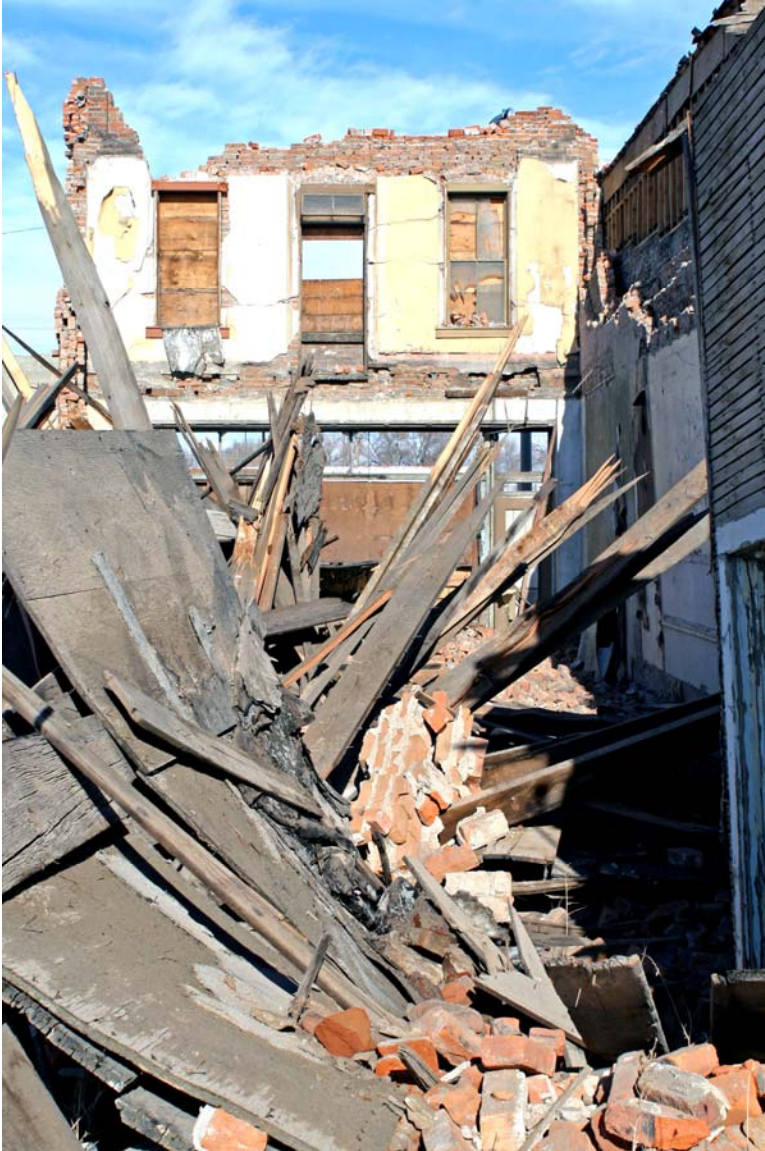


**Observations and
Reported Effects
of the
February 21, 2008
Wells, Nevada
Earthquake**



Observations and Reported Effects of the February 21, 2008 Wells, Nevada Earthquake

Preliminary Live Report, 3/15/08

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This is a living report. It is being put out in a timely manner to assist in the understanding and research effort taking place on the 2008 Wells, Nevada Earthquake. Not all facts have been double checked and much of it stems from conversations and interviews conducted in the field. Part of this posting is for all to review the account of the earthquake and get the facts exactly right while they are fresh in everybody's mind. **Users of this report should bear in mind that details may change as people help refine the report. Information should be considered "PRELIMINARY and SUBJECT TO CHANGE."**

The next version of this report will be released in about a month and comments on this report or corrections to it should be submitted within the next week if possible to cdepolo@unr.edu. I may update this report any time it is deemed important to do so.

This is only part of the story of the Wells Earthquake, and major parts are missing, such as a list of the response and relief agencies. This initial draft is biased towards what I directly interacted with, and many important people, aspects, and efforts have not been discussed yet. Please do not feel intentionally left out.

I've tried to protect my sources in this report. This is probably especially important in a small town, where it is unfair to inject some inference about a person or agency. Nevertheless, I have to use the instances of Wells as a basis for discussion. The intent here is to help us respond as well or better to an earthquake disaster like the Wells Earthquake in the future and help our communities recover from the earthquakes they may eventually experience. Only public figures are specifically referenced.

Days following the earthquake are referenced to the day of the earthquake being "day one." The following days are designated "day two," "day three," and so on.

Introduction

The Earthquake occurred at 6:16 a.m. PST (14:16 GMT) on Thursday, February 21, 2008. Most of the people of Wells, Nevada were well into their mornings by then and many were at work. Wells is a small, rural town, but it has 24-hour

elements because Interstate 80 passes through it. People are generally close to or know one another there and face hardships together head-on.

The earthquake had a moment magnitude 6.0 (a “strong” earthquake) and the epicenter was about 5.5 miles (9 km) to the northeast of Wells, Nevada. Rupture of the earthquake fault was partly towards Wells and likely came much closer to this community than this distance indicates. The shaking was very severe in town and was more of a rolling motion a few miles south of Interstate 80. [Figure 1](#) from the Nevada Seismological Laboratory shows the epicenter and aftershocks recorded on the first day following the earthquake.

There were no immediate foreshocks recorded before the event. A small earthquake swarm with magnitude 3.7 and 3.1 events had occurred on February 28, 2007 in the same area as the 2008 Wells Earthquake.

The Wells Earthquake was a normal dip-slip event. It was oriented (or had a strike) in a northeast direction, but whether it tilted (or dips) in a northwest or southeast direction is still not well defined at this time.

Virtually everybody who felt the earthquake has commented on the sound preceding or during the event. The most common comparisons are that it sounded like a train derailing or a truck crashing. In one place by Interstate 80 they said it sounded like a bomb went off and people initially thought a truck carrying a bomb had crashed.

The Wells Earthquake occurred in an area of moderate earthquake hazard. [Figure 2](#) shows the probability of an earthquake having a magnitude of 6.0 or greater within 50 years and 30 mi (50 km) of any point on the map (please see <http://www.nbmq.unr.edu/eqprob/eqprob.htm> for further information. Wells lies in the category that has a 6% to 10% chance of having a magnitude of 6.0 or greater within 50 years and 30 mi (50 km), near the 10% boundary.

The 2008 Wells, Nevada Earthquake is an important event to understand for the Basin and Range Province because:

- it is a background earthquake or lower-limit design earthquake,
- it occurred in an area of moderate earthquake hazard.
- it is a well-monitored normal dip-slip event, and
- it gives insight into the rural earthquake disaster.

Every community in the Basin and Range Province should be able at minimum to withstand an earthquake of this size and plan to recover from such a disaster with the wellbeing of the community intact. The people of Wells and Elko County have graciously assisted scientist in measuring the aftershocks and allowed us to examine earthquake effects, and observe them so courageously manage this major incident, so others can be better prepared for their earthquake disaster.

Background

I joined the Nevada State Damage Assessment Team early Thursday afternoon and was in Elko by Thursday night (2/21/08). I arrived in Wells Friday morning and spent eight days over the first 16 following the event in the town of Wells (days 2, 3, 7, 8, 9, 14, 15, and 16). I accompanied Nevada Division of Emergency Management and FEMA personnel in their initial damage assessments, attended the morning operational briefings, gave geologic/scientific information and background, answered a wide variety of questions, conducted rumor control, advised in some placement of caution tape (moving it further out), photographed damage, talked to or interviewed over 60 people, and advised the people looking for cracks. I conducted searches for cracks myself on cross-country skis and walking traverses, measured the tracks of objects that slid during the earthquake, and continued interviewing people and making observations about recovery. I have also been serving as coordinating scientist and briefed the Elko County Commissioners on the earthquake.

Quaternary Faults in the Wells Region

Quaternary faults are those that have moved in the last 1.8 million years. Most of these faults have not been studied but have probably moved more recently. In Nevada, it is important to pay attention to any fault that has produced an earthquake in the last 130,000 years.

Earthquakes of the size of the Wells Earthquake might crack the surface or show small ground offsets if the earthquake is shallow enough, but it can also be buried within the Earth's upper crust and not have any distinct surface expression.

Wells lies at the boundary of two regions of Quaternary faults, the "Northeast Nevada Highlands" and the "Shoshone Extensional Area" of dePolo (1998) and dePolo and Anderson (2000), shown in [Figure 3](#). The Northeast Nevada Highlands has less disruption of the geology by Quaternary faults than most of Nevada, indicating a lower overall earthquake hazard. The Shoshone Extensional Area, in contrast, is characterized by many long, range-bounding faults. Faults in the Shoshone Extensional Area appear capable of larger earthquakes (because they are longer) and may have earthquakes more frequently than faults in the Northeast Nevada Highlands, but caution is warranted in these generalizations because most of the faults have not been studied in detail.

The distinction between these two regions fits what we know about the younger faults in the Wells area (those that show geologic evidence of the most recent earthquakes). There are large, range-bounding faults to the south of Wells.

Around and north of Wells are smaller faults within flats or bounding hills and small ranges.

Areas that are near the ends of major range-front faults, like the Ruby Mountains fault system, are commonly broken into many smaller faults. Wells can be considered to be near the end of a couple of range-front faults and distributed smaller faults related to these may help understand earthquakes in the Wells areal.

There are three major faults immediately south of Wells, the Ruby Mountains fault system, the Eastern East Humboldt Range fault, and the Independence Valley fault zone ([Fig. 4](#)).

The most prominent and the longest of these three faults is the Ruby Mountains fault system. This fault system consists of three normal dip-slip fault zones bounding the northwestern side of the Ruby Mountains and the southeast side of Starr, Lamoille, Pleasant, and Huntington Valleys. The system is 69 miles (~115 km) long, but can be broken into parts and might not rupture entirely during a single earthquake.

The Ruby Mountains fault system was studied by geologists from the Center for Neotectonic Studies at the University of Nevada, Reno. They found the last earthquake on the northern part of the Ruby Mountains fault system to be between about 4,800 and 7,600 years ago and to have offset the ground by 3 to 8 feet (1-2.5 m) (Wesnousky and Willoughby, 2003). This amount of offset indicates this was a major earthquake of about magnitude 7.

The Independence Valley fault zone bounds the eastern side of Independence Valley and the western side of the Pequop Mountains and was also studied by scientists from the Center for Neotectonic Studies. They found a paleoearthquake offset of about 10 feet (3 m) and by modeling the erosion of the fault scarp they studied, estimated the last earthquake to have occurred roughly 40,000 years ago (Wesnousky and others, 2005). A major, magnitude ~7 earthquake is indicated by the 10 feet (3 m) ground offset.

Specific studies have not been conducted on the Eastern East Humboldt Range fault.

In the Wells area, and in northeastern Nevada, are smaller fault zones that can produce damaging earthquakes, as the Wells Earthquake so clearly illustrates. Some faults were mapped in Town Creek Flat (the flat that Wells lies on the southwest edge of) by Dohrenwend and others (1991) and most recently by Alan Ramelli (2008, preliminary web report) of the Nevada Bureau of Mines and Geology to support the Wells Earthquake research. These are relatively short faults that may be part of an overall zone, but they have not been studied beyond preliminary mapping.

The Wells Earthquake occurred on a northeast-striking or north-northeasterly striking fault plane based on focal mechanism studies (these are analyses of the nature and shape of seismic waves recorded on seismometers); the nearly pure normal motion limits the range of possible fault strikes. The direction of dip is still not confidently resolved at the time of this writing, but is either to-the-northwest or to-the-southeast, and appears to be a moderate value of 40° to 50° (Dreger and Ford, 2008, preliminary web report). The aftershock pattern is located within Town Creek Flat.

Aftershock Studies

The aftershocks of the Wells Earthquake are being recorded in exquisite detail thanks to the combined efforts of the Nevada Seismological Laboratory, the Utah Seismograph Stations, and the U.S. Geological Survey, and the citizens and local agencies of Wells and Elko County. Under relatively challenging conditions for all involved, scientists, technicians, snow-cat drivers, sheriff's deputies, and others installed 21 seismometers into the local area starting within the first day and completed within a week, and telemetry of these stations was set up rapidly following their installation. This information is not only going to be beneficial for the science of earthquakes and designing future buildings in Nevada with better earthquake resistance, but it should help future builders in the Wells area to understand some details about how the ground shakes from earthquakes.

Please see the University of Nevada, Reno Nevada Seismological Laboratory's web site at (<http://www.seismo.unr.edu>) and the University of Utah, Seismograph Stations web site (<http://www.seis.utah.edu>) for further information.

Emergency Response

The emergency response effort on this earthquake was well executed and, in my view, 100% effective or nearly so. This is a very important statement. It is credited to a group of can-do Wells citizens who reacted quickly to the situation and outside people putting their egos, territories, and personal needs aside and doing what they could to help the citizens of Wells and Elko County. People did what they did best profession-wise. Responders used good judgment so that risks taken seemed appropriate. It is significant that although this earthquake caused major damage to some structures and widespread nonstructural damage in Wells, it was a manageable earthquake. I suspect that an energy release a half a magnitude larger might have begun to overwhelm the response in place. Several people felt that had the strong shaking continued a few seconds longer much more damage would have occurred. There were also some instances of happenstance where people could have been in a different area, such as where they were the morning before, and been injured by nonstructural hazards. In

addition, had this earthquake occurred later in the day when the damaged buildings would have been occupied, the medical services would have been much more challenged and deaths would likely have occurred.

Outside help began to arrive on scene in Wells within about 40 minutes; Elko is the nearest major community at about 50 miles (80 km) distance.

The incident command system used was relatively smooth and effective. Most of the individuals had worked together before on wildland fires and knew each other on a first-name basis. The incident commander for the first few days was an articulate, smart, energetic, knowledgeable, and well-trained individual, which helped to inspire the effort. This individual happened to be only about 50 miles (80 km) away when the earthquake occurred and was able to take over quickly, which contributed to the response running smoother. The incident command center was set up in an Elementary School classroom ([Fig. 5](#)). The school was also used as a relief center and a support facility for the relief operation. There was a very positive, can-do energy about command center, the relief operation, and all the responders. Operations were reduced and moved on Sunday (day four) so the school could be readied to resume on Wednesday (day seven)

The County Sheriff noted that the fire and law enforcement personnel worked particularly well together during this response. This made these elements of the response, such as the search for injured people or gas leaks, faster and more efficient. Deputies worked for fire fighting teams and fire fighters worked for the deputies' teams. Addressing the emergency was job one, period.

To some degree the people of Wells may view the response from outside as larger than needed, especially with the desire to quickly get into the recovery mode. This really wasn't the case. The earthquake was bad, there is no question about that, but it could have easily have been much worst, and overwhelmed the response system in place. A larger and longer earthquake could have caused multiple fires, and likely would have caused serious, life-debilitating injuries, or deaths. Further, there is rarely a complete scope of exactly what has happened in the fog-of-earthquakes and it is better to error on the side of safety.

Most, if not all, of the initial response, however, was carried out by the local emergency responders and the citizens of Wells. The outside help came in and augmented the local effort. Volunteer firemen, utility experts, sheriff's deputies, Nevada Division of Forestry personnel, and U.S. Bureau of Land Management personnel, all from Wells or surrounding communities responded to incidences and searched door-to-door in Wells for injured people, possible gas leaks or fires, and dangerous buildings, using a spray painting scheme to keep track of where had been searched. These people were skilled, had good judgment, a worked well with the resources they had. The local responders did a remarkable amount of work in a very short time. They were focused and dedicated, and responded without fully knowing their own losses.

While inspecting the high school we smelled an odor in the science room coming from the direction of the chemical locker and called it in ([Fig. 6](#)). A HAZMAT team arrived within about 10 minutes with a plan and equipment, and set about inspecting the spill and cleaning it up.

There was a lot of comprehensive, detailed thinking, such as installing smoke detectors in the evacuation areas and checking on and taking care of house-bound people (helping clean up their houses, shoveling the snow off of driveways).

There was a careful, yet heroic response to a dangerous liquid propane leak, coming out of a 500-gallon (1.9 kL) tank that was approximately 60% full. The earthquake rolled a propane tank upside down stopping at and breaking off the hand-wheel of the valve and breaking the POL fitting where the hose was hooked to the valve. The tank began to spray liquid propane on the ground, creating a ground-hugging vapor cloud of propane. The tank was being used to heat a construction site and three other tanks were connected to heaters at the site as well. The power was also on in the under-construction facility, which is located next to Interstate 80.

A volunteer fire crew arrived within 5 to 10 minutes at the site (men ignoring their own situations for the greater good). The situation was immediately perceived and the fire department took up a position about 250 yards (225 m) away. A Wells Rural Electric electrician was part of the volunteer crew and went to get equipment to cut the power and a Wells Propane technician who was familiar with the site was called.

The propane technician arrived within about 5 minutes of being called and took proactive steps that were tactically careful, but brave in my opinion nonetheless. When he arrived the cloud of propane was about 3 to 4 feet (~1 m) deep, and about 40 to 50 yards (36–45 m) in diameter. The technician was able to go around the perimeter of the propane fog and approach the back side of the tank. About that time the technician heard the propane heaters were burning inside the building and proceeded to turn off the other three propane tanks, cutting gas to the heaters. He stuck his head inside the building and noted the heaters were off, but the power was still on.

The propane service technician with 25 years experience was trained in working with propane vapor clouds and knew the flash point of the cloud and where the possible sources of ignition were. So he carefully approached the tank that was still spraying liquid propane and with a 2x4-inch (5x10 cm) board was able to tip it 20° to 30° before the weight caused him to lose his footing in the snow. At that point he saw the valve stem was broken off and couldn't just reach in and turn it off, so he backed away, back to the watchful and ready fire crew. The Wells

Rural Electric electrician arrived back on scene and turned off the power to the building, and Interstate 80 had been closed by the Nevada Highway Patrol, so ignition sources for a wide perimeter were gone. The Highway Patrol was also evacuating a nearby truck stop. The cloud was drifting and dissipating in a favorable direction, the leaking tank was gradually becoming lighter in weight, and there were two other potential gas leaks to check on, so the technician left to secure those with the fire department monitoring the situation.

After checking the other two reported leaks (neither of which was real), the propane technician returned and approached the tank again with two 2x4-inch (5x10 cm) boards and was able to roll the tank up so that the valve was above the vapor space of the tank, and the tank switched from spraying liquid propane to spraying propane gas and began to stabilize. At that point the technician noticed there was a tiny piece of the valve stem visible and he turned the valve off by gripping the stem with a pair of channel-lock pliers, stopping the leakage. They waited 10 to 15 minutes for the propane cloud to dissipate and then allowed traffic to flow again on Interstate 80.

Early on, the town was closed to all but locals and response professionals by the Nevada Highway Patrol, and it was kept closed for about two days. After reopening the road, law enforcement kept a visible presence along the main road and in old town. School busses were used to block streets with hazards, such as the road with the water main breaks ([Fig. 7](#)).

There were no fires associated with the Wells Earthquake. There were three situations where propane leaks could have led to a fire, but these leaks were stopped by local people.

There were at least two communication difficulties associated with the emergency response. The first was the dependence of the Wells Volunteer Fire Department on cell phones for communication. Cell phones were operating but there was a saturation of the available lines. Plans are being made to switch the volunteer fire department to radios for emergencies. The second challenge was the use of two radio systems, 800 Mhz and VHF, that initially could not talk to each other. This was solved on day two by a Nevada Department of Transportation communications expert who patched the two systems together. As far as I know, these communication difficulties were only a serious nuisance and did not result in any exacerbation of incidences.

By days two and three, extra response personal were helping clean up home-bound or elderly people's homes, and taking down precarious chimneys. Fire personnel were inspecting chimneys so people could resume using their wood stoves.

Injuries

There were three reported injuries and one case of trauma caused by the earthquake. As far as I know, there have been no injuries during the emergency response and early recovery activities.

One girl had her arm broken when an object fell on it during the event. Her arm was set in a temporary cast and she went to Elko for x-rays. A man had a head laceration from a falling object and had stitches sewn by the local doctor. One boy reportedly slipped on the ice when going to turn off the propane to his home and injured his leg; he did not enter the response system. There was one lady who was traumatized and was having difficulty breathing.

Injuries were caused by the fall of nonstructural objects and slippage on ice during an individual response to the earthquake. Many were unsettled or scared from the earthquake, and at least one lady had a bit of a panic attack.

Damage Assessments

I don't have any of the initial damage assessments, but I want to report about how it was done. I may have some details slightly off here on exactly who did what (such as whether there were additional people).

The first emergency response consisted of firemen and law enforcement officers canvassing of structures for injured people, broken gas lines, and precarious damage. The comment was made by one of the responders that people were generally more comfortable with fire services coming to their door to check on them in this rural environment.

The first resource for indicating the condition of a house or building on the first day was spray painting the snow with circles for checked and ok, circles with "X"s checked and damaged, and circles with "?"s for uncertain. The responders didn't want to paint on the house. That night it snowed and covered most of the spray paint. The next day they used flagging instead of spray paint. They had "candy striped" (red and white), orange, and green tape available ([Fig. 8](#)). At times, this was a bit confusing (orange and green together meant nobody was home and orange looked a bit like red) and the flagging was generally difficult for the public to understand. Placards began to arrive on Saturday (day three) – some placards were earthquake specific and some were not.

An adequate number of green/yellow/red Earthquake Disaster Placards for a major disaster in a community should be stored in each county with county

personnel who can deliver them within a day of the earthquake to an affected area (before the next morning's operational meeting would be tactical).

Within days all homes and buildings in Wells had red, yellow, and green earthquake placards, placed by inspection teams ([Fig. 9](#)). These teams were made up of local, Elko County, and other Nevada and Utah public and private building inspectors. There was re-inspection of some structures after major aftershocks as well.

Directions of Sliding Objects in Wells

I tried to document the sliding direction of objects in an effort to have information for understanding the earthquake wave pulses that might have caused damage in Wells. The preliminary results of three locations are given.

High School Woodshop

41°06.548'N 114°58.214'W (location outside to the east of the shop)

I measured seven items that slid or walked ([Figs. 10–18](#)). The directions they slid varied from 261° to 291°. Three and possibly four pieces of equipment showed evidence of slight counter-clockwise rotation (<10°?). It was difficult to measure and project magnetic north into the building and there is an uncertainty of +/-10° in measuring magnetic north. The overall direction of sliding of this equipment can be characterized as in a direction of **271° +/-10°**, or just about due west (corrected to true north). Most equipment was free standing and not restricted. Most items slid 4.5 to 10 cm in a relatively smooth track. An exception is the radial arm saw table that has rubber feet ([Fig. 19](#)); its track showed hesitations (stick-slip motion?). And some equipment appeared to walk. The floor was smooth concrete (smooth to the touch) with some sawdust on it. The sawdust appeared to be cleared out of the track.

Station Class RTE AS Transformer at substation west of town

41°06.782'N 114°58.661'W

This transformer weighs 102,000 pounds (46,200 kg) and made tight an electric cable on top and a ground wire cable on bottom. The transformer was rotated clockwise on its pad ([Figs. 20 and 21](#)). The southeast corner moved 14 cm in a direction of **260°** and the northeast corner moved 11 cm in a direction of **245°**. There is 171 cm between these two corners. It is on an even-surfaced concrete pad. These measurements are **+/-10°**.

A 92,600-pound (41,950 kg), unattached transformer sitting not far from the measured one did not appear to move.

Industrial Water Heaters at Truck Stop north of Interstate 80

Two water heaters moved at the truck stop and casino on the east side of town. One heater had been moved back, but the technician who moved it back showed me what he had done, and the other was still in its slid position. The latter was at:

41°06.054'N 114°57.379'W

The filled 100-gallon water heater slid in a direction of **175° +/-10°** about 9.5 to 10 cm ([Fig. 22](#)). It was restricted at the top by rigid piping that pulled along with the tank. The floor was an even, semi-smooth concrete with some rust.

The other water heater moved in a similar, if not exactly the same, direction and had flexible hosing.

General Damage

This earthquake is a distinct example of an earthquake that damaged vulnerable structures ([Figs. 23–26](#)) and did limited damage to modern, well-built, or reinforced structures ([Fig. 27](#)). Many unreinforced masonry buildings (URMs) in the old town area were severely damaged with partial and total failure. But many of these buildings had fallen into disrepair long ago and were weak to begin with. There was some revitalization of a couple of buildings in old town and these buildings seemed to do better during the earthquake.

Overall most homes and buildings appeared to survive the earthquake structurally ok ([Fig. 28](#)). There were cracks in walls, plaster, and tile within homes ([Fig. 29](#)). At least two homes appeared to have significant damage with walls that are possibly detached from their roofs or some wall collapse ([Fig. 30](#)). The high school auditorium and gymnasium have some damage to ceiling-beam connections at bearing walls, cracks along the edges of infill walls, other cracks in walls, a few broken windows, and a large, damaged chimney ([Figs. 31–35](#)).

Some manufactured homes were fell off their jacks, but in general most manufactured homes and buildings remained on their jacks or cinder blocks with shims. Some of these manufactured buildings were shifted or had shims move about an inch (2.5 cm). In at least some cases, these structures are being tied down as they are being fixed

Infrastructure

Wells was experiencing cold nights (~27° F) and cold fronts with snow coming through in February, pretty much a nightmare scenario for exposure from an earthquake disaster. Fortunately this did not develop into a major issue because windows were not generally broken, the power was maintained through the following night (hats off to the local power company!), and the propane tanks and connections were generally ok.

There were some local electric line breaks that caused outages to some blocks, but these were repaired and power was restored to these customers on the first day.

There were some breaks in an old metal-pipe water system, which were being addressed quickly. Water was rerouted, and most residences had potable water, so the water main break (one area with multiple breaks) was being fixed with permanent repairs rather than temporary. There were a few businesses with a “boil water” order.

In general, the sewer system appeared to be intact with some home plumbing failing and toilets backing up.

Union Pacific personnel reported that there was no damage to the railroad system. Nevada Department of Transportation (NDOT) reported that there was no damage to bridges (all were inspected by NDOT whether they were owned by them or not).

Nonstructural Damage

There was widespread nonstructural damage in Wells, but it wasn't complete in many homes. Some had heavy nonstructural losses, but most seemed to have a moderate or light amount of loss. Many homes lost items from only one set of walls (for example the northwest-southeast walls, but not the walls in the opposite orientation). Most people cleaned up on the day of the earthquake or in the following days. Community garbage dumpsters were provided for people to get rid of their earthquake debris.

An example of this limited loss is at the high school, which was obviously shaken substantially. There were three free-standing fish tanks in the high school buildings that were still upright (some aquariums were lost at residences). Generally, most monitors and computers at the high school had not fallen to the floor. Books and other objects were thrown to the floor in classrooms, but it didn't appear to be complete and some classrooms had little nonstructural damage.

The shelves were emptied of many items at the local grocery store. Watching video of the store shows that most of the items were knocked off the shelves in one or two pulses.

At a local bar located across the alley from damaged URMs, only 18 bottles fell and broke. Bottles are stored there from counter height and lower. There was a report of lost stock in a liquor store room at one business, which is now installing retaining rails on the liquor shelves.

About 58 chimneys had damage or toppled within the town of Wells. Most were older brick chimneys or were slender and tall ([Figs. 36–42](#)). Modern or well reinforced chimneys fared well. In some cases, stove pipe inserts into brick chimneys appeared to help chimneys maintain integrity and not fall, even though some bricks were dislodged. All the stove pipes I observed did very well during the earthquake. Fireplace stove inserts, wood stoves, and gas-stove false logs were commonly displaced a few inches by the earthquake; these were pushed back in place by residents or support personnel. Emergency responders and support people were asked to keep a list of peoples' needs, such as displaced stoves, and report these to the relief operations.

There were a few buildings that shed brick fronts or parapets, in a fashion that people running out of buildings or down alleys could have been badly hurt or killed ([Figs. 43–48](#)).

In general, windows in homes and businesses were not broken. This helped protect against the cold in the evenings.

There were several slot machines toppled by the Wells earthquake. Most of the machines were saved by the chairs in front of them ([Fig. 49](#)).

In one case a china cabinet was anchored to the wall. Things fell off the top of the cabinet, and things were rearranged inside the cabinet by it stayed up and items inside it were not broken.

Propane Tanks and Water Heaters

I observed and photographed many propane tanks because there is a question in Nevada right now about whether propane tanks should be anchored. Propane tanks in the Wells earthquake were generally undamaged. There was a major propane leakage at a truck stop that was under construction, and a few connections within homes that were broken, but there was no other damage. According to Wells Propane, the truck stop failure was due to an unapproved move of a 500-gallon (1.9 kL) propane tank for construction purposes; there was no damage outside of the tank valve connection and hand-wheel. The tank was being used to fuel propane heaters at the construction site. The tank appeared to

have been temporarily put on a snow bank and it rolled upside down (~180°) during the earthquake, breaking a POL connection at the valve, being stopped by the valve, and breaking off the valve hand-wheel. Propane liquid was spraying out of the tank. Propane has a very high expansion ratio (270 times) and a propane vapor ground-fog cloud was forming. Wells usually has at least a light breeze, but on the morning of the earthquake, the air was relatively still. Thus, the 3- to 4-foot (~1-m) deep propane cloud stayed in the area. This was a very dangerous situation and there could have been a conflagration if something went wrong. Please see the discussion of the emergency response to this tank for more information on how it was mitigated and the leak secured. It is felt that if the tanks were moved in a safer manner, there would likely have been no incident at all. Again the only consequence of this incident was a connection and valve hand-wheel on the tank and spilled propane.

I observed many propane tanks for residential homes and businesses and none had failed and only one had slid on its blocks a bit ([Figs. 50 and 51](#)). This included propane tanks in the damaged old town district, which hadn't moved at all as far as I could see. Wells Propane was systematically inspecting all the propane tanks and gas systems in town, and only found that a couple tanks may have shifted an inch (2.5 cm) at most.

Wells Propane found three leaks in factory-installed piping in two manufactured homes. In both cases, the owners turned off their gas immediately. At least one break was at an elbow that was reducing the line diameter from 1 to ¾ inch (2.5 cm to 1.9 cm) and another at a ¾-inch (19 mm) "T" connection. Systematic leak tests have turned up a few leaks that were very minor (not enough to keep a pilot light going) and these were secured (some may have existed before the earthquake). The propane tank at one building was found to contain less fuel (20%) on inspection than the computer projected it should be (55%). A pressure test at that facility revealed no leaks, however, and the discrepancy was deemed to be the result of the very cold winter.

Wells Propane technicians noted one water heater had fallen and others had shifted; when asked about anchoring of propane tanks, they said that bracing of water heaters was more important. In one case, a water heater braced with plumber's strap, screws were pulled through the strap, and sheet metal screws were pulled out the tank (but the plumber's strap probably kept the heater in the cabinet, nevertheless). In one case a water heater broke the water line in the basement of a volunteer fireman. He didn't discover it until he returned from working the emergency response, and pumped the water out himself.

This is a general success story for propane tanks (despite the potential incident that it is felt could have been avoided). But before we get too confident that the questions of propane tank anchoring are answered, common set-ups of propane tanks should be tested on shake tables to see what kind of ground-motion levels (read magnitudes of earthquakes) these can sustain and not fall over and pose a

hazard. An additional level of safety is peoples' knowledge and ability to turn off their gas. They are taught about the smell of propane, how to turn the gas off, and not to be afraid of the gas valve but to respect it when there is a new propane tank installed at a home.

Business Disruption and Effects on Business

Generally all businesses were closed the day of the earthquake and were in the process of cleaning up to try to reopen. A few reopened within days, and most (if not all) were reopened within two weeks.

The local bank was closed until day two. They did have ATM functions on the day of the earthquake, however. All securing systems and locks remained intact at the bank, as designed.

In many cases the employees pitched in to clean up the businesses and get them going again. In one case, employees worked through the night to resume business the next day.

Sociology

Wells is a rural community of wonderful people. The main economy is based on truck stops; travelers spending the night; hunters and vacationers stocking up for an adventure; government services (such as the Bureau of Land Management and Nevada Department of Transportation); and the sustenance of the community. Wells is a community of 1,300 people, of which 64% are low income (keep in mind when you do your building and so forth around your house you need less money). These are people of strong character, but even small losses and recovery/rebuilding are going to be a challenge for most and an impossibility for some.

The loss of the old town area means something significant to the middle-aged and older residents of Wells. They remember when it was an active area (before the freeway bypass) and it is a memorable part of their lives. There was an effort underway to revitalize the old town through the renovation of some buildings and an advertisement of the historical nature of old town. Those involved in this effort may have suffered the largest financial losses. There is a debate as to what to do now with the damaged old town. Although the town has other economic basis, the old town is clearly the heart of the history of Wells. It also seems to be the largest draw for bringing people off the freeway and into town, doing some business as well.

Several people mentioned how much the loss of mementos, gathered over decades and lost in seconds, hurt. Those whose china cabinets stayed up were grateful for that.

I am impressed with how innovative, forward planning, realistic, energetic, and responsible many community leaders were, such as the mayor, the city manager, the school principal, and the volunteer fire chief, to name a few. Their attitudes and efforts have contributed to Wells successful handling the emergency response, the earthquake response (that is, the inundation of Wells with responders – somewhat inserted between emergency response and early recovery), and the early recovery efforts. The community leaders have helped guide the community through this disaster, and have help set the course for a return of Wells to normalcy. This includes the efforts to get children back in school quickly and welcoming and coordinating outside relief efforts coming into the community.

The leadership, commitment, and resources of Elko County were also a major factor in the success of response and recovery efforts from the earthquake. It was an all-out and an all-for-one effort by the county. Familiarity and trust of fellow professionals made most processes go as fast as possible.

Children were out of school and concern was expressed that everybody help watch out for them. Be careful when driving round and help keep them out of trouble. It was noted that kids will be kids and the responsibility lies with the adults to keep them with their natural curiosity out of damaged buildings and the like. They were kept busy in part helping to clean up and being tasked with the distribution of emergency fliers, such as “Public Meeting Tonight ...” or “Earthquake Safety Alert ... if you smell gas.” They had a daily job that was all theirs. Wells children missed only four days of school because of the earthquake, and returned to school on day seven, some in temporary classrooms.

As usual, earthquakes are perhaps the most disconcerting to children, who have less understanding and experience for what is happening. Several children of Wells have had trouble sleeping and eating since the earthquake, and do not want to sleep alone. This was reported to be beginning to ease by days 14 and 15, possibly coincident with the subsidence in felt aftershocks. Not surprisingly, the children and teenagers that have been the most upset were from the most damaged homes (mostly nonstructural) or were home alone waiting to go to school (these might be considered as metrics for determining how many counselors might be needed on the first day returning to school, etc). The children of Wells and the surrounding area have generally come to terms with the earthquake, and have generally been understanding and patient with the adults as they try to deal with the situation (at least they have been “as patient as kids can be”). For example, high school kids no longer have lockers because the high school building is closed and are using boxes or backpacks. The children had excellent role models to watch deal with and recover from a major challenge in

life. School children were subjected to State Standardized Testing three days after returning to school despite appeals for a delay; I wonder if it is hard to concentrate on a test in an atmosphere of aftershocks.

People are feeling a lot of stress from the earthquake and aftershocks. A strong aftershock at midnight around day 6 woke everybody up and most people commented they couldn't get back to sleep following that event. Aftershocks caused additional damage and caused parts of damaged buildings to sway in precarious ways. People appeared to calm down significantly as the aftershocks subsided. Rumors of larger imminent events are not entirely believed, but cause concern until the rumors are countered. Rumor of an imminent magnitude 7 earthquake (promulgated by a news agency) stressed people out. They could handle the small percentage chance of an earthquake occurring over 72 hours, however. Many people looked to, and are watching, various earthquake professionals and agencies for advice on how to best deal and cope with this initially poorly understood earthquake phenomenon.

The mayor's message at public meeting day three (paraphrased): I know you are frustrated and angry. These are negative energies. Let's turn these to positive energies of getting things better. The city manager noted that citizens need not worry about the town limits, if you need help in the outskirts, Wells will try to help you. The people have been accepting and grateful for the neighborly outside help that has helped accelerate early recovery efforts.

It was difficult to keep people from using their wood stoves following the earthquake, even some that were slightly damaged, because in some cases they are the primary source of heat. The fire personnel did their best in these cases to inspect the chimneys, including in the attic, to look for obvious problems. It was very cold and snowy when this event occurred.

The news media came in droves on day one and set up a media alley near old town ([Fig. 52](#)). They used this as their backdrop for reports and interviews, such as with the Governor. After a perimeter of tape was set up, they occasionally appeared to challenge the tape for a picture or dash inside it. They had a difficult time denying their transgression to sheriff deputies, however, because their footsteps were usually left in the fresh snow. By day three the media circus was gone. Day three was a Saturday and the media were replaced by people driving to Wells to see first hand what had happened. Most of these people appeared to be respectful and largely needed to just take it all in for their own understanding.

People seemed to appreciate, and perhaps have a need for, detailed earthquake information. They commonly had aftershock maps or printed listings of the aftershocks. They called the Nevada Seismological Laboratory to let them know when a preliminary questioned earthquake was definitely felt and the question mark should be removed. Several people have learned about the aftershock

decay curve and felt better when the aftershocks occur less frequently as they should.

Surface Ruptures Studies

No surface ruptures from the Wells Earthquake have been found that I am aware of. The ground was frozen at the time of the earthquake, but it was also covered with about a few inches to a foot or so (10 to 30 cm) of hard-packed or refrozen snow. Most of the ground (90 to 100%) was covered with snow and there were intermittent snow showers during the first few days inhibiting detailed searches for surface cracks or disturbance.

Various points have been investigated on the major local faults and some secondary faults within the first 48 hours by field crews from the Utah Geological Survey and the University of Nevada, Reno Center for Neotectonic Studies. Specific reports from these groups will be posted on the Web at <http://www.nbmgs.unr.edu/WellsEQ/CH/index.html> (surface rupture report). I also inspected the northwest part of the fault on the northeast side of Town Creek Flat. I did find a hill where the snow had been apparently shaken violently, causing it to slide down the slope a little. No cracks or ground offsets were found in any of the field reconnaissance studies, but we will have to look again when the snow melts. I also did a northwest transect in the hills to the northwest of Wells over the up-dip projection of the southeast-dipping plane solution, but snow prevented me from seeing anything.

A preliminary fault map of Town Creek Flat has been made by Ramelli (2008, NBMG Web posting) to offer targets for looking for surface breaks in Town Creek Flat.

A sinkhole developed in the Metropolis Road that was reportedly caused by a leak in the sewer system.

Recovery Efforts

Wells turned to recovery just about as soon as they were sure everyone was all right and they had secured any dangerous situations. This demonstrates the nimbleness and straightforward-thinking that was taking place in this rural community. There were a number of Nevada Division of Forestry crews who were released from the response effort early on and immediately began helping people. These crews took down damaged chimneys, cleaned up around houses, and shoveled walks and driveways for safety ([Fig. 53](#)). Fire truck ladders were used to get up on houses and in at least one case, a Wells Rural Electric truck with a bucket on it was used to help bring down a precarious chimney before it could fall into a house. By day three these recovery efforts were in full swing.

When Wells Propane went to a home with a leak, they found the leak, pulled the pipe, threaded a new part or whatever repair was needed, replaced or repaired it, pressure tested the line, and turned the gas back on. All in one visit! This kind of action makes the recovery effort significantly faster.

Most people cleaned up their homes on day one and two. Employees went to their businesses to help clean them up as well, in one case working through the night so the business could reopen as soon as possible. There was a focus and support from the City of Wells to get businesses back open as quickly as possible. Several businesses reopened day two and three, as soon as they were cleared by inspectors as being safe to do so. The limited number of businesses allowed them to be inspected relatively quickly.

Financial help for this community is still not fully certain, but the local Nevadans and businesses, Elko County, and the State are stepping up to do what they can. There were city, county, and state disaster declarations, but no federal declaration. In a distinct twist of unfairness, this was partly because the city and school buildings had earthquake insurance and thus were removed from the measure of the damage that occurred that determines whether a community should qualify for federal assistance. There is potential assistance from the Small Business Association, the U.S. Department of Agriculture, and the Nevada Homeowner's Disaster Assistance Program for Wells.

The local statewide bank has opened up a donation account to help with Wells disaster recovery called the "Wells Nevada Earthquake Fund" and the Red Cross was taking donations as well. It is my understanding that these and other private donations are being administered by a group of interfaith leaders who are keeping tabs on the needs of the community. The county government and local businesses are giving financial relief to the recovery of the Wells city facilities and infrastructure. There were also some private donations of building supplies. A "Wells Day Rally" is planned where ranchers donate calves for auction to raise money for Wells.

An impressive effort for helping Wells recover were "Wells Fix-Up Days" being held on Saturdays and being organized by the local Church of Latter Day Saints. This is an appeal for carpenters and laborers to come to Wells on Saturdays and help fix things that were damaged by the earthquake (mostly for individuals). The first fix-up day drew 300 people to Wells, who worked diligently to help in blizzard conditions. Not only does this help repair some homes, but it is a nice vote of confidence for the community of Wells from its neighbors.

Understanding the Rural Earthquake Disaster:

The Nevada Earthquake Safety Council and the Utah Seismic Safety Commission and professionals from these two states and Idaho have been trying to assess what the differences are between rural and urban earthquake disasters, and in particular the needed outside response, in an effort to respond better to our rural communities in a disaster. This is because most outside assistance is based on an urban model, so it is likely this doesn't fit a rural event exactly. Careful examination of the Wells Earthquake will give some valuable insight into rural needs. But I also think that with equally careful thought, lessons for how *people* might approach an urban earthquake disaster can be equally beneficial.

I don't have close to the answers or observations to be made on this subject, but three categories of response would be logical to examine. There is the automatic response, the potentially needed response, and the unneeded response. I'm not really sure that anything beyond an automatic response occurred, but debriefing some local and county people should help clarify this. One might say that technically not all the resources were used for emergency response, some were used for initial recovery, but to have had less would have been disconcerting for city personnel and the incident command I am sure. There were many unknowns and response personnel were working in dangerous situations. A strong aftershock or larger earthquake would have directly threatened residents and responders, alike. Potentially needed responses can be identified and made ready for transportation, but wait for the local request. This might include things like garbage dumpsters. I can't identify a specific unneeded response for the Wells Earthquake.

A rural setting is different from an urban setting, and this alone is the starting point for examining contrasts. One interesting difference is getting from here to there. There are two extremes that contrast between these two settings. First there is getting across town. Driving unobstructed and at the speed limit, it only takes a couple of minutes to drive from one side of Wells to the other. This is in contrast to a much longer time it takes in a city. The point is that it can be faster to move around a rural community if communication fails or to do a canvassing view of the town line looking for smoke from fires. Thus, emergency response in a rural environment can have elements that operate faster than an urban. This mobility helps the limited resources at hand to operate efficiently, taking care of situations before they escalated out of control, requiring more resources. It is sobering to think though that a stronger earthquake or a less savvy populace could have easily have divided up or overwhelmed the local responders, and that it would have been about 40 minutes before the first outside help arrived. No doubt though had this larger earthquake have happened, there would have been heroic stories of how the citizens of Wells dealt with the additional, potentially overwhelming situations.

Afterword

The Wells and surrounding Elko County residents are not only stoic individuals and a resilient community, they are rather smartly preparing for future earthquakes during their recovery. Bookshelves, televisions, water heaters, and manufactured homes are being anchored or strapped. Things are being rearranged to be less threatening. They don't need a fancy lecture that earthquakes can occur in Wells. This is yet another lesson for Nevadans and our neighbors in other states. For those that the "belief in earthquakes" is not a question and they have common sense, they are getting prepared to survive earthquakes.

Other Notes

Parts of Wells, such as old town and the Humboldt Wells Springs area, were wet areas before building.

Underground Chinese-built tunnels in the old town area have been mentioned.

A few rockfalls were noted by the science teams putting out the seismometers.

Much of the ground was frozen at the time of the earthquake.

References Cited

dePolo, C.M., 1998, A reconnaissance technique for estimating the slip rates of normal-slip faults in the Great Basin and Application to faults in Nevada, USA: University of Nevada, Reno, PhD. Dissertation, 199 p.

dePolo, C.M., in prep., Quaternary fault map of Nevada: Nevada Bureau of Mines and Geology map, 1:1,000,000 scale.

dePolo, C.M. and Anderson J.G., 2000, Estimating the slip rates of normal faults in the Great Basin, USA: Basin Research, v. 12, p. 227-240.

Dohrenwend, J.C., McKittrick, M.A., and Moring, B.C., 1991, Reconnaissance photogeologic map of young faults in the Wells 1° by 2° Quadrangle, Nevada, Utah, and Idaho: U.S. Geological Survey Miscellaneous Field Studies Map MF-2184, 1:250,000 scale.

Wesnousky, S.G. and Willoughby, C.H., 2003, Neotectonic note: the Ruby-East Humboldt Range, northeastern Nevada: Bulletin of the Seismological Society of America, v. 93, p. 1345-1354.

Wesnousky, S.G., Barron, A.D., Briggs, R.W., Caskey, S.J., Kumar, Senthil, and Owen, L., 2005, Paleoseismic transect across the northern Great Basin.