset of the strongest shaking at those locations (intensity IV).[22] The 2014 South Napa earthquake provided a positive proof-of-concept demonstration of the potential life and property saving value that such an early warning system could provide.

The first location, magnitude, focal mechanism, and ShakeMap ground shaking intensity map were reported four minutes after the earthquake's origin. This data was then used to produce the first ShakeCast estimates of infrastructure fragility for the California Department of Transportation (Caltrans) to use in prioritizing infrastructure investigations within 11 minutes and the first Prompt Assessment of Global Earthquakes for Response (PAGER) alert of probable fatalities and economic loss 13 minutes after the earthquake.[23] ShakeMap and other earthquake information products were updated as additional strong-motion recordings were retrieved.

The California Earthquake Clearinghouse served as a key conduit for collaboration among research organizations and in providing scientific input to State and federal agencies in responding to the 2014 South Napa earthquake. Within 12 hours of the earthquake, the Clearinghouse was physically established at a Caltrans facility in Napa. It provided logistical support to early post-earthquake investigations, including obtaining access to restricted areas, coordinating overflights, Light Detection and Ranging (LiDAR) and field surveys of fault surface rupture, ground deformation and building and infrastructure impacts, and linking investigators with agencies and organizations responsible for emergency response and recovery.[24]

Priority Recommendations: Geosciences

Priority Recommendation 1.1: Identify the locations of complex and integrated fault zones in the state like the West Napa fault zone, and prioritize these zones for evaluation and mapping and potential designation as Alquist-Priolo Earthquake Fault Zones.

FINAL DRAFT

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[22] Brocher et al., "The M_w 6.0 24 August 2014 South Napa Earthquake."
[23] Ibid.
[24] A. Rosinski et al., "California Earthquake Clearinghouse After-Action Report: South Napa Earthquake" (California Geological Survey and Earthquake Engineering Research Institute, April 17, 2015), http://www.eqclearinghouse.org/2014-08-24-south-napa/files/2015/04/California_Earthquake_Clearinghouse_After_Action_Report-South_Napa_Earthquake-2015.04.17.pdf.

The CGS is working to prioritize and complete earthquake fault zone mapping across the state with increased funding in the State's FY2014–15. Complex fault zones, particularly those near urban and urbanizing areas such as the West Napa fault zone, should have priority for evaluation and potential State-designation. The State should also develop advisory guidance for local governments that delineates the portions of such zones that are not sufficiently active and well-defined to be designated as an A–P Earthquake Fault Zone—including blind thrusts—and provide technical guidance for regulating land use and development, characterizing potential seismic hazards, and identifying appropriate actions to mitigate the effects of these hazards within these areas. As appropriate, corresponding updates to the technical guidelines for evaluating surface fault rupture hazard (CGS Note 49, 2002)[25] and for reviewing geologic reports (CGS Note 41, 1998)[26] should also be made.

Priority Recommendation 1.2: Evaluate the aggregate effects of current amendments and exemptions under the Alquist-Priolo Earthquake Fault Zone Act and accompanying regulations, and study ways to better regulate and fund geologic investigations and mitigation in Alquist-Priolo Earthquake Fault Zones.

There are a series of amendments and exemptions to the A-P Earthquake Fault Zone Act that allow housing and other structures intended for human occupancy located in an A-P Zone to be substantially renovated, repaired, or rebuilt without requiring geologic investigations. The logic for some of these amendments and exemptions stems from concerns that it would be a financial hardship to require owners of one- to three-unit structures and other exempted structures to investigate and delineate potential future surface fault rupture and creep hazards, and then take actions appropriate to mitigate the hazard effects. An assessment should be conducted to better understand the number of structures and occupants that reside within active fault zones across the state. A working group of State agencies, which might include the Commission, CGS, Cal OES, California Earthquake Authority (CEA), and Housing and Community Development (HCD), should also study ways to help local governments and property owners fund geologic investigations and undertake necessary mitigation measures to improve the seismic-resistance of these structures. The group should look at financial incentives and regulatory mechanisms, insurance rate reductions or underwriting conditions, post-disaster voluntary buyout programs, and deed restrictions[27] on construction upon an active fault trace as well as limiting post-disaster repairs and rebuilding of structures located on an active fault trace.

FINAL DRAFT

[25] California Geological Survey CGS, "Guidelines for Evaluating the Hazard of Surface Fault Rupture" (California Geological Survey, 2002), http://www.conservation.ca.gov/cgs/information/publications/cgs_notes/note_49/Documents/note_49.pdf.
[26] California Geological Survey CGS, "Guidelines for Reviewing Geologic Reports" (California Geological Survey, 1998), http://www.conservation.ca.gov/cgs/information/publications/cgs_notes/note_41/Pages/index.aspx.
[27] The approach to recordation and execution of deed restrictions consistent with conditions specified in a coastal development permit, under the California Coastal Act, merits further study.

2. INFRASTRUCTURE

Many regional rail, air, and road-based transportation systems initially shutdown for safety inspections following the August 24, 2014, earthquake; most resumed service shortly with little to no substantial damage. Otherwise, most of the service disruptions and damage to infrastructure systems caused by the earthquake were confined to portions of Napa, Solano, and Sonoma Counties. Mutual aid in making repairs and restoring system services were provided through the mutual aid systems of the California Utilities Emergency Association (CUEA) and Pacific Gas & Electric (PG&E)[28], and the California Water/Wastewater Agency Response Network (CalWARN)[29].

Power outages affected approximately 76,000 customers.[30] [31] Downed wires and subsequent wire-to-wire contact in the distribution system caused most of the outages. The peak customer outage period occurred around 3.75 hours after the earthquake, and over 99% of customers had power restored within 26 hours.[32] Power outages also had cascading impacts on other infrastructure systems. Telecommunications system outages were linked in large part to power outages that impacted service equipment and cell towers.

The main causes of physical damage to infrastructure systems were surface fault rupture and ground shaking effects on older and less ductile system components. For example, all of the 11 sewer main breaks in the Napa Sanitation District system occurred in brittle asbestos cement pipe and most were located near the fault.[33] The City of Napa's water system was one of the most damaged infrastructure systems, with 241 water leaks reported in the six months following the earthquake.[34] A seismically-unanchored 67-foot (20-meter) diameter steel tank located near the fault rupture—one of 12 holding tanks in the city's water distribution network—also sustained significant damage; all the water drained out due to a nearby pipe break. [35] Approximately three-quarters of the water main breaks occurred in old cast-iron pipe.[36] Roads, highways, and two

[28] California Governor's Office of Emergency Services Cal OES, "After Action Report: 2104-08-24 Napa Earthquake, Executive Summary" (California Governor's Office of Emergency Services, 2015), http://www.caloes.ca.gov/PlanningPreparednessSite/Documents/16%20Napa%20Earthquake%202014%20Executive%20Summary.pdf.
[29] Earthquake Engineering Research Institute EERI, "EERI Special Earthquake Report, M6.0 South Napa Earthquake of August 24, 2014," October 2014, http://www.eqclearinghouse.org/2014-08-24-south-napa/preliminary-reports/.
[30] This is about 1.4% of the 5.1 million customers in Pacific Gas & Electric's regional electric system.
[31] John Eidinger, ed., "South Napa M 6.0 Earthquake of August 24, 2014" (G&E Engineering Systems, March 17, 2015), http://www.geengineeringsystems.com/ewExternalFiles/NAPA%202014%20Rev%201.pdf.
[32] Ibid.
[33] EERI, "EERI Special Earthquake Report, M6.0 South Napa Earthquake of August 24, 2014."
[34] Eidinger, "South Napa M 6.0 Earthquake of August 24, 2014."
[35] EERI, "EERI Special Earthquake Report, M6.0 South Napa Earthquake of August 24, 2014."
[36] Ibid.

FINAL DRAFT

natural gas transmission pipelines serving the northern Bay Area were also impacted by surface rupture and afterslip in the West Napa fault zone.[37]

While the Napa Sanitation District's wastewater treatment operations performed quite well in the earthquake, the system was subsequently disrupted for two days due to an inflow of considerable quantities of wine spilled from damaged barrels. The wine's acidity disrupted normal anaerobic bacterial processes in the treatment plant's digester; remediation that involved blowing air into the digester took 24 hours to complete.[38] No untreated water or solids were released.

Findings: Infrastructure

Finding 2.1: The 2014 South Napa earthquake demonstrated the long-term benefits of the State's $12 billion highway bridge earthquake strengthening program, which has screened and retrofitted (as needed) more than 2,200 structures statewide to prevent collapse during future earthquakes.

Prior to August 2014, all 412 State-owned highway bridges in Solano, Napa, and Sonoma Counties had been screened and 54 bridges had been retrofitted.[39] All the retrofitted State-owned highway bridges performed well and were able to carry traffic after the 2014 earthquake. The 33-span Napa River Bridge on Route 37 was extensively retrofitted in 1996 after suffering damage in the 1989 Loma Prieta earthquake. No serious damage occurred in the 2014 earthquake, and it was reopened to traffic shortly after inspection.[40]

A more specific comparison of the seismic performance of retrofitted and unretrofitted structures was provided with the State-owned Sonoma Creek Bridge and the nearby Napa Slough Bridge. The Sonoma Creek Bridge had a substructure retrofit in 1999 and sustained no damage. The comparable Napa Slough Bridge did not have a substructure retrofit and it sustained serious damage to the pile extensions in the 2014 earthquake.[41] New bridges also performed well, including the recently completed Carquinez Bridge that registered high peak ground accelerations at its base.[42]

Finding 2.2: The South Napa earthquake highlighted the vulnerability of natural gas transmission and distributions systems to earthquake-related ground failure.

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[37] Eidinger, "South Napa M 6.0 Earthquake of August 24, 2014."
[38] EERI, "EERI Special Earthquake Report, M6.0 South Napa Earthquake of August 24, 2014."
[39] California Department of Transportation Caltrans, "Bridge Investigation Team Report for the August 24, 2014 South Napa Earthquake," n.d.
[40] EERI, "EERI Special Earthquake Report, M6.0 South Napa Earthquake of August 24, 2014."
[41] Caltrans, "Bridge Investigation Team Report for the August 24, 2014 South Napa Earthquake."
[42] The high frequency instrumented motions are believed to have been caused by motions of the bridge, and were not a true representation of the free field ground motions. Caltrans, "Bridge Investigation Team Report for the August 24, 2014 South Napa Earthquake."

FINAL DRAFT

While the earthquake did not break any gas lines, PG&E has accelerated its gas pipeline replacement program in the area—work that wasn't planned for another three to five years.[43] Following the August 24th earthquake, PG&E temporarily decommissioned and replaced about 7,000 ft (2.1 km) of one of the major natural gas transmission pipelines that serves the northern San Francisco Bay Area and traverses the south end of the West Napa fault zone.[44] It also installed 7,600 feet (2.3 km) of new gas distribution lines serving approximately 150 homes in the Browns Valley neighborhood and other rural areas near the fault zone.[45]

As outlined in its State-required gas safety plan, PG&E is replacing all of its older cast iron and steel gas distribution pipe with modern, plastic pipe that is more flexible and seismically-resilient.[46] This includes replacement of gas transmission pipelines in fault areas.[47] It has also installed 150 automated and remotely controlled valves on gas transmission lines that can be opened or closed from the company's gas control center whenever there is a significant change in pressure.[48]

Finding 2.3: The South Napa earthquake highlighted the vulnerability of water and wastewater systems to earthquake-related ground failure, the additional fire hazards that earthquake-related water-system failures can pose, and the fiscal challenges that public agencies face in improving the seismic resiliency of these systems, both pre- and post-earthquake.

The City of Napa's water system sustained damages exceeding $6.4 million from the August 24, 2014, earthquake, subsequent aftershocks, and ground settlement.[49] Immediately after the earthquake, the City of Napa continued pushing water through the damaged system to maintain firefighting and other critical functionality.[50] Although this resulted in an estimated total loss of 100-acre feet of water (about 7% of monthly water usage),[51] it also ensured that water was

FINAL DRAFT

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[43] Noel Brinkerhoff, "PG&E Expands Post-Quake Gas Line Replacement," *Napa Valley Register*, October 16, 2014, http://napavalleyregister.com/news/local/pg-e-expands-post-quake-gas-line-replacement/article_1282c27f-5e97-5fef-9f2d-d0d4d39b79a6.html.
[44] Eidinger, "South Napa M 6.0 Earthquake of August 24, 2014."
[45] Brinkerhoff, "PG&E Expands Post-Quake Gas Line Replacement."
[46] Pacific Gas & Electric Company PG&E, "Pacific Gas and Electric Gas Safety Plan" (Pacific Gas & Electric Company, September 30, 2014), http://www.pge.com/includes/docs/pdfs/safety/systemworks/gas/GasSafetyPlan_2014.pdf.
[47] Pacific Gas & Electric Company PG&E, "PG&E Will Replace Cast Iron Pipe in 2014; Action Reduces Leak Backlog, Cuts Emissions," *Currents: News and Perspectives from Pacific Gas and Electric Company*, August 6, 2014, http://www.pgecurrents.com/2014/08/06/pg-action-reduces-leak-backlog-cuts-emissions/.
[48] Hailey Wilson, "Earthquake-Damage Models Helped PG&E Restore Service in About 24 Hours After Napa Temblor," *Currents: News and Perspectives from Pacific Gas and Electric Company*, September 4, 2014, http://www.pgecurrents.com/2014/09/04/earthquake-damage-models-helped-pge-restore-service-in-about-24-hours-after-napa-temblor/.
[49] City of Napa, "Update on 2014 South Napa Earthquake Recovery," April 21, 2015, http://www.napa-ca.gov/sirepub/pubmtgframe.aspx?meetid=274&doctype=agenda.
[50] SPA Risk LLC, "24 August 2014 South Napa M_w 6 Earthquake - Reconnaissance Report," September 26, 2014.
[51] City of Napa, "City of Napa Drought Response Water Use vs. Base Year 2013" (City of Napa Public Works Department, October 2015), http://www.cityofnapa.org/images/publicworks/Water/Conservation/Progress%20October%202015.pdf.

available for firefighting at all but one of the nine post-earthquake fires.[52] The city spent $860,000 making emergency water system repairs in the first week following the earthquake. Assistance was provided through CalWARN by crews from other local water and wastewater agencies in the San Francisco Bay Area. On-going afterslip and ground settlement have caused multiple ruptures in certain areas.[53] The city appealed to FEMA to fund full replacement rather than repairs at 17 sites since "the system is not in the same condition as it was before."[54]

Priority Recommendations: Infrastructure

Priority Recommendation 2.1: Ensure that all State-required gas safety plans address the mitigation of system risks to seismic hazards.

Following the 2010 San Bruno pipeline explosion, the California legislature in conjunction with the California Public Utilities Commission required each gas corporation in the state to develop and implement gas safety plans for the safe and reliable operation of gas pipeline facilities.[55] The State should work to ensure that these plans give particular attention to accelerating natural gas pipeline replacement and upgrade programs in potential earthquake-induced ground failure areas, as well as the installation of automated and remotely controlled shut-off valves on major gas transmission pipelines especially in seismically-prone urban areas of the state. State-level requirements for automatic gas shutoff valves may also need to be created.

Priority Recommendations 2.2: Convene a State task force that includes local water and wastewater providers as well as fire departments across the state to identify vulnerabilities, mitigation options, and financial mechanisms to enhance the seismic resilience of local water and wastewater systems, particularly in areas vulnerable to widespread ground failure and that lack alternative water supplies for firefighting.

Burdened by aging infrastructure systems, local governments and utility districts across the state are challenged to fund capital investments to improve infrastructure resiliency. Many are working to upgrade systems to reduce leakage and enhance water efficiency in response to the state's persistent drought, and integrating seismic resiliency into this work should be investigated.

FINAL DRAFT

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[52] SPA Risk LLC, "24 August 2014 South Napa M_w 6 Earthquake - Reconnaissance Report."
[53] Howard Yune, "City Seeks $12 Million in Aid for Quake Repairs," *Napa Valley Register*, April 22, 2015, http://napavalleyregister.com/news/local/city-seeks-million-in-aid-for-quake-repairs/article_30648155-8403-5010-bfbf-a81ca9cd9e97.html.
[54] Ibid.
[55] Senate Bill (SB) 705 passed in October 2011 and codified under Public Utilities Code (PUC) §§ 961 and 963(b)(3) mandates that gas operators must develop and implement gas safety plans that are consistent with gas industry best practices. Public Utilities Code § 963(b)(3) specifically requires that the plans identify and minimize hazards and system risks to minimize accidents and dangerous conditions.

It is difficult to locate earthquake damage in buried infrastructure. Local governments also face significant challenges in financing post-earthquake repairs. Even if State and federal disaster declarations are secured, programs such as FEMA's Public Assistance program will not necessarily cover the additional costs of upgrading older lifeline system components and improving overall system resilience. The seismic vulnerability of water systems to fault rupture and ground failure in Los Angeles[56] and the east Bay Area[57], during the 1994 Northridge and 1989 Loma Prieta earthquakes, respectively, are well documented. The task force should also work to promote the adoption and implementation of voluntary performance guidelines for post-earthquake reliability of water supply, which were published by PEER (2013)[58] through a Commission-sponsored project. Areas lacking alternative water resources for fire-fighting are vulnerable to post-earthquake conflagrations and extensive recovery delays.

FINAL DRAFT

[56] Lucile M. Jones et al., "The ShakeOut Scenario," Open File Report (Virginia: U.S. Geological Survey, 2008), http://pubs.usgs.gov/of/2008/1150/of2008-1150.pdf.
[57] Evan Sernoffsky, "9 Water Mains Rupture in East Bay after 4.0 Quake," *San Francisco Chronicle*, August 18, 2015, http://www.sfgate.com/news/article/9-water-mains-rupture-in-East-Bay-after-4-0-quake-6450717.php.
[58] Charles Scawthorn, "Coordinated Planning and Preparedness for Fire Following Major Earthquakes" (Pacific Earthquake Engineering Research Center, November 2013), http://www.seismic.ca.gov/pub/webPEER-2013-23-Scawthorn.pdf.

FINAL DRAFT

3. STRUCTURES

Building damage in the 2014 South Napa earthquake correlates in great part with the pattern of ground shaking intensities; building age and the depth to bedrock also intensified building damage.[59] The vast majority of building damage occurred in the City of Napa and was densely concentrated (more than 100 red- or yellow-tagged structures per square kilometer (about 245 acres) in a 1.5-mile wide × 1-mile long (2.4 km × 1.6 km) kidney-shaped area that extends to the northwest and southwest of Napa's downtown; see Figure 1. This part of the city is older—much of it developed before 1950—and resides atop a deep basin of sedimentary deposits more than 0.6 miles [1,000 meters (m)] thick. In downtown Napa, city officials worked with private property owners to secure structures and install scaffolding and fencing barricades to prevent further damage and associated hazards.

In many respects, the South Napa earthquake offers a valuable accounting of the current state of earthquake structural resilience in California. Within the diverse inventory of structures subjected to moderately strong ground motions, there is strong evidence of the effectiveness of decades of improvements in seismic code provisions with key legislation like the 1933 Field Act for school seismic safety, 1972 Hospital Seismic Safety Act, and the 1986 unreinforced masonry (URM) law. Relatively modern structures (built according to 1998 or later editions of the *California Building Standards Code*) had little to no structural damage, all of which was generally repairable.[60]

Within the inventory, however, there is also strong evidence of important gaps. Even in this moderate seismic event, some older structures (built without modern seismic design requirements) sustained serious life-threatening structural and nonstructural damage, and a significant cohort of more modern buildings sustained extensive nonstructural damage.[61] While most of the damage has been repairable, a few buildings were closed for more than a year. In some instances, the damage levels were so great that the buildings were uninhabitable while being repaired, and a few may even be uneconomic to repair. It is a sobering reminder that the code emphasis on ductility and protecting life safety does not necessarily ensure community resilience even in moderately strong earthquakes. Furthermore, post-earthquake investigations suggest that the near-fault velocity pulses observed in the ground motion records might have had an even greater impact on Napa's building stock if it had included taller and more flexible structures.[62]

FINAL DRAFT

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[59] J. Boatwright et al., "The Distribution of Red and Yellow Tags in the City of Napa," *Seismological Research Letters* 86, no. 2A (April 2015): 361–68, doi:0.1785/0220140234; Kang and Mahin, "PEER Preliminary Notes and Observation on the August 24, 2014 South Napa Earthquake."

[60] Applied Technology Council ATC, "Performance of Buildings and Nonstructural Components in the 2014 South Napa Earthquake" (Federal Emergency Management Agency, February 2015), https://www.fema.gov/media-library/assets/documents/103966.

[61] Ibid.

[62] Ibid.; Kang and Mahin, "PEER Preliminary Notes and Observation on the August 24, 2014 South Napa Earthquake."

Findings: Structures

Finding 3.1: The South Napa earthquake helped to identify important gaps in building safety evaluations and procedures to barricade unsafe areas that should be addressed statewide before the next major earthquakes strikes.

Building safety evaluations were conducted by local building department staff along with volunteers, mutual aid, and State personnel following the general procedures of *ATC-20-1 Field Manual: Postearthquake Safety Evaluation of Buildings* (2005).[63] Using the Standardized Emergency Management System (SEMS) protocol, requests for assistance were made to Cal OES by Napa County for the cities of American Canyon and Napa and the County itself, and Solano County for the City of Vallejo and the County itself. Sonoma County did not request assistance. Safety evaluations for healthcare facilities were managed by the Office of Statewide Health Planning and Development (OSHPD) and mobile home inspections were managed by the State's Department of Housing and Community Development (HCD). The Napa Valley Unified School District used its own team and did not request assistance from the State Architect or Cal OES.

Local officials worked with private property owners to secure buildings and install fencing and other barricades to prevent further damage and injuries. Potential issues raised by assessments of the building stabilization, barricading, and stabilization efforts after the 2014 South Napa earthquake[64] include the following: insufficient setbacks in barricades around damaged buildings including sidewalks, streets, and adjacent structures; and varying unengineered and unanchored approaches to scaffolding around a building.

Finding 3.2: The City of Napa's program to seismically retrofit unreinforced masonry buildings was successful in reducing damage and the risk to life safety posed by unreinforced masonry buildings.

A post-earthquake evaluation of 68 buildings located within a 1,000 ft (300 m) radius of a ground-motion recording station in downtown Napa (station N016 located on Main Street) was funded by FEMA.[65] Within that group, there were 28 of unreinforced masonry (URM) buildings, of which 20 had been seismically strengthened, seven had not, and one's condition was unknown. Of the retrofitted buildings, 16 (80%) buildings sustained only minor to no structural damage and four (20%) sustained moderate to heavy damage. Comparatively, five (70%) of the seven unretrofitted URM buildings were posted UNSAFE or RESTRICTED USE. The study also found that a variety of retrofit approaches were used, with partial retrofits less successful in limiting damage compared to more comprehensive upgrades.

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[63] Applied Technology Council ATC, "Field Manual: Postearthquake Safety Evaluation of Buildings," 2nd Edition (Applied Technology Council, 2005).
[64] ATC, "Performance of Buildings and Nonstructural Components in the 2014 South Napa Earthquake."
[65] ATC, "Performance of Buildings and Nonstructural Components in the 2014 South Napa Earthquake."

FINAL DRAFT

While no URM buildings collapsed in the 2014 earthquake, there were masonry, parapet, and wall-related collapses onto streets, sidewalks, and even other buildings. Stone masonry walls and parapets were more likely to sustain damage than those made of brick masonry.[66]

In the City of Napa, owners of retrofitted URM buildings petitioned to have their buildings removed from the city's URM inventory once work was completed, making it difficult to locate and assess the seismic performance of retrofitted structures after the August 24, 2014, earthquake.[67] Despite this potential roadblock, surveys were able to document damage to spandrel mechanisms, poor performance of flexible moment frames and prescriptive diaphragm-to-wall spacing requirements, and adhesive-type anchors among the retrofitted URM buildings.[68]

Life loss and injuries could have been much higher if the earthquake had occurred at a busier time of day with more people in and around vulnerable URM buildings. Thirty-nine (39) fatalities were caused by URM building damage in the February 22, 2011, earthquake in Christchurch, New Zealand.[69] Subsequent analyses of URM building damage in Christchurch also found that earthquake-strengthened URM buildings sustained much less damage than URM buildings that had not been retrofitted or only had partial retrofits.[70]

Finding 3.3: While modern buildings generally met or exceeded code performance standards in the M_w 6.0 earthquake, damage to non-structural components was the greatest contributor to property losses.

Nonstructural components include architectural, mechanical, electrical and plumbing systems as well as building contents. Damage to sprinkler system piping and heads resulted in major interior building damage and flooding. There were also significant and widespread nonstructural component failures in the detailing for story drift that also impacted exterior cladding, glazing, and interior partitions, as well as roof tiles, suspended ceiling, ceiling lighting, and rooftop piping and conduits.[71] In some cases, the collapse of interior partitions, ceiling lighting, and interior furnishings and equipment blocked doorways and egress routes. The level of non-structural and contents-related damage in some commercial buildings, winery and manufacturing facilities, public and private schools, healthcare facilities, and government buildings was extensive and resulted in building closures and costly repairs. The damage could have been life threatening if some buildings had been occupied at the time of the earthquake.

FINAL DRAFT

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[66] Ibid.
[67] Ibid.
[68] EERI, "EERI Special Earthquake Report, M6.0 South Napa Earthquake of August 24, 2014"; ATC, "Performance of Buildings and Nonstructural Components in the 2014 South Napa Earthquake."
[69] Lisa Moon et al., "The Demise of the URM Building Stock in Christchurch during the 2010–2011 Canterbury Earthquake Sequence," *Earthquake Spectra* 30, no. 1 (February 1, 2014): 253–76, doi:10.1193/022113EQS044M.
[70] Ibid.
[71] ATC, "Performance of Buildings and Nonstructural Components in the 2014 South Napa Earthquake"; Kang and Mahin, "PEER Preliminary Notes and Observation on the August 24, 2014 South Napa Earthquake."

Finding 3.4: There was generally good performance across a range of wood-frame residential construction vintages and styles. The vast majority of damage was caused by two well-known seismic deficiencies: unbraced chimneys and cripple walls foundations.

Many unreinforced masonry chimneys of varying ages and styles failed, sometimes causing significant collapse hazards by falling onto exterior areas or into the interiors of homes. To assist homeowners and localities, FEMA funded the development of a recovery advisory on the *Repair of Earthquake-Damaged Masonry Fireplace Chimneys, FEMA DR-4193-RA1* (2015).[72] Many homes with unbraced cripple walls suffered large horizontal displacements and were even jolted off their foundations. The 2012 edition of the *International Existing Building Code* provides guidance on retrofitting cripple walls four feet or less in height; FEMA funded a recovery advisory on Earthquake Strengthening of Cripple Walls in Wood-Frame Buildings, *FEMA DR-4191-RA2* (2015)[73] to advise on retrofitting taller cripple walls.

Following the South Napa earthquake, the California Earthquake Authority (CEA) conducted an online survey of Napa city residents to document how their homes performed in the earthquake; 633 residents responded.[74] Of these 28% reported chimney damage and 15% reported that their home had been yellow- or red-tagged. Older houses (built pre-1950) experienced higher rates of tagging and more severe types of damage than newer homes. Only 12% of respondents reported that their homes had been retrofitted before the Napa earthquake. Of those respondents with homes that were not retrofitted, more than half expressed interest in retrofitting their property but were "confused about what's involved" (39%) or "want to but it's too expensive" (46%).

FEMA committed to provide $300 million in post-disaster hazard mitigation funds to retrofit 100 houses in Napa as part of the California Earthquake Brace + Bolt program, led by a joint powers authority established between the CEA and Cal OES. Some Napa homeowners on the Earthquake Brace + Bolt program waiting list will be given the option to apply for FEMA funds once available.

Finding 3.5: The significant damage to manufactured housing in the 2014 South Napa earthquake was almost exclusively associated with support systems rather than the homes themselves.

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[72] Federal Emergency Management Agency FEMA, "Repair of Earthquake-Damaged Masonry Fireplace Chimneys," FEMA Recovery Advisory (Washington, D.C.: Federal Emergency Management Agency, February 1, 2015), https://www.fema.gov/media-library-data/1439241984631-3b4c44f900c8893449327f0e764ef849/FEMAP-1024RA1.pdf.
[73] Federal Emergency Management Agency FEMA, "Earthquake Strengthening of Cripple Walls in Wood-Frame Dwellings," FEMA Recovery Advisory (Washington, D.C.: Federal Emergency Management Agency, April 2015), https://www.fema.gov/media-library-data/1439242021425-3b4c44f900c8893449327f0e764ef849/FEMAP-1024RA2.pdf.
[74] California Earthquake Authority CEA, "A Year After South Napa Earthquake, Damage Proves Widespread and Costly," Press Release (California Earthquake Authority, August 24, 2015), http://www.earthquakeauthority.com/media/Lists/Press%20Releases/Attachments/48/Napa%20Anniversary%20Press%20Release_FINAL.docx.pdf.

FINAL DRAFT

Since the 1994 Northridge earthquake, wind tie-down systems (referred to as ETS) are required on all newly installed or relocated manufactured homes in the state. Since the early 1980s, the *California Code of Regulations (Title 25, Chapter 2, Article 7.5)* has also specified minimum requirements for the installation of earthquake-resistant bracing systems (ERBS); but installation is voluntary, not mandatory. Although ETS and ERBS are the predominant types of seismic support systems in use in California, a significant number of manufactured homes across the state only have gravity support systems.[75]

Post-earthquake surveys of 11 mobile home parks in the City of Napa found that the majority of manufactured homes were installed before ETS were required and few had voluntarily installed ERBS. [76] They also observed that support system damage occurred nearly equally in manufactured homes with and without ETS and ERBS.[77] Large near-fault velocity pulse effects experienced in this earthquake and the presence of some older (possibly not approved or inspected) ETS and ERBS may have been contributing factors.[78] Damage to manufactured home support systems has also been observed in past California earthquakes, including the 1994 Northridge and 2003 San Simeon earthquakes.[79]

Priority Recommendations: Structures

Priority Recommendation 3.1: Work with the Federal Emergency Management Agency, the California Building Officials, and other professional engineering and architectural organizations to: ensure that curricula for training and certifying safety assessors are effective and more widely implemented particularly for local government personnel; improve protocols for deploying and compensating safety assessors; expand the use of Building Occupancy Resumption Programs; and grant safety assessment authority to the Division of State Architect for public K-14 schools and State-owned buildings.

Cal OES maintains a database of approximately 6,000 Safety Assessment Program (SAP) evaluators who have completed a training program based on ATC-20-1 and have registered as Disaster Service Workers. Most SAP evaluators are State or local government employees, such as building inspectors, and volunteers. Jurisdictions requesting assistance are responsible for compensating the evaluators, and these costs can be recouped if a federal disaster declaration is made. However, there are some significant differences in compensation. Volunteer evaluators, who are typically from the professional associations, donate their time with travel and lodging expenses reimbursed by the requesting jurisdiction. Compensation for government employees, such as local building officials and State employees, are provided through mutual aid, and

[75] ATC, "Performance of Buildings and Nonstructural Components in the 2014 South Napa Earthquake."
[76] Ibid.
[77] EERI, "EERI Special Earthquake Report, M6.0 South Napa Earthquake of August 24, 2014"; ATC, "Performance of Buildings and Nonstructural Components in the 2014 South Napa Earthquake."
[78] Bruce Maison and Kelly Cobeen, "Analytical Study of Mobile Home Response to the 2014 South Napa Earthquake," *Earthquake Spectra*, no. Preprint (2015), http://earthquakespectra.org/doi/abs/10.1193/020215EQS019.
[79] ATC, "Performance of Buildings and Nonstructural Components in the 2014 South Napa Earthquake."

FINAL DRAFT

reimbursements must account for expenses as well as personnel time. Thus, local governments often initially request the volunteer evaluators (who have lower costs), which may not necessarily provide for the best and most timely match of expertise with needs. FEMA reimbursement procedures, recruitment, and ATC-20-1 training, and real-time deployment procedures should be examined. The use and promotion of Building Occupancy Resumption Programs (BORP), in which licensed structural engineers working on behalf of building owners are deputized by jurisdictions before an earthquake to conduct post-earthquake evaluations of buildings and certify re-occupancy or being the process of securing and repairing damaged earthquakes, should also be considered to determine if it can improve inspection efficiency and reduce the public cost burden.

Priority Recommendation 3.2: Work with the California Building Officials and other professional engineering and architectural organizations, including the American Institute of Architects California Chapter and Structural Engineers Association of California to develop guidance for local jurisdictions on effective coordination and management of post-earthquake safety assessment processes.

Potential guidance needs raised by assessments of the 2014 South Napa earthquake safety evaluation processes[80] include: challenges faced by smaller jurisdictions with limited staff and training; formal authorization of the post-earthquake safety evaluation process (recommended ordinance language); development of plans for the orderly assignment of evaluation personnel and quality assurance; consistent use and communication of placard terminology; consistency in safety evaluations, re-evaluations, and placard placement on a structure; and best practices for evaluation data management, integration, and communication.

Priority Recommendation 3.3: Develop guidance and training for local fire departments and building owners and operators on alternative procedures to safely turn off damaged sprinkler systems following earthquakes.

Although building owners and operators are allowed to shut-off sprinkler systems, many do not know how or wait for local fire departments to respond even when the risk of fire following earthquake is low and extensive water-related contents damage can be prevented.[81] A training program could potentially be part of the Commission's work with the California Small Business Development Centers.

Priority Recommendation 3.4: Evaluate and enhance, as needed, training and inspection materials for school districts and staff to seismically secure non-structural systems, equipment, contents, and furnishings in public and private schools.

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[80] ATC, "Performance of Buildings and Nonstructural Components in the 2014 South Napa Earthquake"; City of Napa, "South Napa Earthquake After Action Report" (City of Napa Fire Department, May 22, 2015), http://cityofnapa.org/images/fire/documents/NapaCITYearthquakeAAR.pdf.
[81] ATC, "Performance of Buildings and Nonstructural Components in the 2014 South Napa Earthquake."

FINAL DRAFT

The State's *Guide and Checklist for Nonstructural Earthquake Hazards in California Schools* was revised in January 2011.[82] Lessons from more recent earthquakes and research may need to be incorporated into the guide. Inspections and mitigation work could be linked to the annual ShakeOut earthquake safety awareness program.[83] Non-structural mitigation programs instituted by the Berkeley Unified School District (involving volunteering parents) and the Los Angeles Unified School District (using post-Northridge earthquake hazard mitigation funds) are some examples that should be studied.

FINAL DRAFT

[82] California Emergency Management Agency CalEMA et al., "Guide and Checklist for Nonstructural Earthquake Hazards in California Schools" (California Governor's Office of Emergency Services, January 2011), www.caloes.ca.gov/PlanningPreparednessSite/Documents/Nonstructural_EQ_Hazards_For_Schools_July2011.pdf.
[83] ATC, "Performance of Buildings and Nonstructural Components in the 2014 South Napa Earthquake."

FINAL DRAFT

4. PEOPLE AND BUSINESSES

The 2014 South Napa earthquake struck during the early Sunday morning hours of a busy summertime weekend. In this instance, the timing of the earthquake was fortuitous as most residents and tourists were in homes and hotel facilities, both of which had good structural performance in the earthquake. Also, they were not in close proximity to commercial, industrial, and public facilities that sustained damaged from the ground shaking. As previously noted, if the earthquake had occurred at a different time of day when more people were in and around significantly damaged structures, casualties could have been far greater. Instead, the two reported deaths occurred from in-home injuries caused by falling objects and debris.[84] The 300 reported injuries were generally split between in-home injuries caused by falling objects and debris, and injuries sustained later during clean-up.[85]

Four emergency shelters were opened in Napa and Solano Counties, two of which housed 53 individuals[86] and remained open for two weeks after the earthquake. The American Red Cross, Salvation Army, and Voluntary Organizations Active in Disaster (VOAD) supplied food and drinking water to more than 2000 individuals.[87] A rapid household assessment of public health conducted in Napa and Solano counties shortly after the earthquake found that 20% of all surveyed households had one or more traumatic psychological exposures, the results of which were used to guide mental health resource allocations and public education efforts.[88]

Individual and Household Recovery

Joint federal, State, and local preliminary assessments estimated that 131 homes sustained major damage or were destroyed, and 1,875 homes sustained minor damage.[89] The rapid household assessment of public health conducted in Napa and Solano counties estimated that 12,669 households—42% of all Napa residences—were damaged enough to require repair, but only 4% were significant enough that residents left their homes in the week after the earthquake.[90] They also found that 30% of households expected that the financial burden of repairs would be "a little

[84] Howard Yune, "Family Makes the Case for a Second Napa Earthquake Fatality," *Napa Valley Register*, September 24, 2014, http://napavalleyregister.com/news/local/family-makes-the-case-for-a-second-napa-earthquake-fatality/article_0ed1554d-bf78-5776-82ce-e247ad7cff54.html.
[85] Attfield et al., "Injuries and Traumatic Psychological Exposures Associated with the South Napa Earthquake — California, 2014."
[86] Governor Edmund G. Brown, Jr., "Governor Brown Requests Presidential Major Disaster Declaration," Office of Governor Edmund G. Brown Jr., (September 2, 2014), https://www.gov.ca.gov/news.php?id=18680.
[87] Ibid.
[88] Attfield et al., "Injuries and Traumatic Psychological Exposures Associated with the South Napa Earthquake — California, 2014"; California Department of Public Health CDPH and Napa County Public Health NCPH, "Community Assessment for Public Health Response (CASPER) Following the August 24, 2014 South Napa Sarthquake, Napa and American Canyon. California - September 2014," January 22, 2015.
[89] Cal OES, "After Action Report: 2104-08-24 Napa Earthquake, Executive Summary."
[90] Kevin Courtney, "Survey Reveals More Trauma after August Earthquake," *Napa Valley Register*, March 16, 2015, http://napavalleyregister.com/news/local/survey-reveals-more-trauma-after-august-earthquake/article_1ba5a2be-5f85-581d-9a53-edd44eb53fb5.html.

FINAL DRAFT

difficult," while 10% or 3,001 households said repairs would be "very difficult" to afford.[91] The CEA's post-earthquake online survey of Napa city residents found that 37% of respondents had household damage costs over $5,000, with 13% exceeding $25,000.[92] Forty-seven percent (47%) of the CEA's post-earthquake online survey participants said their house repairs took over a week to complete, but that included 20% with repairs still unfinished six months after the earthquake.[93]

As of May 2016, FEMA has approved 4,265 Individual Assistance applications, providing over $10.4 million in housing assistance and $1 million in other needs assistance.[94] The Presidential disaster declaration also allowed impacted residents and businesses to apply for low-interest disaster loans through the U.S. Small Business Administration (SBA). As of August 2015, the SBA had approved $26 million in disaster loans to help 805 homeowners.[95] In addition to FEMA Individual Assistance and SBA loans, residents also used personal savings, refinanced and applied for a home equity or new loan for repairs, considered selling their home or relocating, and received help from a community organization.[96] Earthquake insurance was of limited benefit to impacted residents.

The Napa Valley Vintners trade association donated $10 million to the Napa Valley Community Foundation to create a Napa Valley Community Disaster Relief Fund to help local residents and businesses impacted by the earthquake.[97] In the first year following the earthquake, the Foundation awarded an estimated $6.4 million to 1,300 Napa County households, small businesses, and nonprofits. The funds were available for one-time immediate needs as well as short-term assistance for things like temporary housing; basic needs (food, water, etc.); medical care and counseling; and repairs to houses, businesses, and churches.[98] Yet, at the one-year mark, the South Napa Earthquake Recovery Group estimated that 356 families in Napa County still faced $3.3 million in unmet disaster-related repair costs.[99]

The South Napa Earthquake Recovery Group is a collection of agencies including area churches, the American Red Cross, the City of Napa, Napa County, Fair Housing Napa Valley, the Salvation Army, and other nonprofits that formed in early 2015. It works to match disaster recovery resources with earthquake survivors who have long-term unmet needs. The United

FINAL DRAFT

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[91] Ibid.
[92] CEA, "A Year After South Napa Earthquake, Damage Proves Widespread and Costly."
[93] Ibid.
[94] FEMA, "Financial Assistance."
[95] Richard Freedman, "The Napa Earthquake -- A Year Later," *Times-Herald*, August 24, 2015, http://www.timesheraldonline.com/general-news/20150824/the-napa-earthquake-a-year-later/1.
[96] CEA, "A Year After South Napa Earthquake, Damage Proves Widespread and Costly."
[97] Napa Valley Vintners, "Napa Valley Vintners Establishes Community Disaster Fund for Earthquake Relief," *Press Release*, August 27, 2014, https://napavintners.com/press/press_release_detail.asp?ID_News=600224.
[98] Jennifer Huffman, "Community Foundation Planning More Earthquake Aid," *Napa Valley Register*, August 7, 2015, http://napavalleyregister.com/news/local/community-foundation-planning-more-earthquake-aid/article_5469b27c-0c9a-53b9-8117-528ab34191c8.html.
[99] Ibid.

Methodist Committee on Relief provided a $100,000 grant in start-up funding to the Vallejo Earthquake Recovery Group and the South Napa Earthquake Recovery Group to hire professional case managers to train and lead volunteers in assisting community members with long-term unmet financial not covered by FEMA, SBA, or insurance, as well as other material and emotional needs related to the disaster.[100] By the end of 2015, the group had received over 4,000 requests for help including 46 homeowners that applied for $10,000 housing repair grants and 39 families assisted by volunteers with smaller repairs; another 75 homes are on the waiting list.[101] The Napa Valley Community Foundation has committed $1 million to help special needs families.[102]

The cities of American Canyon, Napa, and Vallejo have also worked to expand their housing programs for low-income residents and provide limited funding for earthquake repairs. The City of Napa's Emergency Home Repair Program is for low-income owners of conventional homes, manufactured homes, condominiums, and townhouses, and provides grants for repairs, including windows, doors, leaking roofs, plumbing, and electrical problems.

Business Recovery

Early federal, State and local preliminary assessments estimated 28 businesses sustained major damage and 337 businesses sustained minor damage.[103] This is a fairly low number in comparison to the 24,000 business establishments listed in the U.S. Census (2013)[104] for the three-county impact area. However, there were concentrated impacts in older business districts of the cities of Napa, Sonoma, and Vallejo, and among the region's vintners. Focused attention by City of Napa building officials and business owners helped to re-open 90% of downtown businesses within a week, and a tourist-industry collaborative led an active media and social media campaign that is credited with substantially increasing tourism and hotel revenues in Napa in the year following the earthquake.[105] By the one-year anniversary of the earthquake, 95% of downtown businesses were reportedly reopened; many of these businesses re-opened in historic structures that underwent extensive seismic upgrades as part of their repair.[106] These include the historic Vintner's Collective and Napa Steam Laundry buildings. As of August 2015, the SBA had approved $6.2 million to 92 businesses for property damage.[107]

Estimates of business insurance coverage for the 2014 South Napa earthquake have been difficult to define. Properties in high seismic hazard areas with commercial mortgage-backed

[100] Rosemarie Kempton, "Efforts Continue to Help Napa Quake Victims," *Napa Valley Register*, December 28, 2015, http://napavalleyregister.com/news/local/efforts-continue-to-help-napa-quake-victims/article_e39a6b04-ac07-5446-82a6-d5d7bac64354.html.
[101] Ibid.
[102] Ibid.
[103] Cal OES, "After Action Report: 2104-08-24 Napa Earthquake, Executive Summary."
[104] U.S. Census Bureau, "2013 County Business Patterns (NAICS)," 2013, http://censtats.census.gov/cgi-bin/cbpnaic/cbpsect.pl.
[105] Freedman, "The Napa Earthquake -- A Year Later."
[106] Ibid.
[107] Ibid.

FINAL DRAFT

securities loans are generally required to carry earthquake insurance or seismically strengthen the property.[108] About $620 million of commercial mortgage-backed securities loans were made to properties within the impacted region of the 2014 South Napa earthquake; over one-third of these loans were issued quite recently (2013–2014) to hotel and retail properties.[109] Thus, at least some of the new hotel and retail developments in and around Napa may have had insurance.

There have also been a few significant business closures as owners were unable to afford the high-costs of extensive repairs, the added expense of building code upgrades, and replacing damaged stock. These include the McCaulou's department store in downtown Napa and a Safeway grocery store—leaving downtown Napa without a full-service supermarket.[110] Some major redevelopments have been proposed on the former sites of earthquake-damaged businesses.

At least 120 of the Napa Valley's 500 wine production facilities reported some damage to tanks, barrels or buildings, with most of the damage caused by tumbling barrels.[111] Wineries reported wine losses from as little as 0.5% (bottles and some barrels) to as high as 15% (barrel-stack collapse).[112] Because the earthquake occurred approximately two weeks into the autumn harvest and crush operations, many barrel stacks and tanks were not yet full, minimizing the total wine lost. The vast majority of wineries did not have earthquake insurance; it reportedly costs about three times as much as property insurance and has a high deductible—typically 15% of the total value of the property and all its contents.[113]

Findings: People and Businesses

Finding 4.1: Deaths and injuries sustained in the South Napa earthquake point to continuing gaps in public awareness and education on earthquake safety and preparedness.

Public reactions during and immediately following the 2014 earthquake, and the resulting deaths and injuries, illustrate the ongoing confusion or lack of knowledge about appropriate earthquake safety behavior and the relatively inexpensive household and business preparedness actions that can be undertaken, such as seismic anchoring of interior furnishings.[114] A rapid household

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[108] Samantha Rowan, "Barclays Tracks $620M Of CMBS Exposed To Napa Earthquake," *Euromoney Institutional Investor*, August 18, 2014.
[109] Ibid.
[110] Huffman, "Top Stories of 2015, No. 1: Earthquake Aftermath."
[111] Peter Fimrite, "Small Wineries Suffer Big Losses in Napa Quake," *San Francisco Chronicle*, August 30, 2014, http://www.sfgate.com/wine/article/Small-wineries-suffer-big-losses-in-Napa-quake-5724465.php.
[112] ATC, "Performance of Buildings and Nonstructural Components in the 2014 South Napa Earthquake."
[113] Joel Stein, "A Quake Reminds Napa Winemakers of California's Faults," *Bloombery Business*, August 28, 2014, http://www.bloomberg.com/bw/articles/2014-08-28/napa-winemakers-forgo-quake-insurance-face-cleanup-costs.
[114] Enhancing curricula for public and private schools on earthquake and building safety to better prepare our citizens to live safely with earthquakes and reinvigorate efforts to provide clear, concise, comprehensive, and frequent earthquake safety information to the general public were key recommendations in the Commissions' findings and recommendations from the 2003 M_w 6.5 San Simeon earthquake. California Seismic Safety Commission, "Findings and Recommendations from the San Simeon

FINAL DRAFT

assessment of public health conducted in Napa and Solano counties shortly after the earthquake found that well over half of the respondents in the cities of Napa and American Canyon did not have emergency supplies.[115]

Finding 4.2: The 2014 South Napa earthquake highlighted significant gaps in earthquake insurance coverage for both homeowners and businesses, and the need to improve both the affordability and terms of insurance coverage and plan for housing and business recovery funding needs ahead of a major urban earthquake in the state.

Following large-scale disasters, including the 1989 Loma Prieta and 1994 Northridge earthquakes, widespread availability of insurance coverage has been credited with enhancing community resilience and accelerating recovery.[116] However, in the 2014 South Napa earthquake, estimates of affected households with earthquake insurance coverage have ranged from 6% to 3%, including renters and migrant workers.[117] Also, for those that had coverage, residential damage levels generally were not high enough to meet the 10% and 15% deductible requirements of CEA residential policies.[118] As of August 2015, the CEA had paid $3 million in claims to hundreds of CEA policyholders affected by the earthquake.[119]

Statewide, only about 10% of insured residential and 8.5% of insured commercial properties have earthquake insurance coverage;[120] the overall numbers are even lower given that some properties do not carry any insurance. All these figures are considerably lower than when the 1989 and 1994 Northridge earthquakes occurred.[121] If a major earthquake strikes within any of the state's major metropolitan areas, the lack of insurance and subsequent delays that will occur as other recovery funding resources are assembled could put many communities at risk of long-term population and business displacement, and lead to protracted blight and even bankruptcy, with ripple effects across the impacted region and even statewide.

In recent major U.S. disasters, one crucial source of housing and community recovery funding has been the HUD Community Development Block Grant–Disaster Recovery (CDBG-DR) program. It is not part of the federal disaster declaration process and requires separate

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Earthquake of December 22, 2003" (California Seismic Safety Commission, May 5, 2004), http://www.seismic.ca.gov/pub/CSSC_2004-02_FindingsSanSimeonEarthquake.pdf.

[115] Attfield et al., "Injuries and Traumatic Psychological Exposures Associated with the South Napa Earthquake — California, 2014."

[116] Mary Comerio, *Disaster Hits Home: New Policy for Urban Housing Recovery* (Berkeley, CA: University of California Press, 1998).

[117] "Earthquakes - Going Forward, Lessons Learned from Napa" (Sacramento, California: Assembly California Legislature, October 20, 2014), http://assembly.ca.gov/sites/assembly.ca.gov/files/Earthquakes.pdf.

[118] Kathleen Pender, "Quake Insurance No Big Help Because so Few Have It," *San Francisco Chronicle*, August 28, 2014, http://www.sfgate.com/business/networth/article/Quake-insurance-no-big-help-because-so-few-have-it-5711650.php.

[119] CEA, "A Year After South Napa Earthquake, Damage Proves Widespread and Costly."

[120] California Department of Insurance, "Earthquake Premium and Policy Count Data Call, Summary of 2014 Residential and Commercial Market Total" (California Department of Insurance, July 15, 2015), http://www.insurance.ca.gov/0400-news/0200-studies-reports/0300-earthquake-study/upload/EQEXP2014_ReleasedJuly152015.pdf.

[121] Pender, "Quake Insurance No Big Help Because so Few Have It."

FINAL DRAFT

Congressional action, which is never guaranteed. In the last decade, Congress has appropriated over $40 billion for HUD CDBG-DR funding, a significant proportion of which was provided following hurricanes Katrina and Sandy.[122] The states of Louisiana,[123] Mississippi, New Jersey, and New York all used billions of CDBG-DR dollars to establish large, state-run housing repair programs following these hurricanes. In all these instances, flood and hurricane insurance was relatively abundant (more so than earthquake coverage in California), yet there were still significant gaps in uninsured or under-insured households, businesses, and housing owners, including multi-family housing owners. For each state, it took one to two years to secure the funds and design and launch the programs, with the bulk of repairs not happening until the third and later years of recovery. State-run programs also faced legal challenges and considerable controversy, and fell short in meeting the needs of renters, small businesses, and vulnerable populations, such as immigrants and minorities.[124]

Finding 4.3: The delay in authorization of the federal Individual Assistance program hindered community recovery.

Under the California Disaster Assistance Act (CDAA), California's Governor can issue a State disaster proclamation and authorize State financial assistance for costs incurred by local governments as a result of a disaster event. This means that local governments do not have to wait for a Presidential disaster declaration and authorization of the federal public assistance program to know that resources will be available to reimburse costs for certain emergency activities and repairs or replacement of public infrastructure and facilities damaged or destroyed by a disaster. The CDAA does not include provisions for State financial assistance for households that have been impacted by disasters like it does for local government. Given the limited coverage and high cost of earthquake insurance, the federal Individual Assistance is a critical resource to California households (owners and renters) following federally declared disasters.

In the federal fiscal year 2015, the maximum allowable grant award for the federal Individual Assistance program was $32,900, a very useful amount of funding to take care of the kinds of contents damage and minor structural damage that many households sustained in the 2014

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[122] U.S. Department of Housing and Urban Development HUD, "CDBG-DR Activite Disaster Grants and Grantee Contact Information," *HUD Exchange*, 2014, https://www.hudexchange.info/cdbg-dr/cdbg-dr-grantee-contact-information/. By comparison, the annual expenditure of the traditional CDBG (non-disaster) program for states and entitlement communities is about $3.9 billion.

[123] The largest, Louisiana's Road Home Program, used more than $10 billion in CDBG-DR funds to repair more than 130,000 homes and 8,500 rental units in the state (Louisiana Recovery Authority LRA, "Louisiana Recovery Authority, 2005 - 2010," June 2010, http://lra.louisiana.gov/assets/docs/searchable/Quarterly%20Reports/FinalReportJune2010.pdf). These are comparable figures to the housing damage estimates for major earthquake scenarios in both southern and northern California produced by the U.S. Geological Survey, the Earthquake Engineering Research Institute, and catastrophe risk modeling firms.

[124] Timothy F. Green and Robert B. Olshansky, "Rebuilding Housing in New Orleans: The Road Home Program after the Hurricane Katrina Disaster," *Housing Policy Debate* 22, no. 1 (2012): 75–99, doi:http://dx.doi.org/10.1080/10511482.2011.624530; K. Rose, A. Clark, and D. Duval-Diop, "A Long Way Home: The State of Housing Recovery in Louisiana." (Baton Rouge, LA: Policy Link, 2008).

FINAL DRAFT

earthquake. According to the CEA's survey of Napa residents, over 85% sustained totaled household costs of less than $25,000.[125]

The Presidential disaster declaration #DR-4193-CA was made on September 12, 2014; however, homeowners and renters in impacted regions of Napa and Solano counties did not become eligible to apply for the federal Individual Assistance program until October 27, 2014, eight weeks after the federal disaster declaration for Public Assistance and almost ten weeks after the earthquake. This was a considerable time lag compared with many other presidential disaster declarations in California. Notably, following the much smaller magnitude 5.2 earthquake that impacted Napa on September 3, 2000, federal Individual Assistance was authorized as part of the Presidential disaster declaration issued within two weeks, on September 14, 2000, and credited with speeding-up and reinforcing local recovery from that disaster.[126] Also, although the Napa Valley Vintners trade association had swiftly pledged $10 million within days of the earthquake to help impacted residents and businesses, the Napa Valley Community Foundation delayed distribution of funding until confirmation of the federal authorization for Individual Assistance occurred to determine what the full range of community needs were likely to be.[127]

Following the 2014 earthquake, local governments faced many challenges in identifying and cataloguing housing damage and estimating unmet household and community needs, especially for lower-income residents and rural areas.[128] The Preliminary Damage Assessment (PDA) to qualify for federal disaster assistance programs began five days after the earthquake, but safety inspections conducted in the immediate aftermath of an earthquake were not sufficient to estimate monetary damages, and the likely costs of repairs. Therefore, local governments could not develop a comprehensive list for federal Individual Assistance target sites.[129] The identification of earthquake damage often requires looking under floors, inside walls and attics, and atop roofs—all of which require permission for entry—entailing more evaluation than what is done with a rapid visual survey. Concerns with the appropriateness of the Individual Assistance damage categories for earthquake damage costs have also been noted. Additionally, given the housing shortage and high cost of housing across the San Francisco bay region, some residents were reluctant to report damage for fear of losing housing; others feared having government representatives on their premises.[130]

FINAL DRAFT

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[125] CEA, "A Year After South Napa Earthquake, Damage Proves Widespread and Costly."
[126] City of Napa and Napa County, "2014 South Napa Earthquake Individual Assistance (IA) Supplemental Information" (City of Napa and Napa County, California, September 22, 2014), www.countyofnapa.org/individualassistance/.
[127] Haya Al Nassar, "Napa Earthquake Damage Highlights Tourist Destination's Working Class," *Al Jazeera America*, February 11, 2015, http://america.aljazeera.com/articles/2015/2/11/napa-earthquake-damage-highlights-working-class.html.
[128] City of Napa and Napa County, "2014 South Napa Earthquake Individual Assistance (IA) Supplemental Information."
[129] Ibid.
[130] Peter Jensen, "County Officials Ask for More Residents to Report Earthquake Damage," *Napa Valley Register*, September 9, 2014, http://napavalleyregister.com/news/local/county-officials-ask-for-more-residents-to-report-earthquake-damage/article_e3c48f77-7b17-572c-ba6f-4902b2407e55.html.

Finding 4.4: Insights from the 2014 South Napa earthquake provide an opportunity to consider how State emergency proclamation provisions can accelerate and improve post-earthquake recovery for residents and businesses.

Under *California Government Code (section 8571*), in declaring a State-level emergency, the Governor may suspend any State statute, orders, rules, or regulations of any State agency that may prevent, hinder, or delay the mitigation of the effects of the emergency. Governor Brown proclaimed a state of emergency on August 24, 2014. Then, on September 2, 2014, Governor Brown issued Executive Order 8-24-14 ordering Cal OES to provide local government assistance under the authority of the *California Disaster Assistance Act (Government Code section 8680 et seq.* and *Code of Regulations, Title 19, section 2900 et seq.*) and also exercised his authority under *California Government Code (section 8571*) to suspend a number of State provisions in order to assist impacted residents and businesses in recovery. They included the suspension of State fees and requirements on replacing vital records, such as birth certificates, drivers' licenses and vehicle registration, and manufactured home registrations. The Executive Order also eased a number of other State statutes, orders, rules, or regulations, such as waiving the transfer fees on Alcoholic Beverage Control licenses for businesses impacted by the earthquake and allowing them to temporarily locate further away from their original location and for a longer time period. The Governor's Executive Order also included a request that the Franchise Tax Board and Board of Equalization to consider using their administrative powers to provide individuals impacted by the earthquake with extensions for any filing, or with relief from penalties and assessments, as appropriate; a Senate Bill for tax relief was approved by the Legislature and Governor in September 2015.[131]

Priority Recommendations: People and Businesses

Priority Recommendation 4.1: Establish a State task force to consider the risks posed to the state by the large proportion of uninsured residents and businesses in high-seismic hazard areas, and identify options for improving the take-up, affordability, and terms of earthquake insurance coverage for California residents and businesses, as well as alternative earthquake recovery funding sources for both residents and businesses.

While the CEA has successfully restored stability in California's single-family homeowners insurance market, the high costs to consumers and for reinsurance, restricted policy terms, statutory limitations on its financial capacity and capabilities, and lack of mandatory purchase requirements, all combine to reduce its effectiveness as a major recovery funding resource.[132] The gaps in recovery resources for multi-family rental housing, condominiums, and businesses

[131] Melissa Murphy, "Earthquake Relief Bill Approved by Governor," *The Reporter*, September 2, 2015, http://www.thereporter.com/article/NG/20150902/NEWS/150909972#.

[132] Senate Committee on Insurance California State Senate, "Catastrophic Risk in California: Are Homeowners and Communities Prepared?" (California State Senate, May 14, 2014), http://sins.senate.ca.gov/sites/sins.senate.ca.gov/files/14.05-14.Background.Catastrophic%20Risks%20in%20California.PDF.

FINAL DRAFT

(both large and small) are even greater. Modifications to the CEA program (including the authorization of State or federal post-disaster borrowing guarantees or a pool to cover reinsurance costs) might investigate introducing alternative insurance products (including first-loss programs and micro-insurance) and developing alternative recovery financing mechanisms, including reserve funds. In addition, a robust portfolio of housing and business recovery resources needs to address the following: structural repairs and rebuilding; land remediation costs for liquefaction, landslide and other ground failure damage; household contents and additional living expenses; business contents and relocation expenses; and special populations, including low-income, elderly, unemployed and homeless residents.

Potential members of this task force could include State representatives from the Governor's Office, Senate and Assembly insurance committees, Cal OES, State Treasurer's Office, State Insurance Commissioner and Department of Insurance, CEA, and Housing and Community Development; as well as representatives from the mortgage, banking and insurance industries, local governments and housing agencies, small businesses, community foundations, and other nonprofit disaster aid providers.

Priority Recommendation 4. 2. Evaluate and enhance, as needed, penalties and other consumer protections against post-disaster contractor scamming and cost inflation.

Contractor scamming and cost-inflation post-disaster are widely recognized and repetitive problems, posing even greater problems in a major urban earthquake when demand for services is high and resources are more constrained.

Following the 2014 earthquake, the California Department of Insurance the California Contractors State License Board (CSLB) provided public information and worked with local governments to raise awareness about contractor qualifications and to help ensure that unlicensed contractors were not working in the disaster area. Nonetheless, there were reports of contractor licensing violations, scamming operations, and resource inflation in the year following the earthquake. The CSLB has a Statewide Investigative Fraud Team; its capabilities to mobilize and scale up following a large earthquake disaster needs to be evaluated. Similarly, California's Business and Professions Code (Section 7158) defines the fines and punishment for contractor related scamming and fraud. These penalties should be evaluated to ensure that they are an adequate deterrent; mechanisms for utilizing the penalties for victim compensation should also be explored.

Some cities have established emergency contractor and volunteer registration processes, and the American Planning Association has incorporated guidance into its 2014 model recovery ordinance.[133] It has provisions for cities to create an emergency contractor registration procedure that includes charging a nominal fee to issue photo-identification badges to all construction

[133] "Planning for Post-Disaster Recovery: Next Generation," Planning Advisory Service (Chicago, IL: American Planning Association, December 2014), https://www.planning.org/research/postdisaster/.

FINAL DRAFT

workers and verifies that contractors are licensed by the State and meet minimum insurance and background check requirements, as well as a procedure to register and issue photo identification badges to all volunteers at no-cost. These provisions should be evaluated and consideration given to whether it is more effective for impacted cities to handle such procedures at a time post-disaster when staff resources or constrained, or whether some statewide provisions and procedures might be more expeditious and effective. More guidance for individuals and businesses may also be needed.

FINAL DRAFT

5. GOVERNMENT AND OTHER INSTITUTIONS

The earthquake resulted in wide-ranging response and recovery activities for the State, impacted counties and cities, and a host of special districts and community organizations.

Local emergency proclamations were made in the cities of American Canyon, Napa, and Vallejo, and the cities of Napa and Vallejo activated their emergency operations centers (EOCs). Napa and Solano counties also proclaimed local emergencies and activated their EOCs. Sonoma County proclaimed a local emergency but did not activate its EOC. The Governor proclaimed a State of Emergency for Napa, Solano, and Sonoma counties on August 24, 2014, and Cal OES activated the State Operations Center, the coastal Regional Emergency Operations Center, and implemented the State's Emergency Operations Plan. State and local government emergency mutual aid, including firefighting, law enforcement, medical, and public health emergency responders were also deployed. On September 2, 2014 the Governor issued Executive Order B-24-14 authorizing financial assistance through the California Disaster Assistance Act to local agencies and certain nonprofit organizations. Federal major disaster declarations were granted to portions of Napa and Solano counties on September 11, 2014 (for federal Public Assistance and Hazard Mitigation to qualifying public agencies and non-governmental organizations). As previously noted, the authorization for federal Individual Assistance came later on October 27, 2014.

As of May 2016, FEMA has obligated nearly $27 million in Public Assistance grants to qualifying public agencies and organizations.[134] Of this, $5.2 million was awarded for emergency-related work, such as time and expenses for mutual aid and costs of emergency repairs to the damaged water system. In addition, nearly $21 million was awarded for permanent repairs to public buildings and infrastructure. Two of the key applicants were Napa County and the City of Napa.

Napa County sustained damage to a number of county-owned facilities, which impacted many County operations. The County administration buildings, district attorney's office, public services building, and jail are among the facilities that suffered structural and non-structural damage, which displaced agencies, employees, and other occupants. Napa County was fortunate to have additional space available for temporary office relocations until repairs were completed. While most structures have now been repaired and reoccupied, the Napa County Courthouse remains closed as the repair strategy and costs to restore the historic landmark are still under development.

After eight months of investigations, the City of Napa completed its city-owned facility repair strategy in mid-April 2015.[135] The strategy identifies 35 post-earthquake repair projects for which it was requesting State and federal assistance for an estimated total cost of $12 million.

[134] FEMA, "Financial Assistance."
[135] Yune, "City Seeks $12 Million in Aid for Quake Repairs."

FINAL DRAFT

The majority of projects are for public infrastructure-related repairs–including the water delivery system, roads, and bridges–and for costs related to emergency response and debris removal. With the completion of the repair strategy, the City officially ended its emergency declaration period on April 17, 2015.

Altogether, response and recovery from the 2014 South Napa earthquake has involved considerable commitment from the affected local governments and supporting State and federal agencies, as well as many dozens more organizations and thousands of individuals. The City of Napa estimates that 34,000 working hours were spent on earthquake response and recovery in the first eight months following the earthquake, including 7,200 hours of overtime.[136] The City of Vallejo estimates that during the initial months following the earthquake, 30% of all staff hours were spent in support of response and particularly damage assessment efforts. Support for the recovery efforts is likely to continue for several years.

Findings: Government and Other Institutions

Finding 5.1: The Standardized Emergency Management System was effective in mobilizing a multi-jurisdictional, multi-level emergency response following the South Napa earthquake but some significant areas for improvement and training, particularly with smaller jurisdictions, have been identified.

Five levels of the Standardized Emergency Management Systems (SEMS) (Field, Local, Operational Area, Regional, and State) were activated following the 2014 earthquake. Post-earthquake after-action reports have identified several areas for improvement for SEMS-related response planning and training, many of which are applicable to all five SEMS levels.[137] They include: ensuring staffing to fully operate all SEMS levels; following protocols in requesting resources across different levels; improving communication between the different SEMS levels and between the SEMS structure and local elected officials as well as the general public; and enhancing the use of Geographic Information Systems (GIS) and access to scientific and technical expertise in the EOC. Some specific items that may need some further investigation include: apparent gaps in official notifications of the 2014 earthquake; enhanced training for Public Information Officers and the establishment of Joint Information Centers; and the importance of social media and real time communication and information sharing, both in situational awareness and response operations.

Local emergency personnel reported that the SEMS training they received prior to the 2014 earthquake was a key element of their successful response to the earthquake. While earthquakes occur infrequently, personnel also credited their experience managing floods and other natural

[136] Ibid., 201.
[137] Cal OES, "After Action Report: 2104-08-24 Napa Earthquake, Executive Summary"; City of Napa, "South Napa Earthquake After Action Report."

FINAL DRAFT

disasters as helping to improve their earthquake response. In light of this infrequency as well as staff turnovers, ongoing training and exercises are critical to ensure that local personnel are prepared. The City of Vallejo sent 80 people to the California Specialized Training Institute for SEMS-response training, which it believed helped them to respond to the 2014 earthquake.

Finding 5.2: The 2014 earthquake identified problems with the damage assessment and declaration processes and financing of local government post-disaster assistance that need to be addressed ahead of the next major urban earthquake in the state.

As previously noted, the Preliminary Damage Assessment (PDA) to qualify for federal disaster assistance programs began five days after the earthquake. However, local governments faced challenges in identifying and cataloguing damage to public facilities and infrastructure, in addition to estimating unmet household and community needs. The complexity of earthquake damage and the time needed to identify it are top concerns with the current PDA process. The infrequency of damaging earthquakes is certainly a key concern. Inspectors who work regularly on PDAs across the country still may not have earthquake-specialized knowledge and experience with the kinds of ground failure, infrastructure, and foundation damage, and other structural damage that occur in earthquakes.

Once the State and federal declarations have been issued, the long process of developing project scopes and costs and negotiating with insurers and State and federal agencies on the ultimate payouts continues for months and years. As previously noted, it was after eight months of investigations that the City of Napa completed its repair strategy for 35 projects totaling $12 million.[138]

Finding 5.3: The 2014 earthquake highlighted significant gaps in contingency planning at many key government and critical facility operations.

The operations of many government agencies and critical community-serving facilities—such as schools and hospitals—were impacted by structural and non-structural damage. In some cases, back-up records were non-existent or destroyed by sprinkler-related water damage.[139] Alternative facilities had to be located and equipment quickly moved or replaced. Some local agencies and key departments with critical response and recovery functions did not have plans or procedures to address simultaneously both response and recovery-related efforts as well as normal day-to-day business operations.

Finding 5.4: More pre-disaster planning and training for post-disaster recovery is needed at both the State and local levels.

FINAL DRAFT

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[138] Yune, "City Seeks $12 Million in Aid for Quake Repairs."
[139] ATC, "Performance of Buildings and Nonstructural Components in the 2014 South Napa Earthquake"; "Earthquakes - Going Forward, Lessons Learned from Napa."

Local governments faced challenges in transitioning from response to recovery efforts and in balancing their on-going post-disaster workload with normal day-to-day business operations.[140] Although capacity was certainly an issue, prior knowledge, experience, and training, particularly for recovery, were also factors. In particular, more emphasis is needed on planning for and managing long-term recovery.

In 2014, Cal OES launched its development of the California Disaster Recovery Framework that will address the operational structure for State agencies in coordinating and supporting post-disaster recovery. It is consistent with the administrative guidance provided in the National Disaster Recovery Framework developed by FEMA (2011).[141] Over the past few years, more and more cities in the state have begun to develop disaster recovery frameworks that follow the structure of the NDRF. The NDRF calls for pre-designation of a Local Disaster Recovery Manager (LDRM) and identification of lead and supporting agencies for a series of Recovery Support Functions (RSFs) addressing community planning and capacity building, housing, infrastructure, the economy, natural and cultural resources, and health and social services. As of today, the level of planning for post-disaster recovery by local governments throughout the state remains quite varied.

The California Disaster Recovery Framework currently under development by Cal OES identifies debris removal as a state-level recovery priority. Cal OES offers post-disaster technical assistance to help disaster-impacted local governments understand State and federal program cost eligibility guidelines and to prepare appropriate documentation for debris removal contracting and monitoring. Cal OES estimates that debris management is, on average, 45% of the total cost of a disaster.

The City of Napa initially used schools as debris disposal sites. Residents were provided with "disposal coupons" that were valid for up to six months following the earthquake.[142] This program has been credited with helping to expedite community recovery. The City of Napa estimates that the program cost $1.6 million to remove 7,400 tons of quake debris.[143]

Napa County and the City of Napa established a Local Assistance Center (LAC) within days of the 2014 earthquake. Besides the local agencies, federal and State representatives, as well as insurance companies and nonprofit and volunteer organizations, were on hand to provide

FINAL DRAFT

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[140] City of Napa, "South Napa Earthquake After Action Report"; "Earthquakes - Going Forward, Lessons Learned from Napa."
[141] Federal Emergency Management Agency FEMA, "National Disaster Recovery Framework: Strengthening Disaster Recovery for the Nation" (Federal Emergency Management Agency, September 2011), http://www.fema.gov/pdf/recoveryframework/ndrf.pdf.
[142] City of Napa, "South Napa Earthquake After Action Report."
[143] Yune, "City Seeks $12 Million in Aid for Quake Repairs."

immediate help and information on disaster assistance programs.[144] The Napa LAC has been credited with helping to expedite community recovery.

Priority Recommendations: Government and Institutions

Priority Recommendation 5.1: Strengthen seismic performance standards and contingency planning for all State and local correctional facilities.

An older section of the Napa County Jail built in 1975 that included the jail communications center was damaged to the point that it affected the operations of the facility and compromised the safety of occupants.[145] The County had to substantially reduce inmate capacity, relocating about 75 inmates to the Solano County Jail in Fairfield at a cost of $87 per inmate per day.[146] That figure increased to 125 inmates to handle the summertime population, and the cost to the County is estimated to exceed $3 million per year.[147] Civilian volunteers and non-corrections personnel were prohibited from entering the damaged jail building; this caused a temporary suspension of some programs, including mental health counseling, vocational instruction, and religious support. Previously scheduled upgrades to the jail have been postponed as the earthquake related repairs are being addressed. Besides the earthquake damage, the Napa County Jail suffers from severe overcrowding and aging infrastructure, and needs improved services and programming.[148] A 2015 grand jury report calls for a new jail facility, and some county leaders are now making the case for a bond measure for its funding.[149]

Priority Recommendation 5.2: Review and revise, as needed, State regulations guiding the transfer and housing of inmates in county jails during times of emergency.

Napa County officials reported that they could only transfer inmates from the damaged county jail to facilities in neighboring, contiguous counties.[150] This requirement would be difficult to meet if multiple facilities were impacted as a result of larger disasters or in more populous areas.

FINAL DRAFT

[144] City of Napa, "South Napa Earthquake After Action Report."
[145] Napa County Grand Jury, "Napa County Jail and Department of Corrections, Annual Review 2014- 2015" (Napa County, CA, May 15, 2015), http://www.napa.courts.ca.gov/sites/default/files/images/grandjury/grandjury14-15/Napa%20County%20Jail%20&%20Department%20of%20Corrections-G.pdf.
[146] Ibid.
[147] Ibid.
[148] Ibid.
[149] Rachel Raskin_Zrihen, "Napa County Urgently Needs a New Jail," *Vallejo Times Herald*, February 20, 2016, http://www.timesheraldonline.com/general-news/20160220/napa-county-urgently-needs-a-new-jail.
[150] "Earthquakes - Going Forward, Lessons Learned from Napa."

FINAL DRAFT

APPENDIX: ADDITIONAL RECOMMENDATIONS

Several additional recommendations for possible action and improvement were developed during the course of this study. The Commission did not select these recommendations for short-term focus due to priority, logistical, and financial considerations. These recommendations are presented below.

A1. Geosciences

Recommendation A1.1: Work with federal agencies to develop pre-disaster protocols and funding mechanisms for large-scale post-earthquake geologic investigations necessary to characterize future risks and mitigation measures for buildings and infrastructure in ground failure areas. Future earthquakes, especially in more urbanized areas of the state, may cause large-scale ground failure that extends across many jurisdictions. The pace of recovery can be impeded as individual jurisdictions struggle to fund the necessary post-earthquake investigations and develop appropriate policies for repairs and rebuilding.

Recommendation A1.2: Develop advisory guidance for State agencies and local governments, utilities, and property owners for conducting geologic investigations to evaluate fault afterslip and fault creep hazards, for reviewing geologic reports, and appropriate temporary and permanent land use policies and mitigation measures for buildings and infrastructure in areas with these hazards. As appropriate, corresponding updates to the technical guidelines for evaluating surface fault rupture hazard (CGS Note 49, 2002) and for reviewing geologic reports (CGS Note 41, 1998) should also be made.

Recommendation A1.3: Complete mapping of seismic hazard zones as defined by the Seismic Hazard Mapping Act with priority given to urban and urbanizing areas in the state. In the San Francisco Bay Area, gaps in the State Seismic Hazard Zone mapping for liquefaction and earthquake-induced landslide hazards includes portions of Alameda, Santa Clara, Marin, Sonoma, Napa, and Solano counties. State Seismic Hazard Zone maps for tsunami and seiche (also called for by the Act when appropriate hazard information and funding are available) have not yet been developed. In the near future, the CGS is in the process of developing appropriate information that will make it possible to map tsunami hazards across the State.

Recommendation A1.4: Conduct a formal review of the guidelines and criteria for delineating seismic hazard zones (CGS Special Publication 118, 2004) as well as the guidelines for evaluating and mitigating seismic hazards (CGS Special Publication 117A, 2008) in light of lessons learned and research emerging from the 2014 South Napa earthquake and other recent earthquakes. The Seismic Hazard Mapping Act recommends that the criteria for delineating State Seismic Hazard Zones be updated as, and when, the understanding of seismic phenomena and the methods used to assess their likelihood and potential impacts on the built environment improve. The last update of this publication was conducted in 2004. The State's guidance for the site-specific investigations and analysis of

FINAL DRAFT

hazards, mitigation of hazards, and review of site-specific investigation reports for State seismic hazard zones was last updated in 2008. The State should work with State agencies and local governments and the geology/geotechnical community to evaluate current guidelines, as well as the current state of practice, for mapping, evaluating and mitigating seismic hazards. In addition insights gained from ground failure hazard mapping, evaluation and mitigation efforts following the 2014 South Napa earthquake, the 2010–2011 Canterbury New Zealand earthquake sequence and other recent disasters should be incorporated.

Recommendation A1.5: Continue investments in upgrading and expanding the network density of the California Strong Motion Instrumentation Program. The mechanisms necessary to improve the real-time collection and conveyance of strong-motion information to infrastructure providers and others to aid in post-earthquake evaluation and response should also be developed.[151] Regulatory and funding mechanisms to systematically investigate and inventory the underlying soils and geology at each station should be explored. This data is critical to understand seismic wave propagation and amplification, site response, and soil-structure interactions when earthquakes occur.

Recommendation A1.6: Continue planning and investment in the California Earthquake Clearinghouse. Emphasis should be given to expanding the access to clearinghouse data and clearinghouse involvement with local governments and infrastructure operators.

Recommendation A1.7: Continue implementation planning and development of a statewide earthquake early warning system. The Commission and Cal OES have recently funded PEER to assess the costs and benefits of such a statewide earthquake early warning system, including the potential cascading effects of both real- and false-warnings. The results of this assessment should be considered in the design of the statewide system, and there should be expanded engagement with infrastructure operators, local governments, and private partners in the planning and development of the system.

A2. Infrastructure

Recommendation A2.1: Continue investment in research and implementation to advance the seismic performance of both existing and new highway bridges and other roadway structures. Emphasis should be given to developing cost-effective measures that ensure higher levels of seismic resilience (i.e. beyond a collapse prevention standard), particularly on State routes critical for post-disaster emergency response and regional recovery.

Recommendation A2.2: Collaborate with the California Utilities Emergency Association and the California Water/Wastewater Agency Response Network to glean "best practices" and needed improvements in water-system restoration and coordination based on lessons

[151] Caltrans, "Bridge Investigation Team Report for the August 24, 2014 South Napa Earthquake."

FINAL DRAFT

learned from the 2014 earthquake, and work to expand the participation of all local lifeline operators in statewide mutual aid programs. Investigate ways to help facilitate and streamline mutual aid in large-scale urban earthquakes as well as issues of post-earthquake ground settlement and repetitive system damage and ways to improve federal and State cost reimbursement processes. Consider whether formation of a statewide lifelines council (as created in San Francisco) would be useful in enhancing operator coordination in response and recovery and advancing mitigation of lifeline system vulnerabilities and interdependencies.

A3. Structures

Recommendation A3.1: Together with the California Building Officials and other professional engineering and architectural organizations, develop guidance for local jurisdictions for barricading, cordoning, and stabilizing earthquake-damaged buildings, and consider whether post-disaster safeguards should be included in the next update of the California Building Code. Requirements in *California Building Code Chapter 33, Safeguards During Construction*, apply only to stable buildings under construction and not unstable, damaged buildings. Potential guidance needs raised by assessments of the building stabilization, barricading, and stabilization efforts following the 2014 South Napa earthquake[152] include: insufficient setbacks in barricades around damaged buildings including sidewalks, streets, and adjacent structures; and varying unengineered and unanchored approaches to scaffolding around a building. Following review of the 2010 and 2011 earthquakes in Christchurch, New Zealand, volunteers developed *CALBO's Interim Guidance for Barricading, Cordoning, Emergency Evaluation and Stabilization of Buildings with Substantial Damage in Disasters (2013)*.[153] The adequacy of these guidelines and other guidance should be evaluated. Also, local governments should be provided with best practices on cordoning and barricading substantially damaged areas. There can be conflicting priorities and pressures to limit access controls in order to spur recovery versus maintaining extensive cordons so that safety is ensured and demolitions and repairs can proceed with less interruption.[154] Both can have cascading and deleterious effects that merit further evaluation and guidance.

Recommendation A3.2: Work to educate and incentive local governments in high-seismic areas of the State to effectively complete unreinforced masonry retrofit programs within the next five years.[155] The Commission's 2006 progress report to the State Legislature on the

FINAL DRAFT

[152] ATC, "Performance of Buildings and Nonstructural Components in the 2014 South Napa Earthquake."
[153] California Association of Local Building Officials CALBO, "CALBO's Interim Guidance for Barricading, Cordoning, Emergency Evaluation and Stabilization of Buildings with Substantial Damage in Disasters" (California Association of Local Building Officials, November 2013), http://www.eqclearinghouse.org/2014-08-24-south-napa/files/2014/08/calbo-interim-guidance.pdf.
[154] Stephanie E. Chang et al., "Urban Disaster Recovery in Christchurch: The Central Business District Cordon and Other Critical Decisions," *Earthquake Spectra* 30, no. 1 (February 2014): 512–32, doi:http://dx.doi.org/10.1193/022413EQS050M.
[155] Reducing the vulnerability and risks posed by URM buildings was a major focus of the Commissions' findings and recommendations from the 2003 M_w 6.5 San Simeon earthquake; this recommendation is carried forward from that report. California Seismic Safety Commission, "Findings and Recommendations from the San Simeon Earthquake of December 22, 2003."

State's unreinforced masonry law (*Section 8875 et seq, California Government Code*) noted that while most local governments (98%) in high-seismic hazard areas of the State had complied with requirements to inventory URM buildings and establish a URM loss reduction program, only about 70% of that inventory had actually been retrofitted in accordance with a recognized building code or other means.[156] In some communities, the deadlines for completing retrofits have been extended by years. Best practices in program design, policy adoption, and implementation (including retrofit approaches) should be shared as part of an updated evaluation of progress and in local government advocacy and guidance. The State should also explore ways to better incentivize local program implementation, with consideration given to the State's hazard mitigation planning and funding programs, and potential reductions of regulatory barriers and conditions imposed by local governments on proposed URM retrofit projects.

Recommendation A3.3: Conduct a more systematic study of variations in the performance of retrofitted unreinforced masonry buildings in the 2014 earthquake and update guidance as appropriate. A key study funded by FEMA focused on a small sample structures, including URM buildings, located in downtown Napa.[157] Damage to spandrel mechanisms, poor performance of flexible moment frames and prescriptive diaphragm-to-wall spacing requirements, and adhesive-type anchors are among the issues identified in this post-earthquake evaluation of Napa's retrofitted URM buildings.[158] A larger and more systematic study of the performance of retrofitted and unretrofitted URM buildings is still needed. It might involve the larger inventory of URM buildings with the City of Napa, as well as URM buildings in several other jurisdictions impacted by the earthquake, including the cities of American Canyon, Vallejo, and Sonoma; Napa, Solano, and Sonoma counties; State of California buildings; and the U.S. Postal Service and other federal buildings. Evaluations of the performance of retrofitted URMs in Christchurch[159] and other recent earthquakes may also be valuable to consider. Lessons should be incorporated into guidance for the evaluation and retrofit of URM buildings, and known gaps in the existing guidance should also be addressed. Possible local variations in interpretations of *State Historical Code* and California's existing building code requirements and how this affected retrofit approaches also merits further investigation and will require plan reviews. Efforts to protect historic features may have contributed to damage and increased life safety risks of some of Napa's retrofitted URMs.[160]

FINAL DRAFT

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[156] California Seismic Safety Commission, "Status of the Unreinforced Masonry Building Law, 2006 Progress Report to the Legislature" (California Seismic Safety Commission, 2006), http://www.seismic.ca.gov/pub/CSSC%202006%20URM%20Report%20Final.pdf.
[157] ATC, "Performance of Buildings and Nonstructural Components in the 2014 South Napa Earthquake."
[158] EERI, "EERI Special Earthquake Report, M6.0 South Napa Earthquake of August 24, 2014"; ATC, "Performance of Buildings and Nonstructural Components in the 2014 South Napa Earthquake."
[159] Moon et al., "The Demise of the URM Building Stock in Christchurch during the 2010–2011 Canterbury Earthquake Sequence."
[160] ATC, "Performance of Buildings and Nonstructural Components in the 2014 South Napa Earthquake."

Recommendation A3.4: Review the placarding provisions of the unreinforced masonry law to improve its effectiveness as well as documentation of both retrofitted and unretrofitted buildings. In particular, the URM placarding requirements enacted in 2004 (*California Government Code, Section 8875.8 – 8875.95*) should be reviewed considering whether penalties for non-compliance are sufficient, and whether local governments are requiring that retrofitted structures be placarded. In the City of Napa, owners of retrofitted URMs petitioned to have their buildings removed from the city's URM inventory once work was completed, making it difficult to locate and assess the seismic performance of retrofitted structures after the August 24, 2014, earthquake.[161] Mitigation progress should be rewarded, and documentation and placarding of retrofitted structures is a necessary element to help encourage monetary valuation of seismic mitigation in real estate sales and leasing.

Recommendation A3.5: Review the adequacy of current code provisions for the design and inspection of non-structural systems and make modifications as appropriate in the next round of State building code updates. In particular, exterior cladding, glazing, interior partitions, sprinkler system bracing, sprinkler head connections, suspended ceiling systems, pendant lighting, and rooftop piping and conduits are among the components that should be considered.[162] Also, seismic restraint exemptions for some building furnishings and contents should be examined to assess whether the resulting risk of injury is acceptable.[163] This includes wine barrels and tanks.

Recommendation A3.6: Enhance awareness among local building officials and contractors of requirements in the current *California Building Standards Code* for the voluntary seismic evaluation and retrofit of select vulnerable buildings as part of significant renovations and modifications. Seismic evaluations and retrofits performed at the time of significant building renovations and modifications should address both the structural and nonstructural seismic risks posed by vulnerable building types.

Recommendation A3.7: Develop better seismic performance-related training and guidance for the design and installation of nonstructural building components targeting architects; mechanical, electrical and plumbing engineers; fire protection engineers; contractors; and building officials. More education and coordination is needed between designers, contractors and building officials to ensure that seismic details are properly implemented. [164]

Recommendation A3.8: Work to expand the State earthquake brace and bolt program, and prioritizing the most high-risk residential structures in the state. In August 2011, the CEA and Cal OES formed a joint powers authority and launched the California Residential Mitigation Program (CRMP) with a mission to design and implement mitigation programs with grants and

[161] Ibid.
[162] Ibid.
[163] Ibid.
[164] Ibid.

FINAL DRAFT

other types of assistance and incentives to assist California homeowners in seismically strengthening their homes. In September 2013, CRMP launched its first program, Earthquake Brace + Bolt: Funds To Strengthen Your Foundation. The program offers up to $3000 to eligible wood-frame residential homeowners to bolt the house to its foundation and add bracing around the perimeter of the crawl space to prevent the home from sliding or toppling off its foundation during an earthquake. After a successful pilot, the program was expanded in 2015 to a select group of ZIP codes with house characteristics suitable for this type of retrofit (in accordance with *California Existing Building Code Appendix Chapter A3 (Chapter A3)*) in the cities of Oakland, Napa, San Francisco, and San Leandro in Northern California; and the cities of Los Angeles, Pasadena, and Santa Monica in Southern California. The ZIP code selection protocol applies a 50% weight to location relative to active fault lines and a 50% weight to structural vulnerability. The program is expected to complete 600 retrofits in 2015 with funding from the CEA.[165] Starting in January 2016, the program expanded to a select group of ZIP codes with house characteristics suitable for this type of retrofit in the cities of Albany, Berkeley, Burlingame, Emeryville, Hillsborough, Millbrae, San Francisco, San Leandro, and Woodside in Northern California; and the cities of Los Angeles, Pasadena, San Bernardino, Santa Monica, South Pasadena, and West Hollywood in Southern California. The 2016 expansion is projected to perform 1600 retrofits – another 600 with CEA funds, and 1000 with $3 million in State funding.[166] The CRMP staff estimate that only about a third of the homeowners in the program are CEA policyholders.[167] The CEA is also proposing to fund a CRMP seismic retrofit program for long-time CEA policyholders. These grants would prioritize about 3000 CEA policyholders with homes built before 1940 in high earthquake-hazard areas. Reducing the risk of the most vulnerable structures in the CEA statewide portfolio provides a risk reduction benefit for all CEA policyholders. Such prioritization should be continued and expanded to include far more jurisdictions and increased levels of funding. The Commission and CRMP Governing Board should continue to work to identify alternative incentives and funding mechanisms, including use of property tax liens as proposed in Senate Bill 602 (2015).[168]

Recommendation A3.9: Enhance and expand training for California home inspectors on seismic performance and retrofit assessments. Home inspections conducted at the time of real estate sales can be an effective mechanism to both raise awareness of structural seismic vulnerabilities and promote mitigation. It can also help encourage monetary valuation of seismic

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[165] California Residential Mitigation Program CRMP, "California Earthquake Authority California Residential Mitigation Program Governing Board Meeting Minutes" (CRMG Governing Board Meeting Minutes, July 28, 2015), http://www.californiaresidentialmitigationprogram.com/Portals/1/CRMP%20MINUTES%207%2028%2015.%20Approved%2020151201.pdf.

[166] Ibid.

[167] Ibid.

[168] Senator Bill Monning, *Seismic Safety: California Earthquake Authority*, 2015, http://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201520160SB602.

FINAL DRAFT

mitigation in real-estate sales and leasing. FEMA has developed training based upon the *FEMA P-50 (2012) Simplified Seismic Assessment for Detached, Single-Family, Wood-Frame Dwellings*[169] and *FEMA P-50-1 (2012) Retrofit Guidelines for Detached, Single-Family, Wood-Frame Dwellings*[170] that can be leveraged and expanded. These documents update and expand the simplified assessment methodology and retrofit guidelines originally developed for use in the City of Los Angeles following the 1994 Northridge earthquake. The simplified assessment methodology uses a six-page form to assign a structural score based on observed dwelling characteristics, a seismic hazard score based on dwelling location and site hazards, and a resulting Seismic Performance Grade between A and D-. The assessment also identifies items that could be retrofitted and the improved grade that could result with retrofit. The retrofit guidelines provide details on retrofitting the assessed items.

Recommendation A3.10: Establish a Statewide residential mitigation program to brace masonry fireplaces in the high-risk residential structures in the state. Not only can earthquake-related chimney damage be life threatening, it has also been one of the main reasons that homes are yellow-tagged and residents are forced to find alternative housing in many California earthquakes. The FEMA-funded recovery advisory, *Repair of Earthquake-Damaged Masonry Fireplace Chimneys, FEMA DR-4193-RA1* (2015)[171], presents a series of alternatives for rebuilding masonry chimneys in one-and two-family dwellings to be more resilient in future earthquakes. The alternatives vary in construction complexity and thus costs, and also affect the future functionality of the chimney. These alternatives may be a useful starting point to consider program design and options for homeowners.

Recommendation A3.11: Evaluate the current design and approval criteria for manufactured home support systems and consider potential improvements to these systems based upon recent earthquake performance. The ability of manufactured home support systems to improve earthquake performance needs further evaluation. The California Department of Housing and Community Development (HCD) regulates manufactured home installation in the state. Local governments can choose to enforce installation requirements; otherwise, enforcement authority remains with HCD. Some mobile home parks in Napa fell under HCD jurisdiction and were included in their post-earthquake inspections, while others did not.[172] Similarly, since the regulations for mobile home support systems have evolved over the years, some of the support systems installed in Napa mobile home parks may not meet HCD's more recent installation and inspection standards.

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[169] Applied Technology Council ATC, "Simplified Seismic Assessment of Detached, Single-Family, Wood-Frame Dwellings" (Federal Emergency Management Agency, May 2012), https://www.atcouncil.org/images/files/FEMA_P-50.pdf.
[170] Applied Technology Council ATC, "Seismic Retrofit Guideline for Detached, Single-Family, Wood-Frame Dwellings" (Federal Emergency Management Agency, June 2012), https://www.atcouncil.org/images/files/FEMA_P-50-1.pdf.
[171] FEMA, "Repair of Earthquake-Damaged Masonry Fireplace Chimneys."
[172] ATC, "Performance of Buildings and Nonstructural Components in the 2014 South Napa Earthquake."

FINAL DRAFT

A4. People and Businesses

Recommendation A4.1: Work to improve public earthquake preparedness and training with an emphasis on safety and preparedness for when the earthquake shaking stops. Lessons from the South Napa earthquake should be incorporated into earthquake preparedness campaigns and training, including the importance of emergency supplies, seeking medical evaluation for injuries, and taking safety precautions during disaster aftermath and cleanup.

Recommendation A4.2: Work with the Federal Emergency Management Agency to improve the federal Individual Assistance damage assessment and declaration process for earthquakes. The federal regulations, methods and protocols for determining whether an earthquake-impacted region qualifies for Individual Assistance all merit further study: to improve the speed of the determinations; ensure that the unique needs posed by earthquake disasters in California are being adequately considered; and that a common approach that best represents the interests of those impacted is in place before the next major earthquake strikes in the state.

Recommendation A4.3: Study the effectiveness of State emergency proclamation provisions issued following the 2014 South Napa earthquake and develop a model set of emergency proclamation provisions for use in major earthquakes. With potential delays in the provision of federal Individual Assistance and a general lack of earthquake insurance and other pre-designated sources of recovery funds for residents and businesses, the authorizations provided under the Governor's Executive Order may be some of the first and vital ways in which the State can help residents and businesses to jumpstart recovery efforts. The assessment should consider what major impediments residents and businesses faced in recovery following the 2014 earthquake and other recent disasters, and then identify State statutes, orders, rules, or regulations that could be suspended or eased to address these issues. The assessment should also consider ways in which State agencies can improve data management and expedite service delivery to impacted residents and businesses.

A5. Government and Institutions

Recommendation A5.1: Address gaps in the Standardized Emergency Management System guidance and training for local governments with consideration for how smaller jurisdictions can more effectively scale up or be linked in with operational areas to manage large-scale disaster response. Areas for potential improvement to the Standardized Emergency Management System (SEMS) include the following: ensuring staffing to fully operate all SEMS levels; following protocols in requesting resources across different levels; improving communication between the different SEMS levels and between the SEMS structure and local elected officials as well as the general public; and enhancing the use of GIS and access to scientific and technical expertise in the EOC. Some specific items that may need some further investigation include: apparent gaps in official notifications of the 2014 earthquake; enhanced training for Public Information Officers and the establishment of Joint Information Centers; and

FINAL DRAFT

the importance of social media and real-time communication and information sharing, both in situational awareness and response operations.

Recommendation A5.2: Work with the Federal Emergency Management Agency to review and improve the damage assessment and declaration processes following the 2014 earthquake and other recent disasters as well as the financing of local government assistance under the California Disaster Assistance Act and federal Public Assistance program. The complexity of earthquake damage and the time needed to properly identify it are top concerns with the current Preliminary Damage Assessment process. Enhanced training for inspectors and State and federal assessment teams, particularly on earthquake-specific issues, is needed. The integration of insurance into the repair cost negotiations and the rules for leased- versus owner-occupied public facilities are some of the specific topics that should be evaluated. Alternative funding mechanisms for public facilities and infrastructure recovery, as well as resources to assist local governments in managing cash flow, covering personnel costs and financing initial repairs on critical infrastructure and facilities while State and federal assistance is being approved should also be considered.

Recommendation A5.3: Strengthen State and local agency disaster preparedness requirements and training for continuity of operations planning. National Security Presidential Directive-51/Homeland Security Presidential Directive-20 requires all federal agencies and branches to incorporate continuity of operations planning into their daily operations and California Executive Order S-04-06 directs Cal OES to provide guidelines to State and local agencies in order to assist them in ensuring the continuity of government and ensuring the provision of essential vital services to the public during and after a catastrophic event. The adequacy of current requirements and training for continuity of operations planning should be evaluated in light of lessons learned from the 2014 earthquake and other disasters. Such requirements and training need to comprehensively address personnel, records, facility safety, and management over the post-disaster period, by considering likely disaster impacts as well as the potential occurrence of subsequent disasters while still in response and recovery. A facilities audit of both structural and non-structural vulnerabilities and succession planning for recovery operations should be part of the planning process.

Recommendation A5.4: Develop a State recovery training program as well as a local disaster recovery framework planning guide and complementary training program with a special focus on key issues for post-earthquake recovery as part of its State Disaster Recovery Framework planning efforts. State and local level recovery planning guidance and training need to take a "whole of the community" approach by going well beyond the traditional post-disaster assistance programs to consider the role and involvement of State agencies and local governments in all aspects of community recovery. Particular attention should also be paid to providing guidance and training on post-earthquake recovery issues, many of which have been identified in this report, such as geologic hazard assessment and abatement, understanding and mitigating earthquake-related damage to structures and infrastructure, the risk and consequences of fire following earthquakes, and overcoming gaps in earthquake recovery resources. As

FINAL DRAFT

damaging earthquakes happen with less frequency compared to other kinds of natural disasters, the guidance and training should incorporate key lessons and best practices from the 2014 South Napa earthquake, the 2003 San Simeon earthquake, and other key earthquake disasters in California and around the world, such as the 1989 Loma Prieta and 1994 Northridge earthquakes, 1995 Kobe earthquake, 2010–2011 Canterbury, New Zealand, earthquake sequence, and 2011 Tohoku Japan earthquake and tsunami.

Recommendation A5.5: Promote local-level planning for post-earthquake debris management. Cal OES reports that only a minority of local governments have debris management plans, and it offers technical assistance ahead of disaster to help community prepare these plans. Training and guidance on local debris management planning should identify debris collection and disposal sites, and potential debris contractors ahead of a disaster, be coordinated with solid waste planning, and address environmental concerns and regulations (i.e., California Environmental Quality Act requirements). It should also look at best practices—especially innovations in recycling—and the public management of both public and private property debris, following the 2014 South Napa earthquake and other key earthquake disasters in California and around the world.

Recommendation A5.6: Promote local government-level planning for the establishment of Local Assistance Centers that also can extend into long-term recovery following future earthquakes. LACs are established by local government to provide a wide array of services at one location to minimize the burden and maximize available assistance for those affected by the disaster. Cal OES has prepared a "Guide for Establishing a Local Assistance Center" to assist local governments in the establishment and management of a LAC.[173] The model recovery ordinance developed by the American Planning Association also outlines the provisions for the establishment of a one-stop center for permit, economic, and housing assistance.[174] Its purpose is to provide coordinated services and assistance to disaster victims including but not limited to: permit processing to expedite repair of buildings, provision of housing assistance, and encouragement of business resumption and industrial recovery. It may be a model for extending the LAC concept further and incorporating it into long-term recovery planning following major earthquake disasters.

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FINAL DRAFT

FINAL DRAFT

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FINAL DRAFT