M 6.5 Earthquake Offshore Northern California
January 9, 2010

Field Reconnaissance Summary

Prepared By:

R. Storesund, L. Dengler, S. Mahin, B.D. Collins, M. Hanshaw, F. Turner, K. Welsh

February 12, 2010

ABSTRACT

At 4:27 PM PST January 9, 2010 (00:27 UTC 1/10/10) a magnitude (M_w) 6.5 earthquake occurred off the coast of Humboldt County, California. The epicenter was located offshore, 23 miles NW of Cape Mendocino, 26 miles WNW of Ferndale and 30 miles WSW of Eureka. The depth was estimated at about 18 miles.

Damage was concentrated along the coast from Ferndale to Eureka and appears to be the result of both distance to the hypocenter and guided energy along the strike of the fault. Areas founded on deep estuary and river deposits appear to have experienced higher pga and "more" geologic damage (due to site amplification) compared with areas located on shallower soils and rock experienced lower pga and "less" geologic damage.

Eureka, the most heavily impacted city by the earthquake, reported over 600 structures affected and nine with major damage. The majority of damaged structures were single-family homes, and several dozen chimneys were severely damaged or knocked down. Eureka's Bayshore Mall, completed in 1987 and the largest commercial property in Humboldt County, had damage to the suspended ceiling and was closed for four days. Earthquake losses for the county (as of February 12, 2010) were estimated at over $40 million. No unreinforced masonry buildings retrofitted after Eureka's 1989 Unreinforced Masonry (URM) ordinance suffered anything more than cosmetic damage.

Information from the USGS Earthquake Hazards Program can be found at the following URL: http://earthquake.usgs.gov/earthquakes/eqinthenews/2010/nc71338066/.

Structural damage to the Eureka Theater building at the corner of 6th and F Street in Eureka, California.

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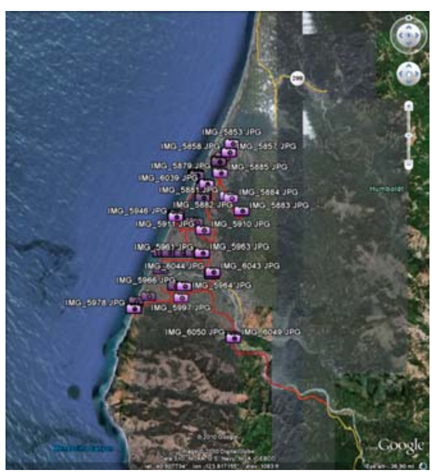
A summary map and Google Earth resources (tracklog with photos and observed features) have been compiled and are available for download from the GEER website:

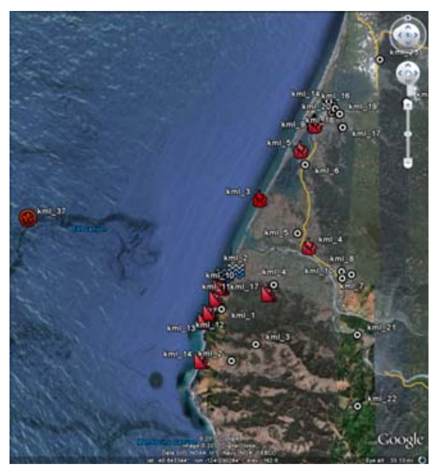
http://www.geerassociation.org/GEER_Post_EQ_Reports/NorthCA/Cover_NorthCA2010.html

Summary Map

Storesund Tracklog/Photographs



Observed Features



Acknowledgements

This effort was accomplished with the help and efforts of a number of people. Countless eyewitnesses provided valuable insights on locations of potential interest to investigate within the very narrow time frame between the occurrence of the earthquake and the rains associated with an incoming storm. A large area was covered in very little time.

Desktop studies, review of seismic hazard maps, and collection of newspaper articles and television news reports were essential and instrumental in helping to quickly identify known regions of damage and guide the reconnaissance team to these valuable sites. Pre-existing GIS datasets with liquefaction zones, seismic slope vulnerabilities, and other natural hazards consequence information are extremely useful and helpful in shaping reconnaissance missions.

The results of this field reconnaissance program are not complete and comprehensive, but do summarize the major features observed by the GEER team in the areas investigated. Additional insights and observations will be incorporated in future updates to this report as they are submitted.

The primary members that helped with the GEER Reconnaissance evaluation were (in alphabetical order):

Brian D. Collins, Ph.D., P.E.	*Research Civil Engr.*	*United States Geological Survey*
Lori Dengler, Ph.D.	*Professor*	*Humboldt State University*
Maiana Hanshaw	*Geologist*	*United States Geological Survey*
Stephen Mahin, Ph.D.	*Professor*	*University of California, Berkeley*
Rune Storesund, D.Eng., P.E., G.E.	*Consulting Engineer*	*Storesund Consulting*
Fred Turner, P.E., S.E.	*Sr. Structural Engr.*	*California Seismic Commission*
Karen Welsh	*Eureka Resident*	

We would like to acknowledge the assistance of Dr. Jonathan Bray (U.C. Berkeley) and Ms. Katherine Jones (U.C. Berkeley) who provided valuable editorial guidance during the assembly of this report.

The United States Coast Guard, Humboldt Bay Air Station provided assistance with flight reconnaissance. We are extremely grateful to Commander Gregory Fuller, Lieutenant Commander Lauren Cox, Lieutenant Michael Chocholak, and Petty Officer Mike Arellano for their extremely timely assistance and support of the aerial reconnaissance.

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The GEER Association is made possible by the vision and support of the NSF Geotechnical Engineering Program Directors: Dr. Richard Fragaszy and the late Dr. Cliff Astill. GEER members also donate their time, talent, and resources to collect time-sensitive field observations of the effects of extreme events. The GEER Association web site, which contains additional information, may be found at: http://www.geerassociation.org.

Earthquake Description and Ground Motions

Contributed by Dr. Lori Dengler

At 4:27 PM PST January 9, 2010 (00:27 UTC 1/10/10) a magnitude (M_w) 6.5 earthquake occurred off the coast of Humboldt County, California. The epicenter was located offshore, 23 miles NW of Cape Mendocino, 26 miles WNW of Ferndale and 30 miles WSW of Eureka. The depth was estimated at about 18 miles. Analysis of the earthquake indicates that slip occurred on an unnamed, near-vertical, left-lateral fault oriented about N46°E within the Gorda plate (Figure 1).

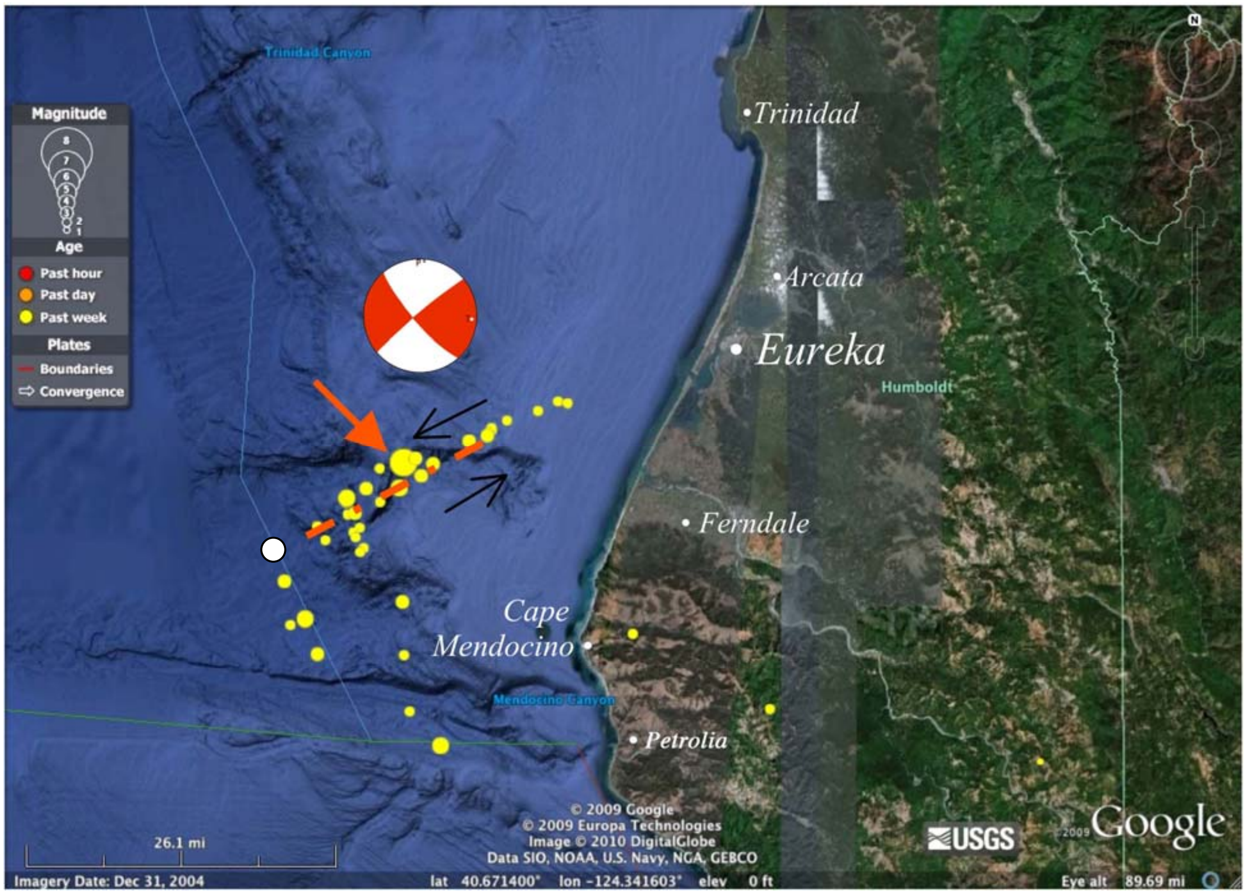

Figure 1 Google Earth image of the January 9 mainshock (red block arrow) and aftershocks. Dashed line shows the location of the probable fault source and black line arrows show the direction of slip. NCSS focal mechanism shows the best fit double couple. The white circle shows the magnitude 5.9 earthquake triggered on February 4.

Inversion of seismic waveforms by the UC Berkeley Seismological Laboratory estimated a fault length of about 25 km; rupture proceeded unilaterally to the southwest. The peak estimated slip between the two sides of the fault was 2.4 meters.

Fifty-nine aftershocks were detected in the first week after the earthquake. Most were located along the trend of the fault rupture (see figure previous page), but some were located in the SE

Gorda Plate, south of the rupture and along the Mendocino Fault. The largest was a magnitude 4.4 that occurred about an hour and a half after the mainshock. It was widely felt in the Humboldt Bay and Cape Mendocino areas. The U.S. Geological Survey's "Did-You-Feel-It" website indicated that most aftershocks larger than M3 were felt by nearby residents. None of the aftershocks to date have caused damage.

On February 4, 2010, approximately three weeks following the main event, a magnitude (M_w) 5.9 earthquake occurred about 43 kilometers west of Cape Mendocino and 28 kilometers southwest of the January 9 epicenter. This earthquake appears to have been a triggered event on a parallel but different Gorda Plate fault than the January 9 rupture.

Shaking was strongest near the coast line between Petrolia and Eureka (Figure 2), although felt reports for this event extend as far south and north as Capitola, California and Eugene, Oregon, respectively, and as far east as Reno, Nevada. The United States Geological Survey (USGS) has received 8888 "Did You Feel It?" reports from 621 zip codes as of February 6, 2010 (Figure 3).

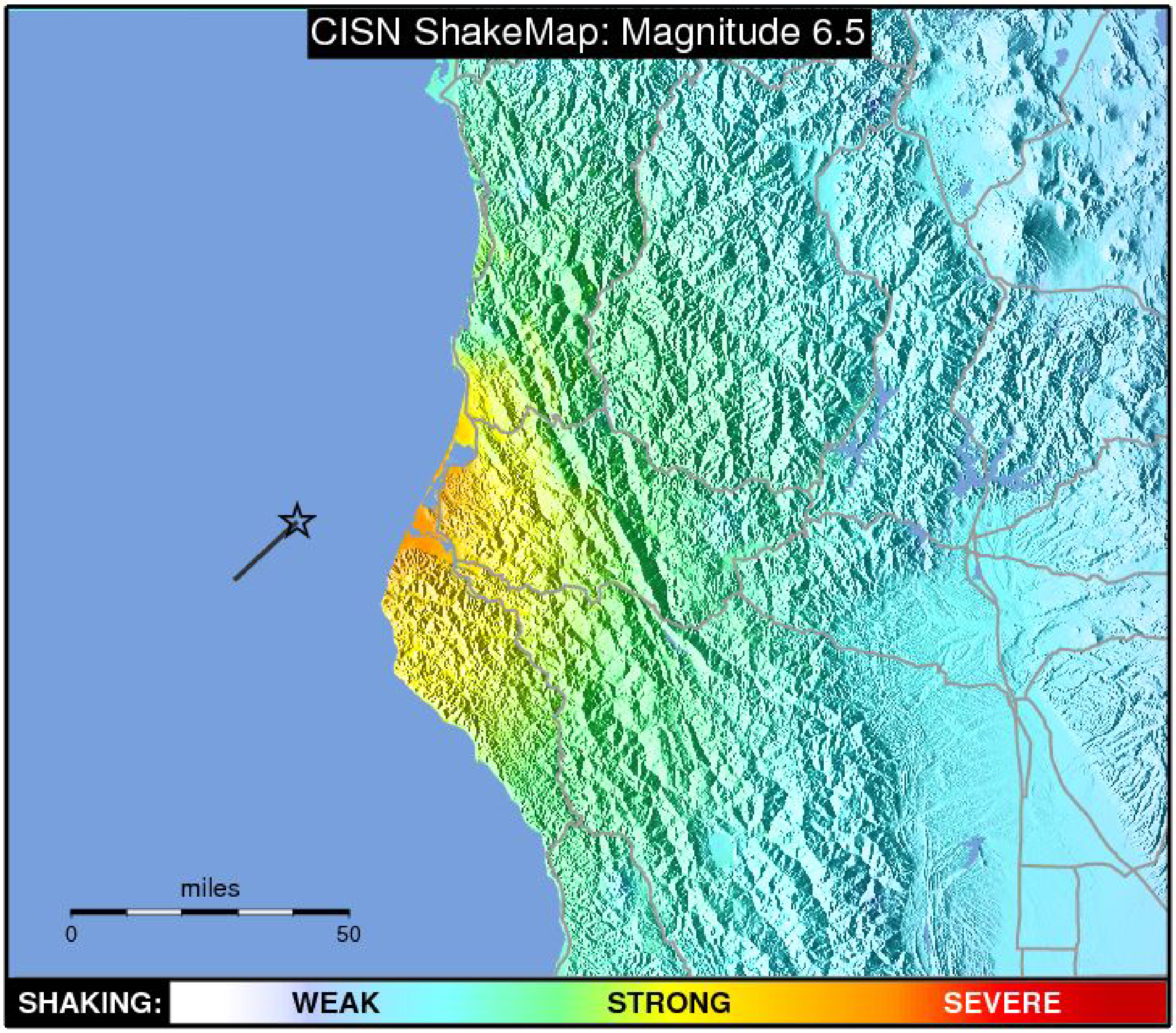

Figure 2 ***Shakemap - Instrument-determined ground shaking. Star shows epicenter and line is the approximate extent of rupture.***

Magnitude is a measure of the relative energy release at the earthquake source. It depends on the size of the fault and the amount of fault slip. Large magnitude earthquakes do not necessarily produce damage if they are located far from population centers.

Intensity measures relative shaking strength at specific locations onshore. Intensity VI is considered very strong and may break windows and produce cracks in buildings. Intensity VII is severe and will topple many unreinforced brick chimneys and displace heavy furniture. Intensity VIII is described as violent and will knock unsecured structures off foundations and damage brick buildings. Intensity IX and larger is extreme and will damage even well-engineered structures.

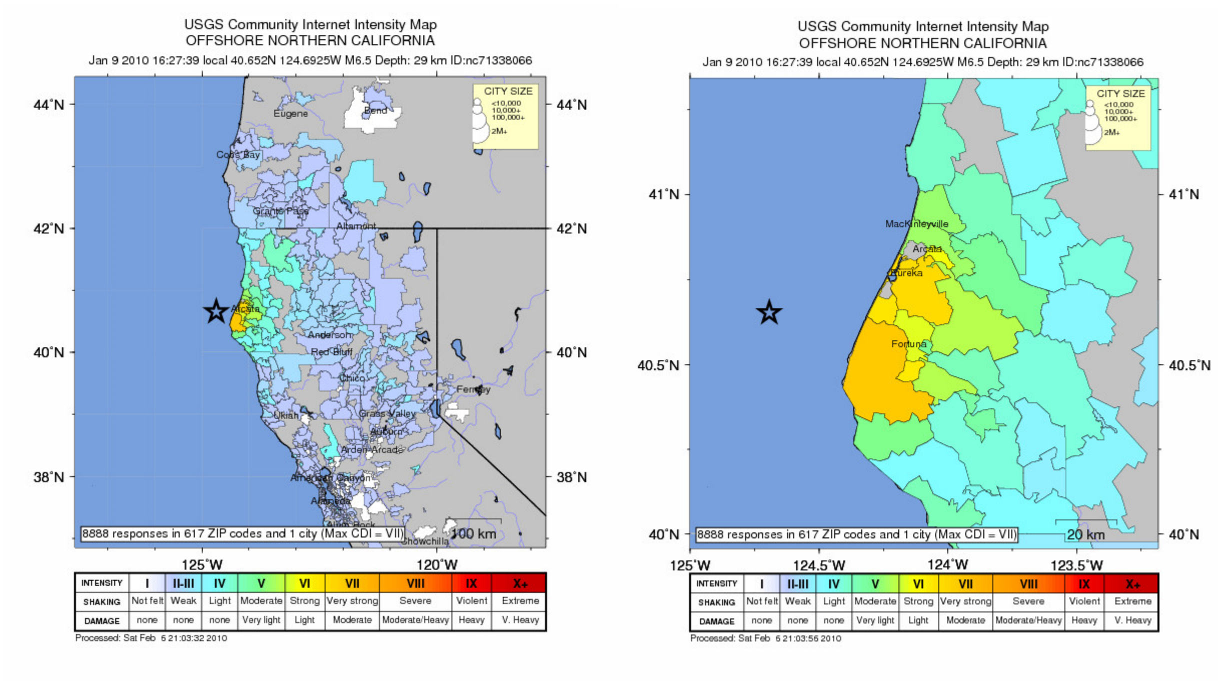

Figure 3 Did You Feel it – individual responses to the USGS Intensity online survey

The maximum recorded shaking was observed in Ferndale (44%g) and at Eureka (33%g), which is sufficient to cause moderate damage. The instrumentally-computed "Shakemap" by the USGS shows a zone of strong shaking along the coast extending from the Eel River Valley to Eureka. About 20% of the vertical monuments at the Ferndale cemetery were toppled or displaced and preliminary analysis suggests an east-west alignment (Figure 4). Cemetery monuments in Eureka, Table Bluff and Loleta show similar, but smaller, amounts of displacement.


Figure 4 Toppled monuments at the Ferndale Cemetery.

Geologic and Seismotectonic Setting

Contributed by Dr. Lori Dengler

The January 9th earthquake occurred in a deformation zone of the southernmost Juan de Fuca plate that is commonly referred to as the Gorda Plate. The earthquake's epicenter was northwest of the Mendocino Triple Junction, which is formed by the intersection of three plates (the Gorda, Pacific, and North American) and three plate boundaries - the Mendocino Fault, the San Andreas fault and the Cascadia subduction zone. According to the U.S.G.S., the Gorda plate is subducting beneath the North America plate at about 2.5-3.0 cm/year to the northeast. The Gorda plate is also subjected to intense compressive stresses by oblique-convergence of the northwestward migrating Pacific Plate and the spreading direction of the Juan de Fuca plate to the north, as well as localized eastward spreading at the Gorda Ridge. The resulting internal deformation of the Gorda plate is manifested primarily by intraplate strike-slip events on vertical NE-oriented, left-lateral faults. The majority of historic earthquakes have occurred in this zone or along the Mendocino fault.

During historic times, the coastal and offshore areas of Humboldt and Del Norte Counties, California have been the single most seismically active region of the coterminous United States. On average, an earthquake with strength enough to topple items off shelves has occurred every two to three years, strong enough to topple chimneys every seven years, and cause major damage about every twenty years.

Figure 5 shows historic North Coast epicenters from 1975 to the present. Figure 6 shows North Coast offshore earthquakes with a magnitude greater than 6 from 1980 until the present. Figure 7 summarizes magnitude 6 or larger events between 1900 and the present and Figure 8 summarizes historic North Coast Earthquakes of peak Intensity VI or larger since 1900.

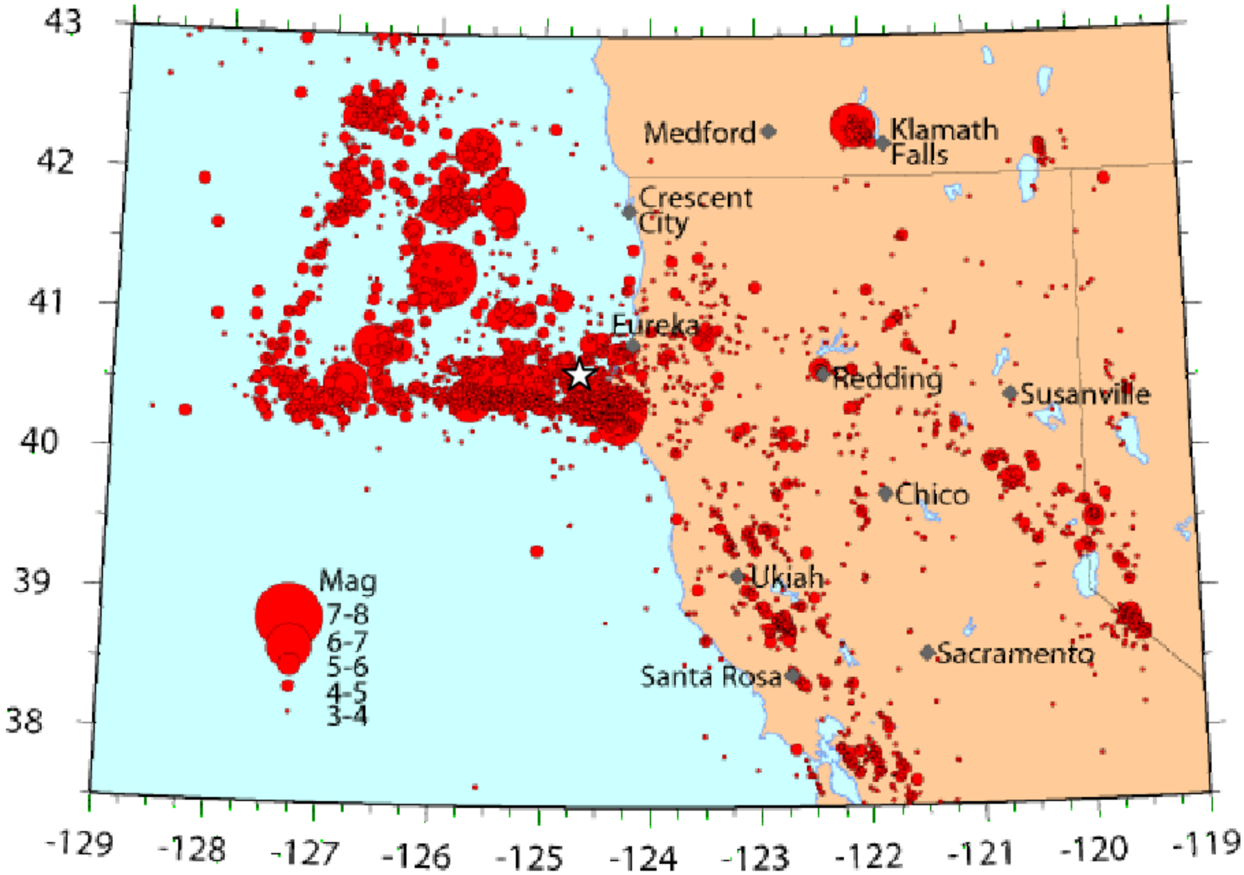

Figure 5 Historic North Coast Earthquakes epicenters 1975 to the present. Star shows the location of the January 9, 2010 earthquake (USGS).

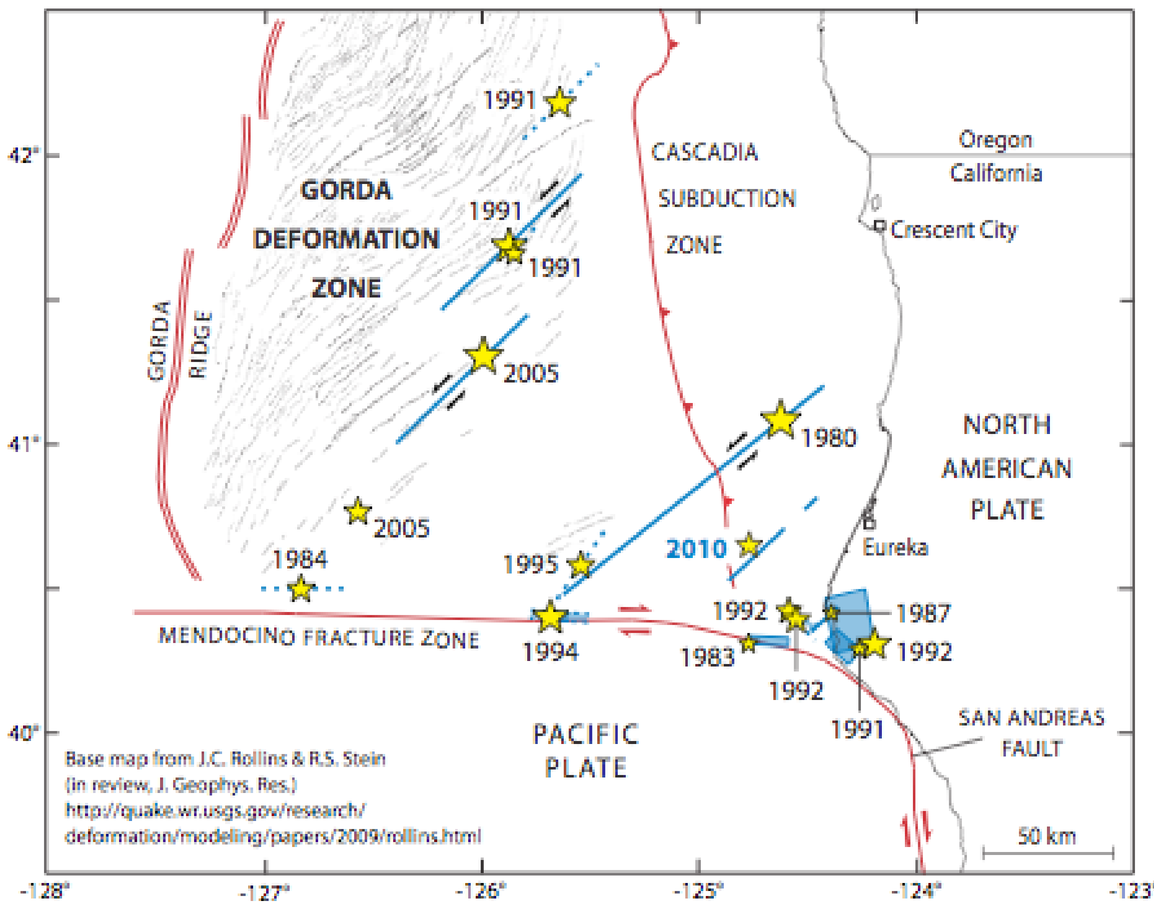

Figure 6 Earthquakes with M>6 offshore northernmost California since 1980.

Since 1900, 27 earthquakes have caused damage to structures in Humboldt County (Intensity VII or greater), an average recurrence of less than five years. Most of these earthquakes have been centered offshore or near Cape Mendocino, sparing the more populated Humboldt Bay region the strongest shaking levels. The greatest impact to the Eureka area was most likely caused by the 1932 magnitude 6.5 earthquake which toppled hundreds of chimneys and caused one death.

The January 9, 2010 earthquake is the largest quake to occur in Humboldt County since the June 15, 2005 magnitude 7.2 offshore Eureka earthquake. That event triggered a tsunami warning for the entire west coast of the United States but was fortunately too far offshore to cause damage. The January 9, 2010 earthquake was the first event to cause damage since a magnitude 5.4 earthquake on December 26, 1994. The most significant recent earthquake sequence occurred on April 25-26 1992 when a magnitude 7.2 earthquake occurred onshore near Petrolia and was followed by magnitude 6.6 and 6.7 earthquakes in the following 18 hours. The sequence caused at least $60 million in damages and resulted in a federal disaster declaration.

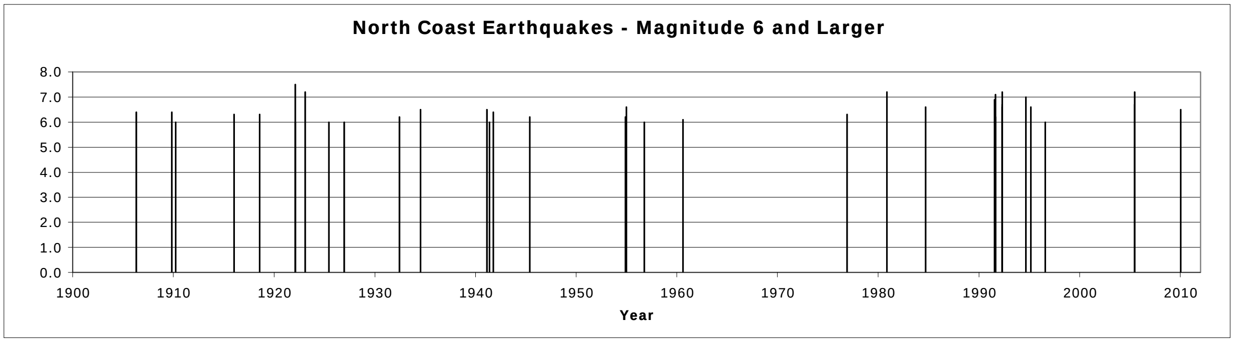

Figure 7 Historic North Coast Earthquakes of magnitude 6 or larger.

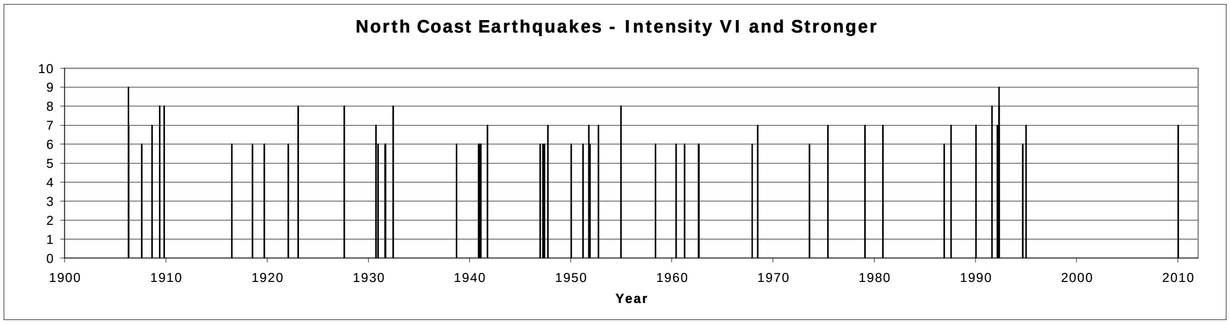

Figure 8 Historic North Coast Earthquakes of peak Intensity VI or larger.

Fault Rupture Features

Due to the off-shore location of the earthquake, no surface fault rupture features were observed by the GEER Reconnaissance team and/or reported by any residents.

Tsunami Observations

Contributed by Dr. Lori Dengler

The earthquake did not cause a tsunami. Strike-slip earthquakes are generally unlikely to produce large tsunamis because they cause relatively little vertical ground displacement. The NOAA National Weather Service West Coast/Alaska Tsunami Warning Center (WCATWC) issued a Tsunami Information Statement at 4:32 PM PST, four minutes after the earthquake stating that a tsunami was not expected. The Information Statement was sent to emergency managers via the State's CLETS (California Law Enforcement Telecommunications System) and NAWAS (National Warning System) but not broadcast on NOAA Weather Radio. There was no evidence of any water level disturbance on the nearest tide gauge located just inside Humboldt Bay.

Landslides and Rock Falls

Contributed by Dr. Brian Collins, Ms. Maiana Hanshaw, and Dr. Lori Dengler

Landsliding can generally be anticipated within a 150 km radius from M6.5 earthquake epicenters (Keefer, 1984) and particularly along stretches of coast as steep and landslide-prone as those located nearest to this earthquake's epicenter. Due to the likelihood of widespread landsliding in the on-land epicentral area and the inaccessibility of coastal slopes between the Eel River and Cape Mendocino in this region, both ground and aerial reconnaissance were performed.

Using ground-based reconnaissance in the days following the earthquake, GEER team members and media reports identified several small landslides in the Humboldt Hill area (48 km epicentral distance) and on the bluffs adjacent to Highway 101 south of Eureka (about 50 km epicentral distance). In addition, failure of an embankment damaged the Mattole Road several kilometers south of Ferndale at approximately 43 km epicentral distance (Landslide #8 - Table LS1). Reports of landsliding affecting infrastructure were identified in media sources (The Independent 1/12/2010, "SoHum Feels Quake", pg. 1-2; McKinleyville Press 1/13/2010, "Earthquake" pg. 10) which indicated that some landslides temporarily closed roads, but were generally minor and cleaned up within one day.

In cooperation with the United States Coast Guard, GEER team members performed aerial helicopter-based reconnaissance of the coast and immediate inland areas to approximately 60 km epicentral radius on January 15, 2010, less than one week following the earthquake. The focus of the reconnaissance was on the coast between Punta Gorda to the south and Trinidad Head to the north (Figure 9). However, flight lines were also made to interior sections of the coast, extending as far inland as Liscom Hill, Blue Lake, Rohnerville, Mount Pierce and Buckeye Mountain.

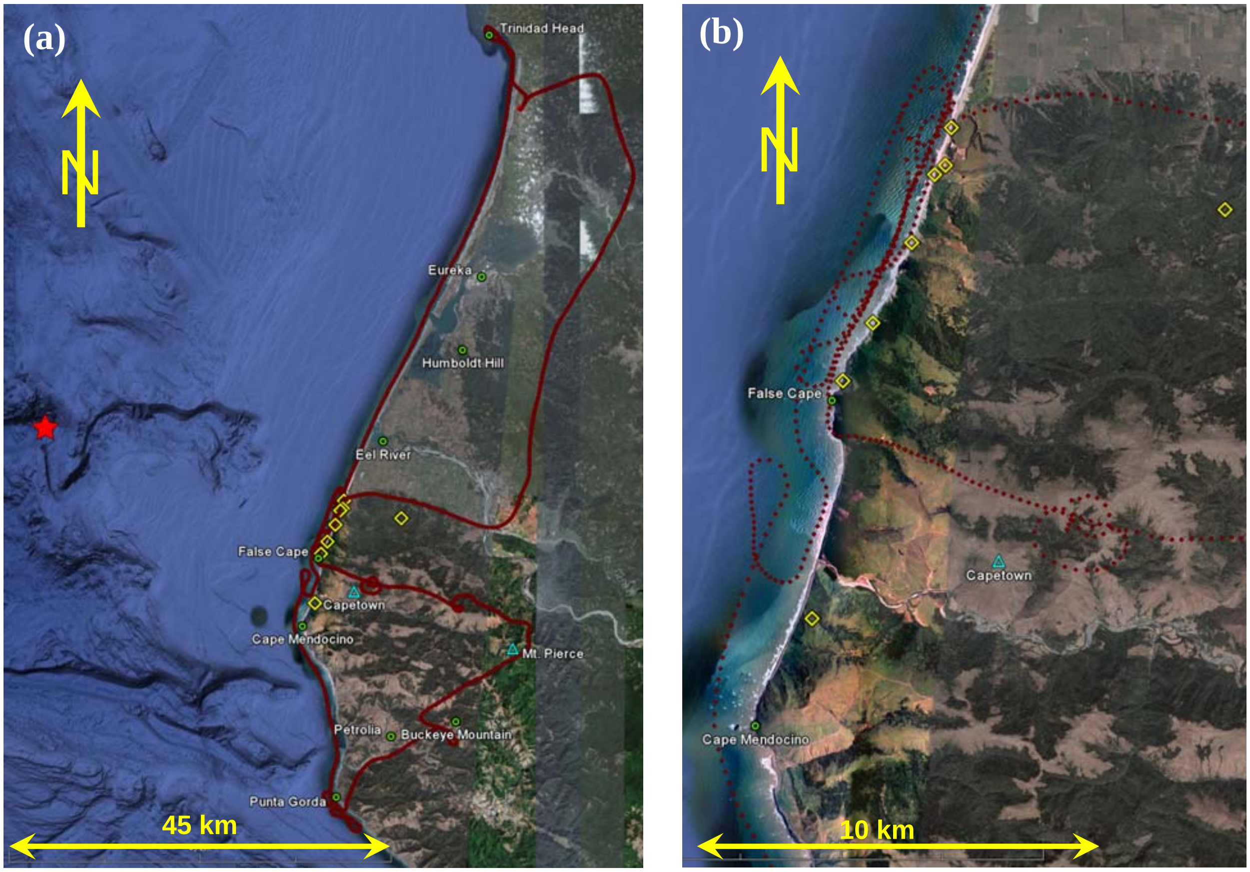

Figure 9 (a) Overview and (b) observed landslide maps from aerial reconnaissance. Star is January 9, 2010 epicenter, dashed line is flight path, diamonds are observed landslides, triangles are selected nearby seismological stations, dots are locations mentioned in this report. Imagery source: Google Earth/Digital Globe.

Overall, 340 km were flown, encompassing a reconnaissance area of approximately 790 km^2. A total of seven landslides were observed during the aerial reconnaissance, all located along the coast between False Cape and the Eel River delta at approximately 36 km epicentral distance (Landslides #1-7, Table LS1).

Table LS1. Observed landslides from the M6.5 Offshore Humboldt County Earthquake

Landslide	Type	Lithology[1]	Epicentral Dist. (km)	Latitude (WGS84)	Longitude (WGS84)
1	rock fall	QTw	36.1	N40.559231°	W124.357405°
2	rock fall	QTw	36.0	N40.544394°	W124.363980°
3	rock fall	QTw	35.8	N40.526835°	W124.374868°
4	rock fall	fc	35.7	N40.514241°	W124.383575°
5	soil slide	QTw	37.8	N40.462761°	W124.391888°
6	rock fall	QTw	36.2	N40.569433°	W124.352587°
7	soil slide	QTw	36.3	N40.561130°	W124.354008°
8[2]	soil slide	QTw	43.5	N40.551321°	W124.273344°

[1] QTw = marine and nonmarine overlap deposits of weakly lithified siltstone and sandstone; fc = sedimentary rocks of the False Cape terrane – thin bedded argillite, sandstone and limestone (McLaughlin et al., 2000)

[2] Landslide No. 8 was reported by Humboldt County Public Works and not directly observed by the aerial reconnaissance. Several additional landslides were reported by the media, but their locations were not able to be identified.

Observed landslides were checked for consistency with recent (September 2009) high-resolution photographs obtained from the California Coastal Records Project (http://www.californiacoastline.org/), a publicly available coastal image archive. Identified landslides were typically either rock fall (60%) or soil slides (40%) and small (less than 100 m^3) in volume. Source area slope inclinations were on the order of 50° to 90° based on visual observations (Figure 10). In all cases, shaking mobilized weakly lithified siltstone and sandstone of Quaternary and Tertiary age (McLaughlin et al., 2000) that were each associated with existing active landslide or coastal erosion areas.

Figure 10 Typical coastal rock falls at 36 km epicentral distance. Arrows point to location of earthquake-induced rock fall in each case. (a) Rock fall from approximately 30 m tall cliff located at N40.559231°, W124.357405°, photo taken on 1/15/2010 at 10:49 a.m., (b) Rock fall from approximately 50 m tall cliff portion of existing larger deep-seated landslide located at N40.526835°, W124.374868°, photo taken on 1/15/2010 at 10:48 a.m.

These observations indicate that typical landslide concentrations from this event were on the order of 0.13 landslides per square kilometer (LS/km^2) at epicentral distances of between 30 and 40 km. This compares favorably with Keefer's (2000) empirical relationship for earthquake induced landslides triggered during the M6.9 Loma Prieta, California event in which the landslide concentration at 30 to 35 km epicentral distances was between 0.1-0.5 LS/km^2. Overall, the maximum epicentral distance for landsliding from this event is well within and somewhat below the empirical limit (~150 km) of similar magnitude (M6.5) events (Keefer, 1984). However, seismological observations nearest to observed coastal landsliding indicate that horizontal peak ground acceleration (pga) values were only on the order of 0.1g (Capetown Station, Northern California Seismic Network, NCSN, Station KCT, pga=0.089). In the 1999 Chi-Chi, Taiwan earthquake, mean horizontal pga values of at least 0.15g caused 81% of landslides with values of between 0.35g and 0.45g causing the majority of failures (e.g. Khazai and Sitar, 2003). Thus, low accelerations, such as those measured in the steep landslide-prone areas of the Humboldt County coast, were likely a major reason why more widespread landsliding did not occur.

Liquefaction Events

Contributed by Dr. Lori Dengler

Liquefaction (sandboils) was observed on Centerville Beach and along the Eel River (Figure 11). The Centerville Beach features were subtle and had been overtopped by high tide washover. Small sandboils were better preserved on the banks of the Eel River and associated with spread failures ranging in length from less than a meter to 20 meters. Approximate locations of liquefaction features are presented in the "Observed Features" Google Earth file.

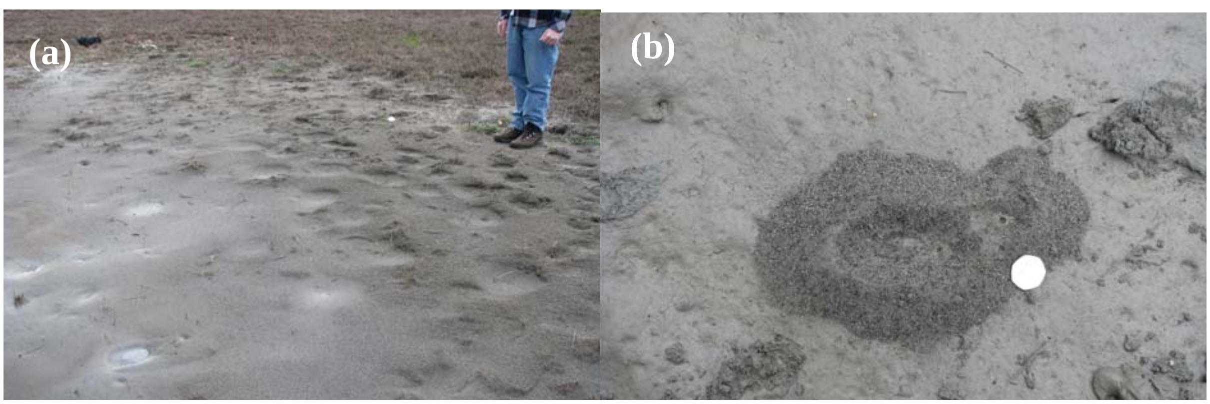

Figure 11 Liquefaction features: remains of sandboils at Centerville Beach (a) and sandboils along the Eel River (b).

Ground Cracking and Lateral Spreading

Contributed by Dr. Lori Dengler and Dr. Rune Storesund

Lateral spread failures were observed at King Salmon and along the banks of the Eel River (Figure 12). The most well developed spread failures were located on the spit north of the mouth of the Eel River, where some features extended 10 meters or more with offsets up to 40 cm. Field reconnaissance for surface features was limited by weather constraints. There may have been features elsewhere but heavy rainfall on January 12 erased most traces. Approximate locations of ground cracking features are presented in the "Observed Features" Google Earth file.

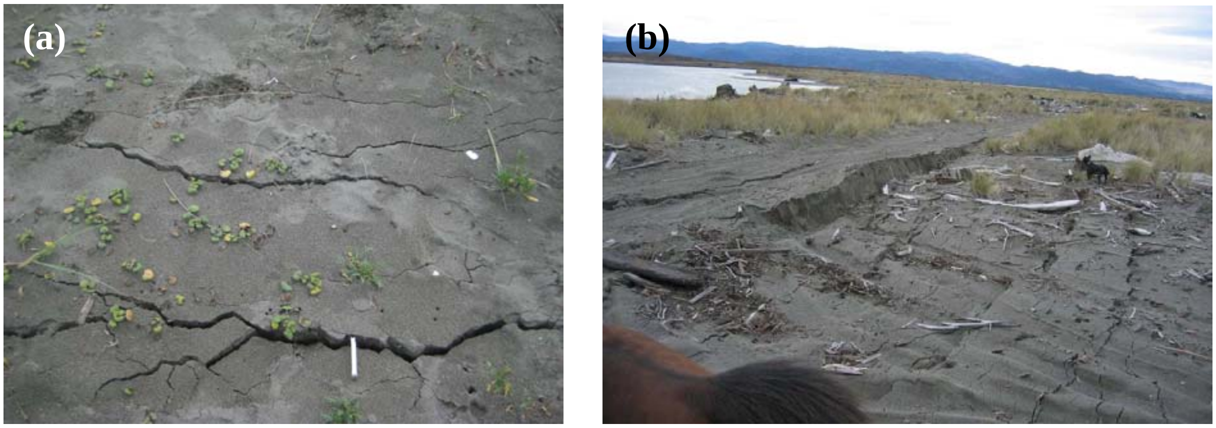

Figure 12 Spread failures at King Salmon(a) and spread failures on spit north of Eel River mouth (b).

Observations were made along the waterfront in Eureka, starting at the Adorni Center working southwest to the Bayshore Mall. Three items of interest were observed in this stretch, all very minor:

1. Minor differential ground displacements were observed at the interface of the pile-supported W. Del Norte Street Fishing Pier and approach embankment. Cracking was observed at the pier/embankment interface and a fracture line in the asphalt concrete pavement appeared to indicate the near-onset of a slope failure (Figure 13).

Figure 13 W. Del Norte Street Fishing Pier fractures in pavement indicated near-onset of slope failure (40.790688N; 124.187810W). Arrow indicates directly of movement of embankment and dashed line shows outline of cracking.

2. Fracturing and displacements (Figure 14) of the Ray's Food Place Market slab on grade concrete floors were observed, indicating differential settlement of foundation soils. No significant structural damage was observed to the exterior of the structure or any interior columns/beams. Some ceiling panels fell down and some shelves were knocked over. The structure was in operation at the time of the field observations.

Figure 14 Cracking of the slab on grade concrete slabs at cold joints indicating differential settlement of foundation soils at Ray's Food Place Market (40.776538N; 124.192284W).

3. Ruptures in the asphalt concrete pavement at the Bayshore Mall (Figure 15).

Figure 15 Ruptures in the Bayshore Mall parking lot (40.778562N; 124.190219W).

Figure 16 shows cracking in the AC pavement south of the Bayshore Mall and Ray's Food Place. These cracking features extend from Truesdale Street to Tomlinson Street (mostly parallel to Broadway Street/Highway 101).

Figure 17 shows landslide features on an earthen slope, east of Highway 101, approximately 640 meters north of Pound Road. It was not possible to access the site, so it was unclear if this was actually seismically induced movement.

Figures 18 through 25 show a variety of ground cracking conditions (as well as regions with no damage) south of Eureka and north of Ferndale.

Figure 16 Cracking in AC pavement in the parking lot at the Best Western, NW corner of Broadway Street and Truesdale Street (40.775312N; 124.1919019W).

Figure 17 Landslide features on an earthen slope at the east of HWY 101, approximately 640 m north of Pound Road (40.763860N; 124.186335W). It was not possible to easily access the site, so it was not possible to ascertain potential for seismic induced movement.

Figure 18 No apparent ground deformation was observed during my drive on Elk River Road (40.702672N; 124.146964W).

Figure 19 Ground cracking at the King Salmon region at Buhne Drive and King Salmon Avenue. Figure 20 shows the approximate extents of these 'cracking' features (40.741957N; 124.216385W).

Figure 20 Approximate extents of the 'cracking features' shown in Figure 19.

Figure 21 Deformations were observed in the Humboldt SouthJetty. Some apparently fresh concrete spalling was observed; however, it was not apparent that this cracking was a caused by the Jan. 9 earthquake (40.75770N;124.234943W).

Figure 22 No significant structural damage and or ground features were observed in the Eel River valley along Cannibal Island Road (40.642967N; 124.262067W).

Figure 23 No significant features were observed in the southern portion of the Eel River valley (40.594551N; 124.274756W).

Figure 24 Some lateral displacement cracking was observed on the bluffs immediately south of Centerville Beach; however, this is an area of active bluff erosion (40.560943N; 124.353851W).

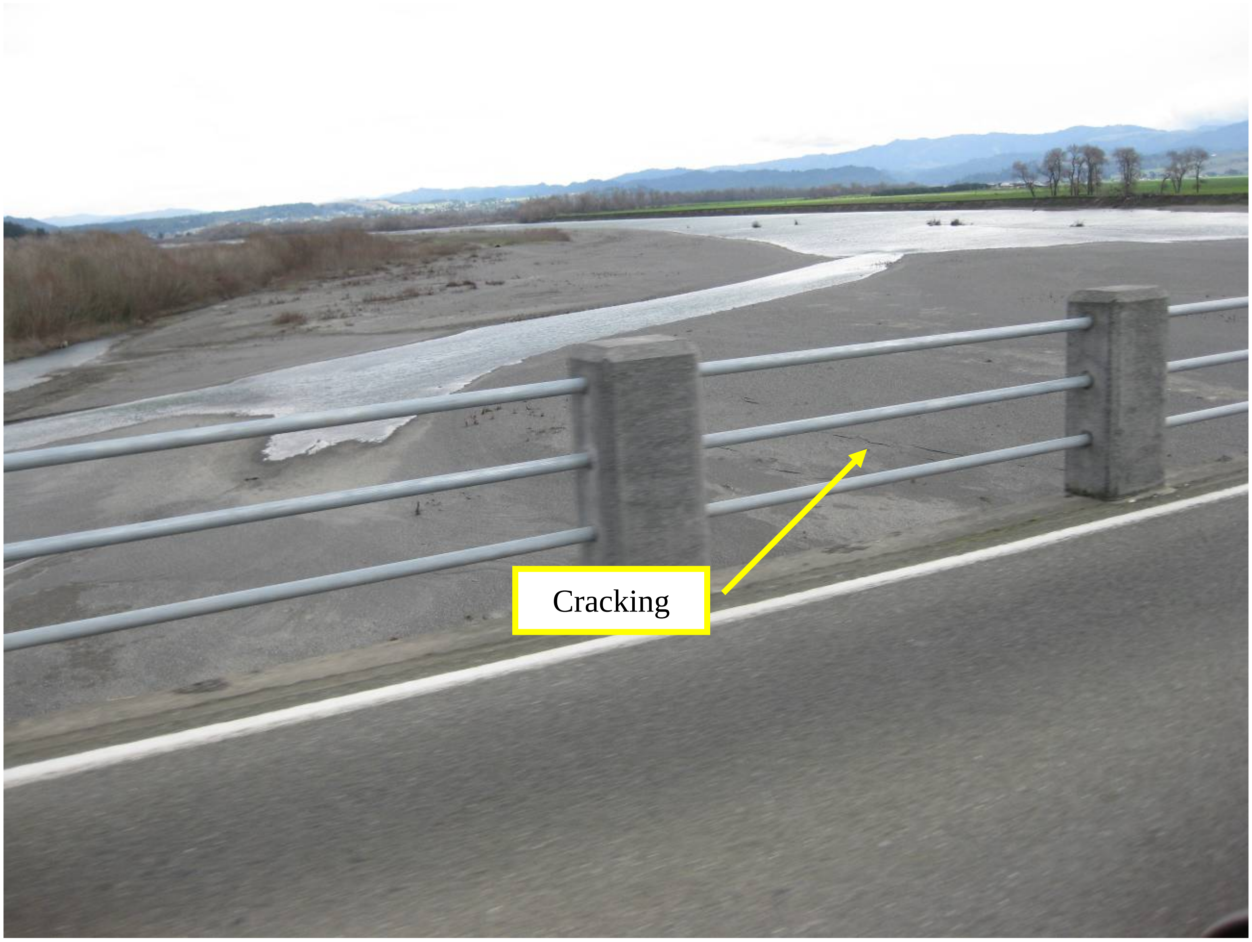

Figure 25 Ground cracking was observed in the Eel River channel near Fernbridge. This gravel bar was inaccessible by foot (channels on either side) and Fernbridge is a narrow two lane bridge without any pullouts, thus, additional information was not able to be collected at this location. (40.613716N; 124.202568W).

Seismic Response of Structures

Contributed by Dr. Stephen Mahin

The seismic response of structures in the epicentral area was evaluated through ground reconnaissance by the GEER team. A detailed first-person account of the damage and observations was made with the purpose of documenting important features of the structural damage, or lack of damage, from seismic shaking. The following section describes this account:

My plan was to go to as many SMIP instrument locations as possible, and to spread out from each looking for damage. I flew up, arriving at the Arcata Airport near McKinleyville at 8:30 AM and began looking, from North to South, until it was too dark to look any more. It was raining by late afternoon. In my travels, I kept an eye out for any repair or construction work that was going on, and stopped by several electrical substations, and other structures of interest. Generally, there was very little evidence of any earthquake related construction or repairs underway.

It must be recognized that what follows is based on the observations of one person, and I may have missed some important damage.

Overall, most of the people I talked to in Eureka said that the shaking was quite violent, stronger than any previous earthquakes that they had experienced. They said that at their homes (I did not see them) a lot of material fell off of shelves and cracking of partitions/ceilings occurred, but no structural damage developed for those individuals I talked to. Even though most people I talked to said they had been through several previous earthquakes, of the half dozen offices and residential units I went through, no one had bolted bookshelves and similar cabinets to the walls. Nonetheless, only a few cabinets of bookshelves toppled (mainly in upper stories). This is of course a limited sample, so it should not be taken as a generalization. One person I talked to said the chimney on their house toppled, but I did not see it myself. This was the only incidence of chimney damage I saw or heard of.

I tried to keep an eye out for signs of liquefaction or lateral spreading. Eureka has an enormous coastline and many marshes. Thus, there is a potential for a lot of liquefaction, but I did not see any significant evidence of it where I looked (waterfront in Old Town Eureka, Samoa Island, etc.). I am not an expert and my search was not comprehensive. There is evidence of small amounts of subsidence and lateral movement at Ray's Grocery and at the adjacent Bay Shore Mall.

With regards to damage to structures, I saw virtually no major structural damage and very limited exterior cladding damage, even in areas where ground motions were on the order of 30%g (except for URMs). This held for older RC buildings, some with short columns, and for wood buildings of various types. There was moderate to serious content and interior partition damage in some buildings. In other buildings, there was little damage to contents (including falling damage).

One reason I visited Eureka was to look at older wood building, especially ones supported on cripple walls. These are ones related to Plan Set A. There were many buildings of this type, ranging from old Victorians to perhaps 1970s-vintage houses. I was not able to find many seriously damaged buildings of this type, although at least one case (2135 California Street, Eureka, California) was documented (Figure 26).

Figure 26 This home was knocked from its foundation (2135 California Street, Eureka, California).

There are also more modern, multistory wood buildings. The two below (Figure 27) show extremes of wood buildings. Neither building appeared to be damaged from looking at their exteriors.

Figure 27 Many types of multistory wood buildings were undamaged.

There are also lots of mobile homes. Many of these had no lateral bracing, and in most, it was difficult to see if there were lateral bracing, but my guess is that there was no lateral bracing due to the age of the mobile homes. I looked at four parks, two north, one in, and one south of Eureka. I was not able to see any damage that looked like it was caused by this earthquake. There is evidence of lateral movement at the base of some mobile homes (Figure 28), but it looked old. The vertical supports under the end of the mobile home on the far right appeared to predate the earthquake.

Figure 28 Evidence of lateral displacements on mobile homes in the Eureka area.

Eureka also has many URMs (Figure 29). These range from one story to three or four stories tall. Most of these buildings had little apparent exterior damage. I found two that had broken windows at front at the ground floor level. I was able to go into two three story URMs and there was lots of cracking of interior lath and plaster walls and ceilings, even though the exteriors did not look too damaged. There are two large URMs in Old Town that are cordoned off. One lost a parapet that fell into an adjacent building. The other seems to be leaning slightly into the street. I was told by neighbors (not necessarily a reliable source of information) that both had been given deferments for meeting the URM ordinance. I saw no classic examples of "X" cracking or similar structural damage in the masonry.

Figure 29 Damaged URMs in downtown Eureka.

I spent a lot of time in St Joseph's Hospital. There will be a lot of useful information coming from these buildings. The hospital seems to have grown in stages, and they have ended up as one large organic building (vs. separate buildings). The first was done in the 1950s. I understand that there was additional addition in the 70s and two more in the 1990s. There is an old concrete frame, a concrete shear wall building, a tilt up, and a 1998 steel moment resisting frame. Most of the damage to nonstructural elements was cosmetic, especially at the various expansion joints (only perhaps 2 or 4 inches in dimension), especially those adjacent to the steel SMRF.

A water supply pipe started leaking in a mechanical room in one wing, but a nearby valve was shut off. Two 6000 gallon, plastic, auxiliary potable water tanks broke (they had a concrete restraining ring around their base and this seems to have sheared the plastic at the top of the ring). There was some damage to an evaporative cooler, but there was an active debate underway as to whether this pre-dated the earthquake. The elevators were not damaged, but the elevator company needed to restart them following the earthquake. The fire and other alarm system needed to be reset.

There seemed to be excellent planning and implementation of a plan for response and recovery. An interesting note is that the 1997 steel SMRF has significant damage to the nonstructural gypsum wallboard around stairs. Damage to nonstructural elements in this part of the building is increasing during aftershocks. There appear to be 11 accelerometers in the 1978 RC shear wall building addition, and three more adjacent free field instruments. The peal base acceleration was 29% g, the free field was 33%g, and the roof acceleration was 1.18g according to CSMIP. The hospital currently is in the process of adding a large three story steel SCBF building, and the hospital services will move into the new building in the Spring of 2011. There is no evidence of damage to the new building (Figure 30) and the braces do not appear to have yielded or buckled. The engineer for the new building (KPFF-LA) was arriving in the afternoon, and after examining the new building, he was going to look at the other parts of the building, especially the SMRF.

Figure 30 No evidence of damage to the new building (St. Joseph's Hospital) and the braces do not appear to have yielded or buckled

I looked at the residential and commercial construction near the hospital. The houses do not appear to have any damage, even ones on cripple walls. There is a shopping center a few blocks away (corner of Harris and Harrison Streets) that had a Safeway grocery story that had two broken windows (Figure 31).

Figure 31 A Safeway grocery store with two broken windows.

I also looked at several bridges (Samoa Bridges), in particular the Middle Channel Bridge studied by PEER, and the Eureka channel bridge, and outer harbor bridge (Figure 32). These have all been retrofitted, and two of them have instrumentation by CSMIP. Peak accelerations are about 26%g-28%g. There was no evidence of any damage, other than very minor working at the end expansion joints and some cracking in the end diaphragms, used to restrain the precast concrete I-girders.

Figure 32 There was no evidence of any damage to the Samoa Bridges, other than very minor working at the end expansion joints and some cracking in the end diaphragms, used to restrain the precast concrete I-girders.

I ended the day trying to look at the Rio Dell bridge, but I could not find a way to get under the bridge legally. It is in operation, and seems undamaged (there is a slight bump on the north end, but that may have existed for some time). There is not evidence of any damage to other largely RC bridges that cross over Highway 101. In the morning, Caltrans was clearing a large tree that had fallen on the freeway near Arcata.

Other sites of interest, or near instruments:

- Arcata Airport: A new RC building with a Glulam and timber roof. No damage. I asked maintenance workers, and they said there was no damage elsewhere at the airport.

- Humboldt State University (Arcata): I did not see any damage. Students questioned said that they knew of none. Peak ground acceleration was 8.6%g.

- Woodley Island Marina: There is a large Marina on the island off of Eureka (Figure 33). There are several small wood buildings (NOAA, Corps of Engineers, Coast Guard, Harbor Master, restaurant, etc.). Inspection of these buildings did not reveal any damage. Occupants said they had minor falling of contents. The emergency generator at the NOAA weather station worked fine, and their computers continued to work, and the radar was up within 15 minutes on emergency power. The docks did not appear to have any damage, nor did the embankment.

Figure 33 Wood-framed buildings on Woodley Island appeared to suffer no physical damage.

- Substations and power generation facilities: I stopped by several substations while driving around, and saw no evidence of damage or recent repair activity. PGE is decommissioning a nuclear power plan in Eureka. There is work being done on it, but there was no indication that this was related to the earthquake.

- Chevron Oil Docks: There is a pier and numerous large oil tanks. The tanks appear not to have suffered damage, and there was a ship off loading oil docked at the pier. No construction work was in evidence.

- Bay Shore Mall: This is a very large shopping mall. 80% of the mall was closed. There was no evidence of structural damage from the outside, but looking through the windows, it was apparent that large portions of the ceilings, lighting fixtures and HVAC in the common areas has fallen. There were several (but by no means all) items of inventory had fallen on the floor in stores that were visible from the outside of the mall. One store (Kohl's) remained open and had little damage on the inside. The adjacent Ray's grocery, had large amounts of product still being put back on the shelves in late afternoon, large regions of the suspended ceiling had fallen (especially around the edges), and some damage to the floor (differential movement) were evident.

- Ferndale: There seemed to be a lot of nice Victorian houses and commercial buildings that appeared to have soft stories or cripple walls (Figure 34). No damage was seen. CSMIP indicates that ground accelerations as great as 44%g were experienced in this area. CSMIP had not released information on the fire station and bed and breakfast before I left the Bay Area, so I did not look at them specifically, but there was virtually no damage to structures in town.

Figure 34 There seemed to be a lot of nice Victorian houses and commercial buildings that appeared to have soft stories or cripple walls. No damage was seen.

- Rio Dell: I could not go to the bridge, but drove over it. It seems not to have damage. I looked at portions of Rio Dell and there was no evidence of damage where I looked. Due to darkness, I did not go to the nearby city of Fortuna.

Susceptible Structures Inventory Information

Contributed by Dr. Lori Dengler and Mr. Fred Turner

The Humboldt County (CA) Office of Emergency Services and the Humboldt County Emergency Operations Center were activated and conducted assessments and information gathering immediate following the earthquake. The CA State EOC was not activated. About 30 people visited hospitals for minor injuries, and one report of a major injury (an elderly man with a broken hip).

Damage was concentrated along the coast from Ferndale to Eureka and appears to be the result of both distance to the hypocenter and guided energy along the strike of the fault. Eureka, the most heavily impacted city by the earthquake, reported over 600 structures affected and nine with major damage (Figure 35). The majority of damaged structures were single-family homes, and several dozen chimneys were severely damaged or knocked down. Eureka's Bayshore Mall, completed in 1987 and the largest commercial property in Humboldt County, had damage to the suspended ceiling and was closed for four days. Earthquake losses for the county (as of Jan. 14, 2010) were estimated at over $40 million. None of the unreinforced masonry buildings retrofitted after Eureka's 1989 URM ordinance suffered anything more than cosmetic damage.

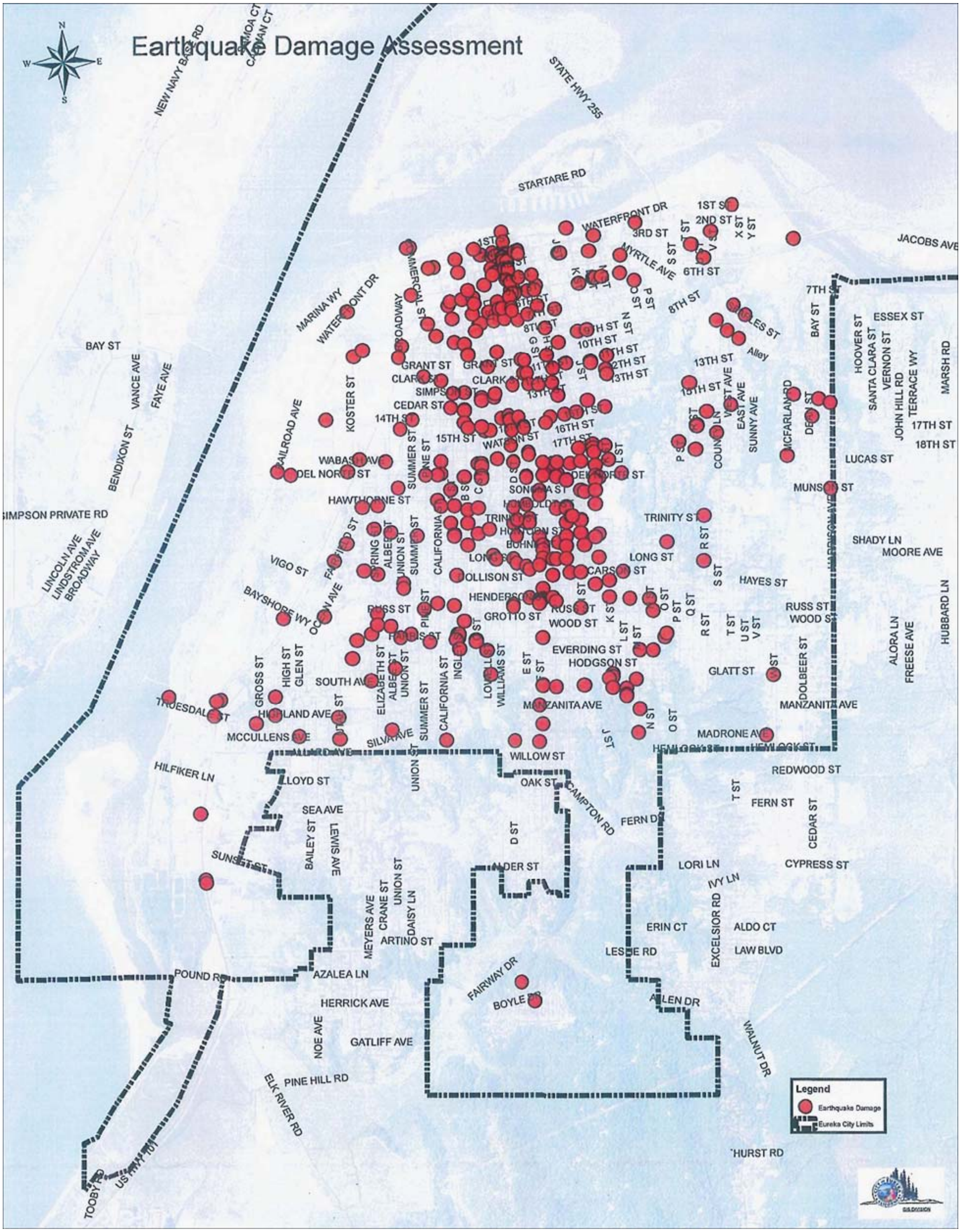

Figure 35 ***Preliminary map of damaged structures in the city of Eureka, compiled by Eureka Fire Department.***

As of 6/2006, the URM's that have not been retrofitted in Eureka are at:

- 211-219 5th St. – Lloyd Building
- 3900 Broadway – Hilfiker Pipe*
- 501 3rd St. Carson Block*
- 215 F St. - Ricks Building*
- 325 2nd St. Six Rivers Brewery Bldg then vacant
- 213 G St. Art Center*
- 503 2nd/123 F St Dunaway Bldg*
- 525 F St. - Rialto Theatre*
- 426 3rd St.*

In 2006, the City Council extended the timeline for compliance with retrofits for the starred building above. The Carson Block was supposed to have submitted permits by June 2006.

An addition 18 buildings out of a total of 27 URM's have been mitigated:

Three were demolished as of 2006, Foot of J St. which was scheduled to be demolished in 2006. Fifteen were retrofitted to UCBC A1, IEBC or their equivalent:

- 632 F St.
- 226 G St. Retrofit completed in 7/99
- 426 3rd St. Retrofit permit was issued in 1996
- 3530 Broadway
- 507 2nd St.
- 525 2nd St.
- 108 F St.
- 211 5th St.
- 238-240 E St
- 407 F St.
- 408-414 F St.
- 203 F St.
- 507 F St.
- 203 E St. – It was listed as a partial retrofit only in 1999, but may be completed now.
- 423 F St. Partial (roof) retrofitted listed in 1990, but may be completed now.

Eureka has the City Council, Mike Knight, the city's Building Official, and Wendy Butler, a reporter for the Eureka Reporter to thank for the amount of mitigation that took place before the earthquake. The City's overall mitigation rate was 67 percent as of 2006, that is 18 out of 27 buildings either retrofitted or demolished.

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