1 INTRODUCTION AND GEOLOGIC SETTING

1.1 Introduction

On August 24, 2014 10:20:44 (UTC), a magnitude M_w 6.0 earthquake occurred on the West Napa Fault zone, a system of faults striking NNW from American Canyon and along the western edge of Napa Valley in Northern California. The epicenter was located at N 38.220 W 122.313, approximately 8 km SSW of Napa, California, 14 km ESE of Sonoma, California, and 81 km WSW of Sacramento, California, with a focus depth of 10 km. The West Napa Fault zone is located within the greater San Francisco Bay regional fault system in association with the western tectonic boundary of the North American plate, which accommodates approximately 40 mm/year of dextral shear. Effects of the earthquake were widely observed across the Napa Valley region from Vallejo and Mare Island in the South to the North end of Napa Valley. Clear expressions of surface fault rupture extended approximately 12 - 15 km northward from Cuttings Wharf to Alston Park and approximately 1-2 km southeast in American Canyon (Figure 1.1). The South Napa Earthquake is the first to produce significant surface rupture in Northern California since the 1906 San Andreas fault event, and the first to rupture through a densely populated area in Northern California.

In response to this event, the National Science Foundation (NSF) funded Geotechnical Extreme Events Reconnaissance association (GEER) deployed teams throughout the region to investigate the effects of the earthquake. The preliminary objective of the reconnaissance was to record the effects of strong shaking and ground failure on infrastructure, such as the prevalence of liquefaction, landsliding and surface fault rupture. Within 24 hours of the event, the initial observations showed a remarkable absence of liquefaction or landslide induced ground deformations. However, there was well defined surface rupture that produced various types of damage to structures and there was a pattern of damage to sidewalks and curbs suggesting sympathetic ground deformations within the vicinity of the fault zone.. As a result the subsequent investigative effort was focused on documenting the following:

- Seismology and ground motions of the event,
- Detailed mapping of surface fault rupture and the affected fault traces,
- Recording infrastructural damage due to ground surface rupture,
- Measuring ground deformation in the very near fault region,
- Assessing the performance of ground and buried utilities,
- And, assessing the performance of dams and levees.

The results of these efforts are presented in this report.

The characteristics of the strong-motion recordings from the earthquake, in the vicinity of American Canyon, CA, are summarized in Section 2 and Appendix A. The data are compared to the latest ground motion prediction equations (GMPEs) and current design spectra.

Section 3 and Appendix B document the key observations of surface fault rupture in the weeks following the South Napa event. Given the rare opportunity to study the effects of surface rupture, a significant effort was made to document the rupture both in the field and using various remote sensing methods as Interferometric Synthetic Aperature RADAR (InSAR), Light Detection And Ranging (LiDAR), and Global Positioning Systems (GPS).

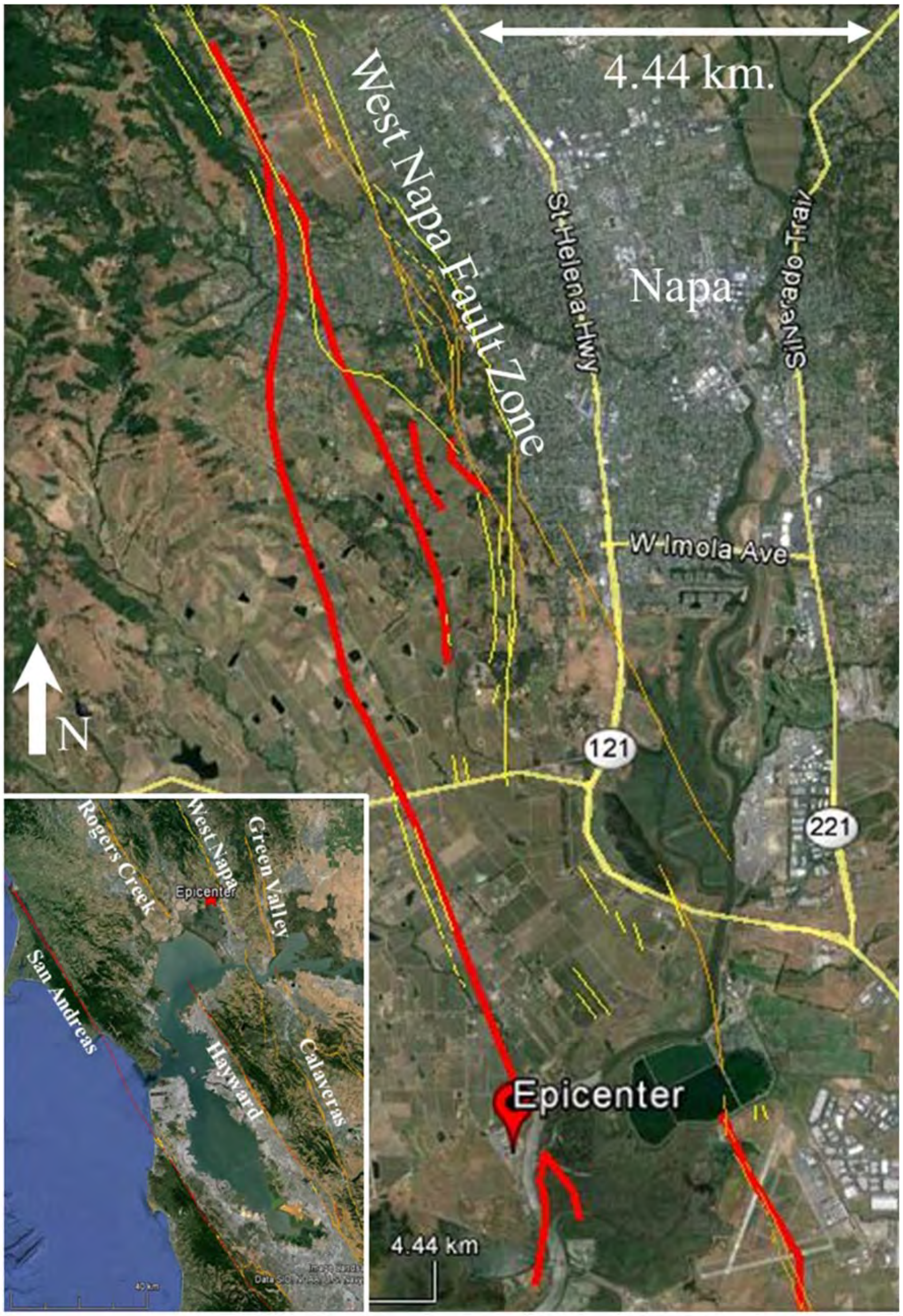

Figure 1.1 Map of the approximate tectonic rupture trace for the August 24, 2014 $M_w = 6$ South Napa Earthquake with Regional Fault Map of the San Francisco Bay Area. [NSF-GEER; J. Cohen-Waeber; 09/14/2014]

Section 4 and Appendix C address the effects of surface fault rupture on infrastructure. This effort consisted of an extensive investigation of damaged property along densely populated lengths of the rupture trace. Permanent deformation of and damage to different types of residential structures were carefully recorded and are summarized here.

Section 5 and Appendix D address ground deformation in the very near fault region. The focus of activities for this section was to record deformation near areas with prominent surface fault rupture, primarily in sidewalk pavement. Local and global (on the order of street lengths) strain measurements were computed to provide insight into the distribution of strains in the fault parallel and the fault normal directions. Additional observations concerning deformation of long, linear infrastructure were noted and addressed as necessary.

Section 6 and Appendix E address the performance of ground and buried utilities. This section describes the investigations of damage outside the zone of surface fault rupture and associated very near fault ground deformation. Notably, the low occurrence of liquefaction and landslide induced ground deformation is discussed, as well as several isolated instances of broken underground pipelines and masonry building damage.

Section 7 and Appendix F address the performance of dams and levees. 34 dams are located within 20 kilometers of the South Napa Earthquake energy source, all of which experienced little to no significant damage. Observations of their performance from aerial and field reconnaissance are summarized.

1.2 Geologic Setting

The August 24, 2014 $M_w = 6$ South Napa Earthquake occurred near the North shore of San Pablo Bay, and the South end of the Napa Valley, at the North end of the greater San Francisco Bay, California. The local geology is the product of an approximately 360 million year old accretionary process during which the North American Plate margin transitioned from subduction of the Farallon Plate to a transform boundary against the Pacific Plate. Geomorphically the region is within the California Coast Range province and is characterized by northwest trending valleys and low lying mountain ranges.

The Napa Valley is underlain by marine Cretaceous and Jurassic sedimentary rock which are overlain by Early Tertiary marine sedimentary rocks and Late Tertiary volcanics which outcrop primarily at higher elevations within the Valley. The Valley itself is filled with up to 160 m of older Pleistocene alluvial deposits overlain by up to 10 m of recent Holocene alluvial deposits, generally composed of moderately to poorly sorted sands, gravels, silts and clays. Where the South end of the Napa valley meets San Pablo Bay, recent Holocene Bay Mud deposits reach up to 40 m in thickness. Groundwater tables range in depth from 1.5 – 24 m with seasonal fluctuations of 1.5 – 3 m.

The West Napa Fault zone is generally considered as a relatively minor but active system of faults within the greater and seismically active San Francisco Bay Region which accommodates approximately 40 mm/yr of dextral shear. It is located East of the Hayward-Rogers Creek Fault zone, and West of the Concord-Green Valley Fault zone. The South Napa Earthquake occurred along the West Napa Fault, near the Carneros-Franklin fault and is known to be a right lateral fault with a slight westerly dip-slip component. Though this is the largest seismic event to have occurred in the San Francisco Bay Area since the $M_w = 6.9$ 1989 Loma-Prieta Earthquake, an unmapped fault West of the West Napa fault produced the M_w = 5 Yountville/Napa Earthquake in September of 2000, within 30 km of the South Napa Earthquake epicenter. Hence this area is clearly seismically active.

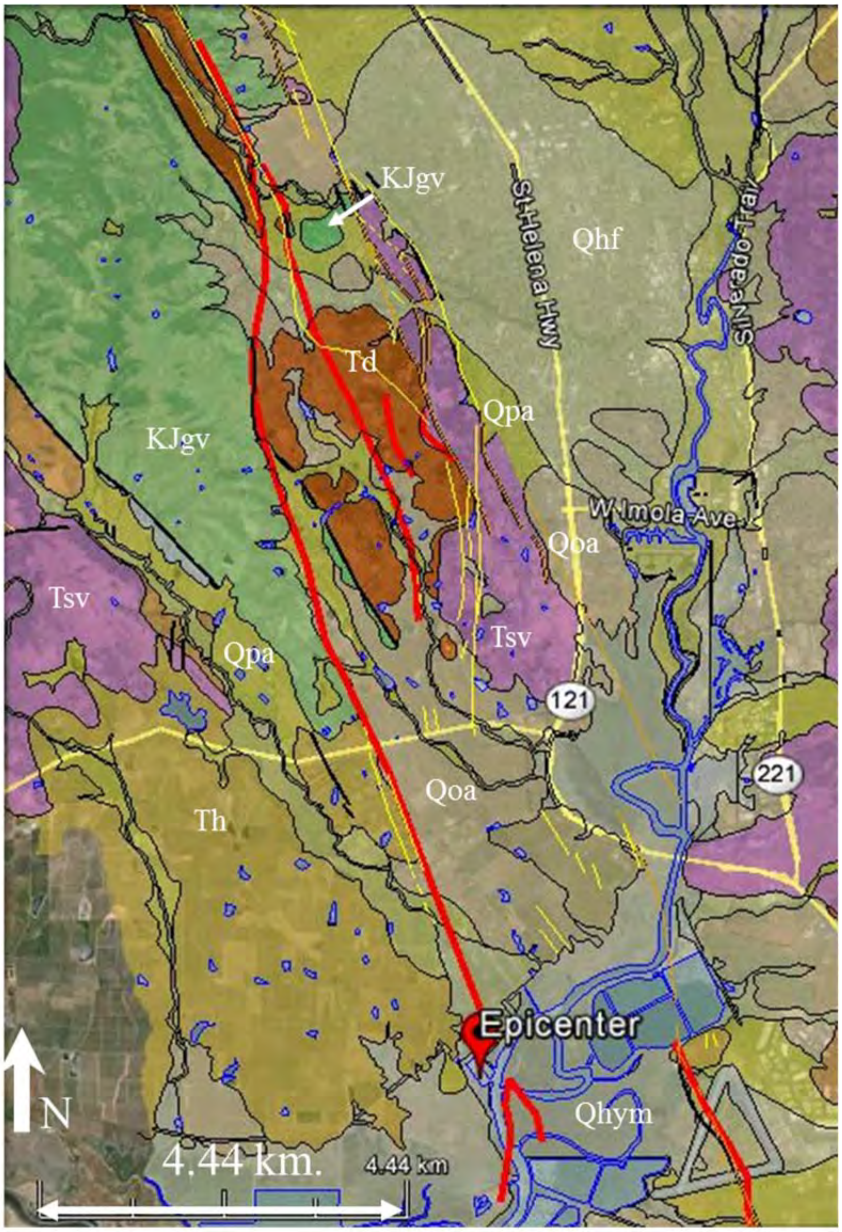

Figure 1.2 Geologic map and approximate trace of tectonic rupture (red) for the August 24, 2014 M_w = 6 South Napa Earthquake. Qhym - Holocene Bay Mud Deposits, Qhf - Holocene Alluvial Fan Deposits, Qpa/Qoa - Pleistocene Alluvium, Th - Pliocene/Pleistocene Huichica Fm. Sedimentary, Tsv - Miocene/Pliocene Sonoma Volcanics (Mafic flows and Tuffs), Td - Eocene/Miocene Domengine Sandstone, KJgv - Cretaceous/Jurassic Great Valley Sequence Sedimentary. [NSF-GEER; J. Cohen-Waeber; 09/14/2014]