CHAPTER THREE
SECTION 3.4
HAZARD PROFILE-EARTHQUAKE

AFFECTED JURISDICTIONS

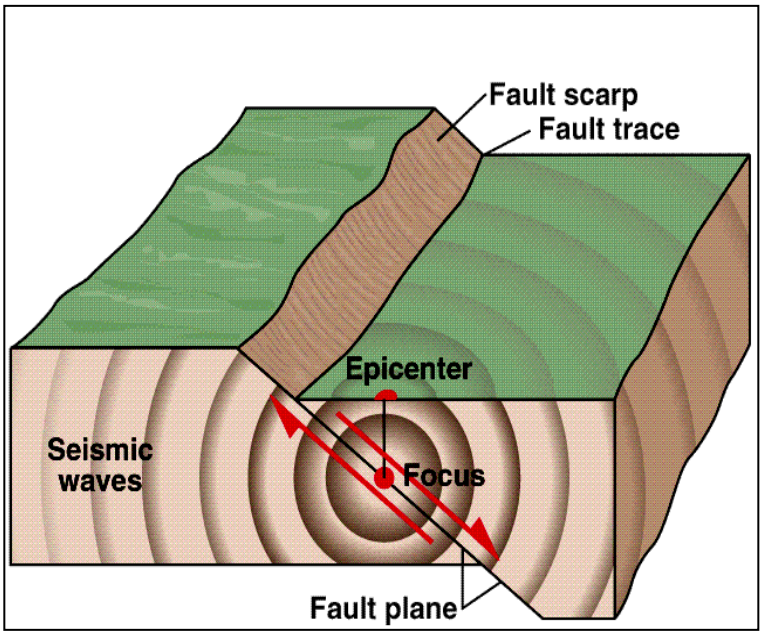
COMMUNITIES
Unincorporated Pottawatomie County
Town of Asher
Town of Bethel Acres
Town of Brooksville
Town of Earlsboro
Town of Johnson
City of Maud
Town of Macomb
City of McLoud
Town of Pink
City of Shawnee
Town of St. Louis
City of Tecumseh
Town of Tribbey
Town of Wanette
PUBLIC SCHOOL DISTRICTS
Asher Public Schools
Bethel Public Schools
Dale Public Schools
Earlsboro Public Schools
Grove School
Macomb Public Schools
Maud Public Schools
Macomb Public Schools
McLoud Public Schools
North Rock Creek School
Shawnee Public Schools
South Rock Creek School
Tecumseh Public Schools
TECHNOLOGY CENTERS
Gordon Cooper Technology Center

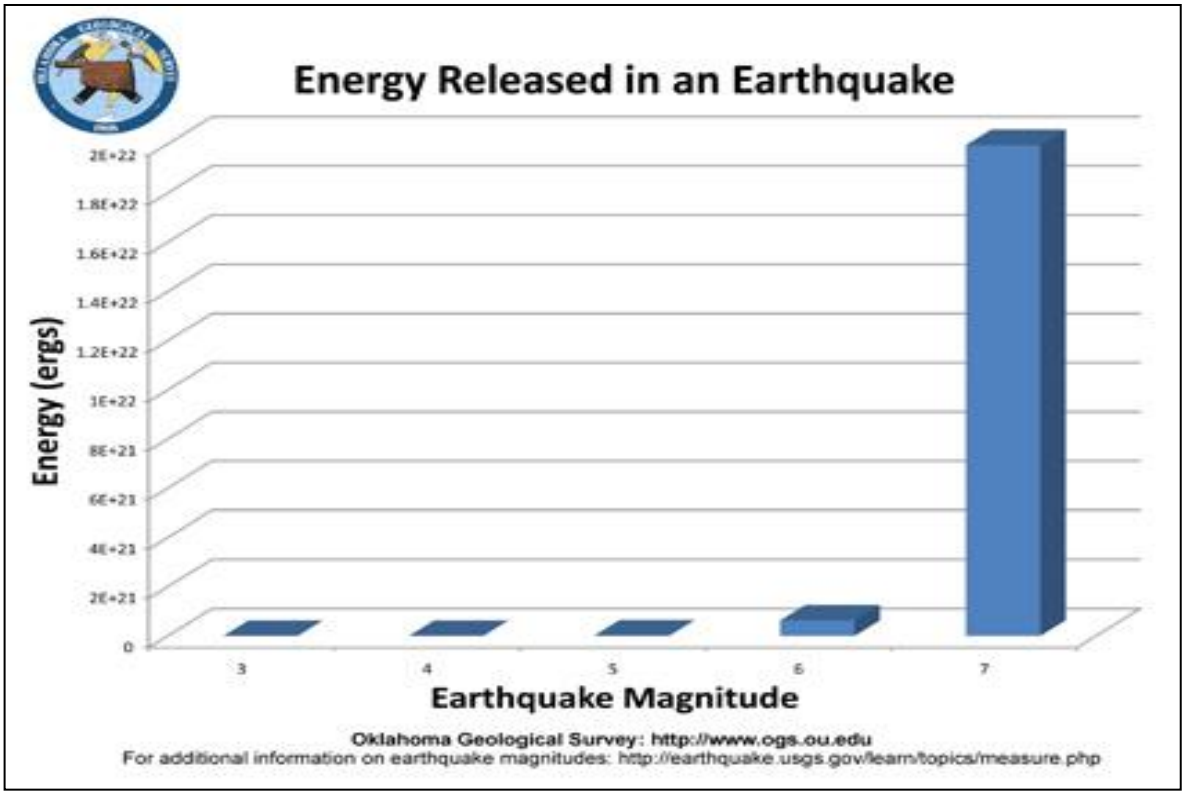
This page intentionally left blank

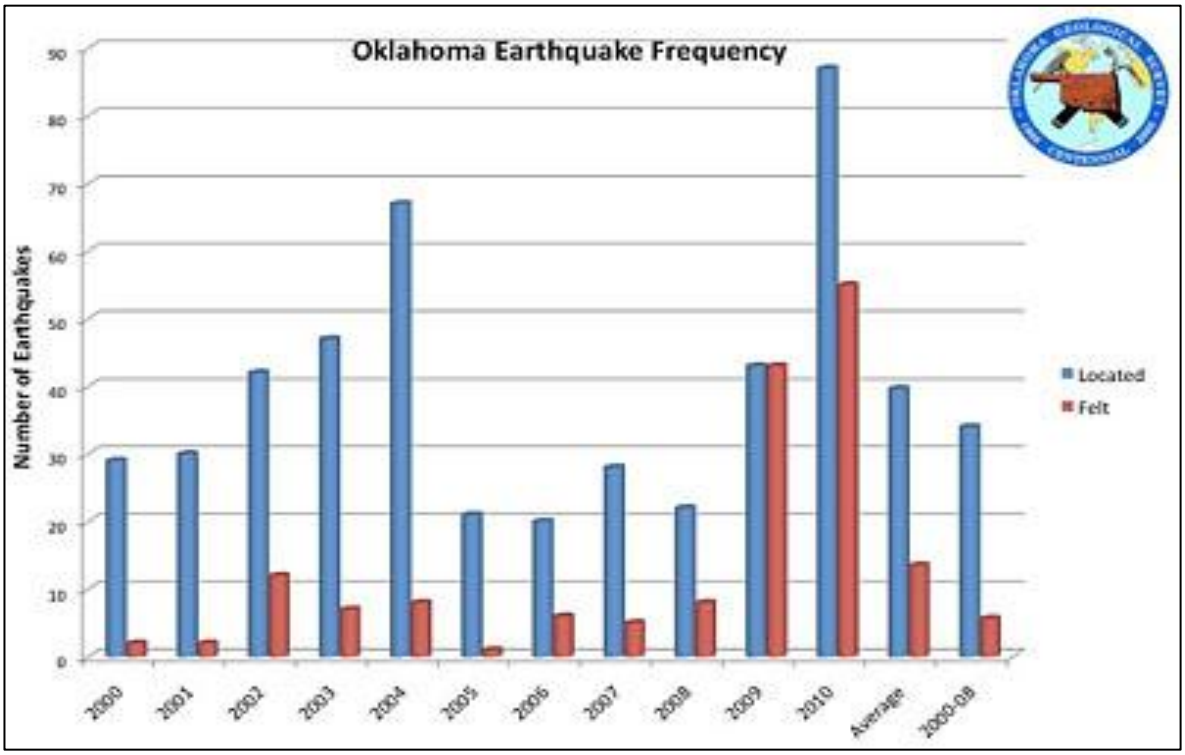
EARTHQUAKE

Earthquakes are one of nature's most damaging hazards. An earthquake is a sudden motion of trembling that is caused by a release of strain accumulated within or along the edge of Earth's tectonic plates. The severity of an earthquake is dependent on the amount of energy released from the fault or epicenter. An earthquake is a sudden, rapid shaking of the Earth caused by the breaking and shifting of rock beneath the Earth's surface.

For hundreds of millions of years, the focus of plate tectonics have shaped the Earth as the huge plates that form the Earth's surface move slowly over, under, and past each other, sometimes the movement is gradual. At other times, the plates are locked together, unable to release the accumulating energy. When the accumulated energy grows strong enough, the plates break free causing the ground to shake. Most earthquakes occur at the boundaries where the plates meet; however, some earthquakes occur in the middle of plates. More than 930,000 earthquakes occur throughout the world each year. Approximately 95% of these have a magnitude of less than 2.5 and usually are not felt by humans. Earthquakes strike suddenly, without warning and can occur at any time.

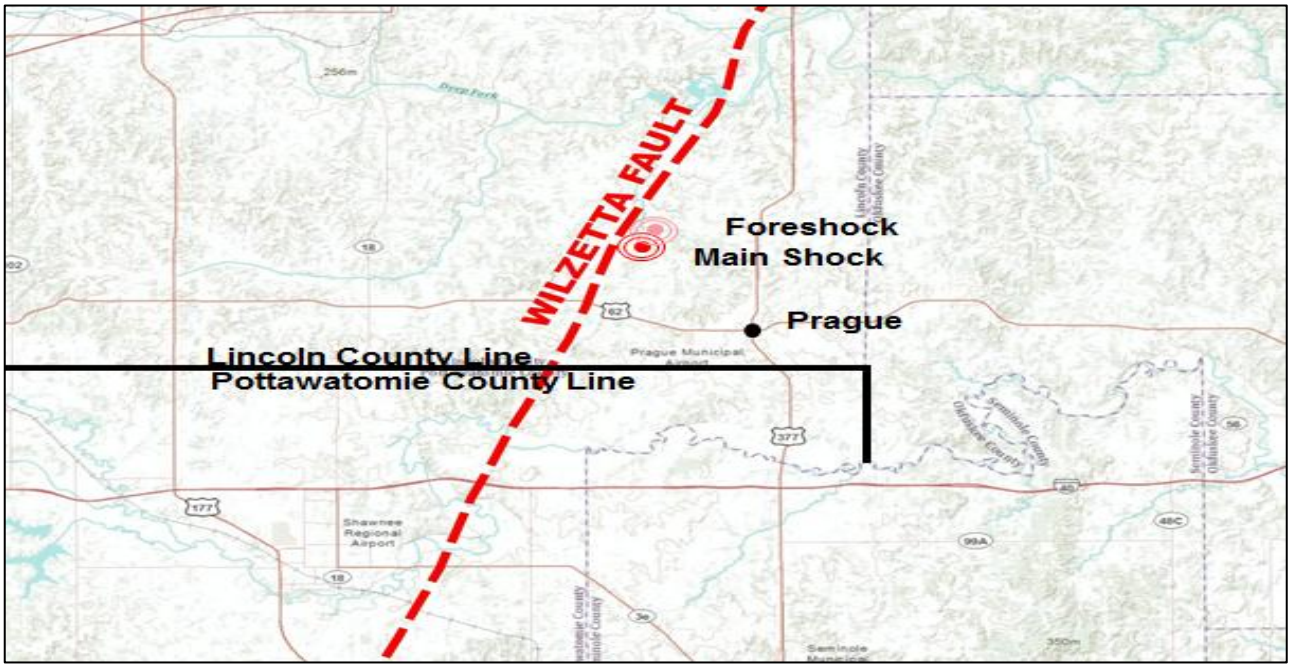



Energy Released in an Earthquake
Energy (ergs)
2E+22
1.8E+22
1.6E+22
1.4E+22
1.2E+22
1E+22
8E+21
6E+21
4E+21
2E+21
0
3
4
5
6
7
Earthquake Magnitude
Oklahoma Geological Survey: http://www.ogs.ou.edu
For additional information on earthquake magnitudes: http://earthquake.usgs.gov/learn/topics/measure.php


Oklahoma Earthquake Frequency
Number of Earthquakes
90
80
70
60
50
40
30
20
10
0
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
Average
2000-08
Located
Felt

LOCATION

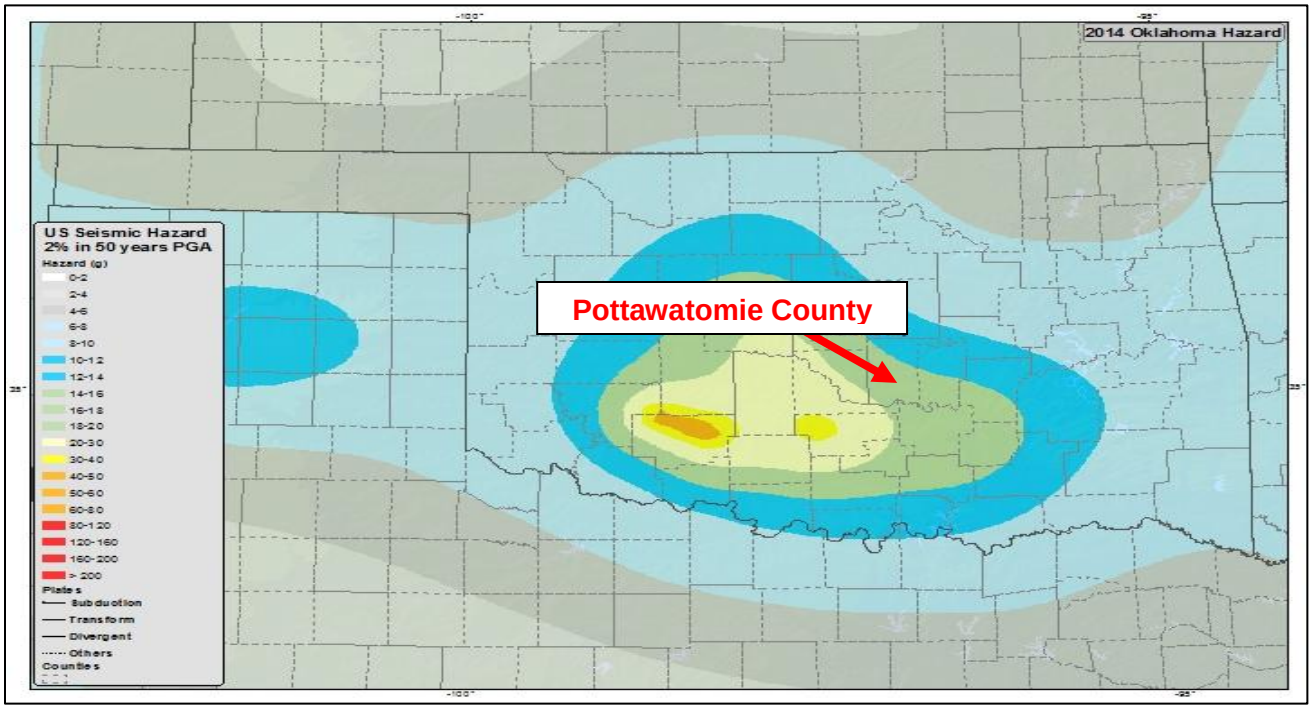
All participating jurisdictions, school districts and Gordon Cooper Technology Center and the unincorporated area of Pottawatomie County are susceptible to earthquake although the Shawnee area have experienced the most incidents over the last five years.. (Refer to Table 1-1) Earthquakes have increased in recent years in the county due to activity just north of Pottawatomie County in Lincoln County. The effects of those earthquakes have caused damage in Pottawatomie County. The Oklahoma Geological Survey has joined with the Oklahoma Corporation Commission in a study of the cause of the earthquakes and have found the activity primarily along the Wilzetta Fault Line. Text from that study will be referenced through this hazard profile.



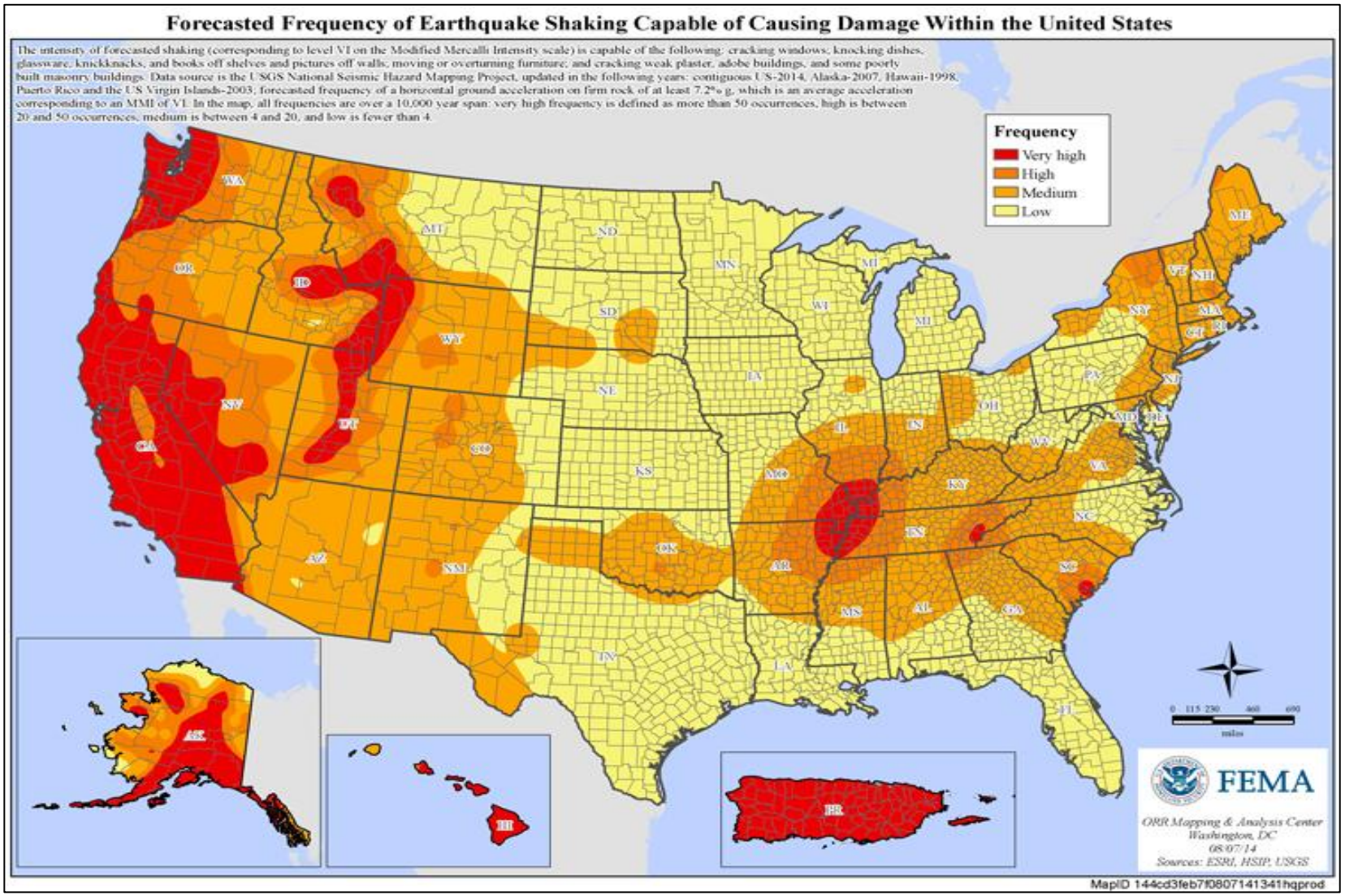
EXTENT

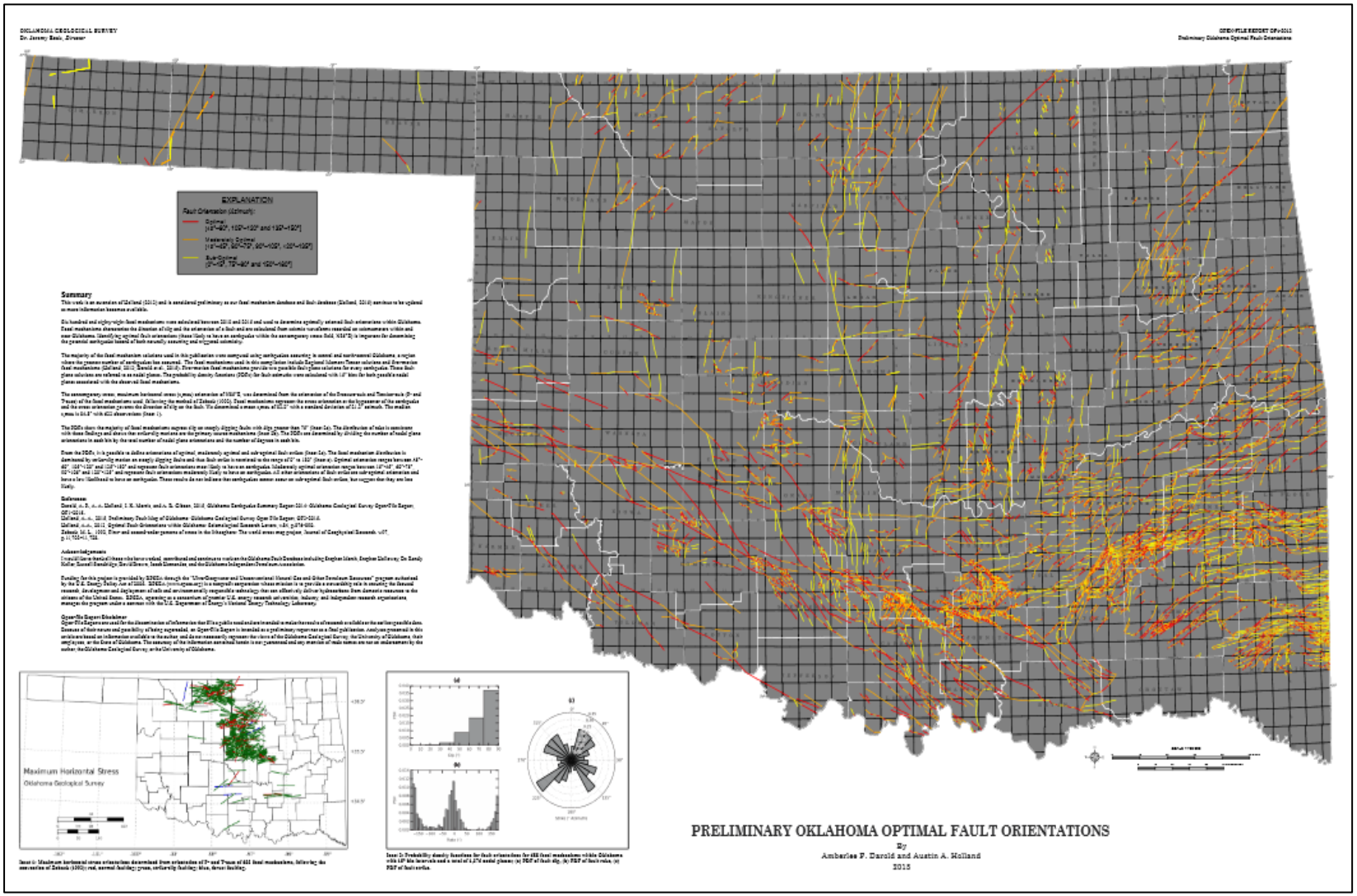
The Seismic Hazard Map shows that jurisdictions in Pottawatomie County fall within the United States Geological Survey (USGS) 2.1%g Peak Ground Acceleration (PGA) with a 2.1%g probability of excedance in 50 years.

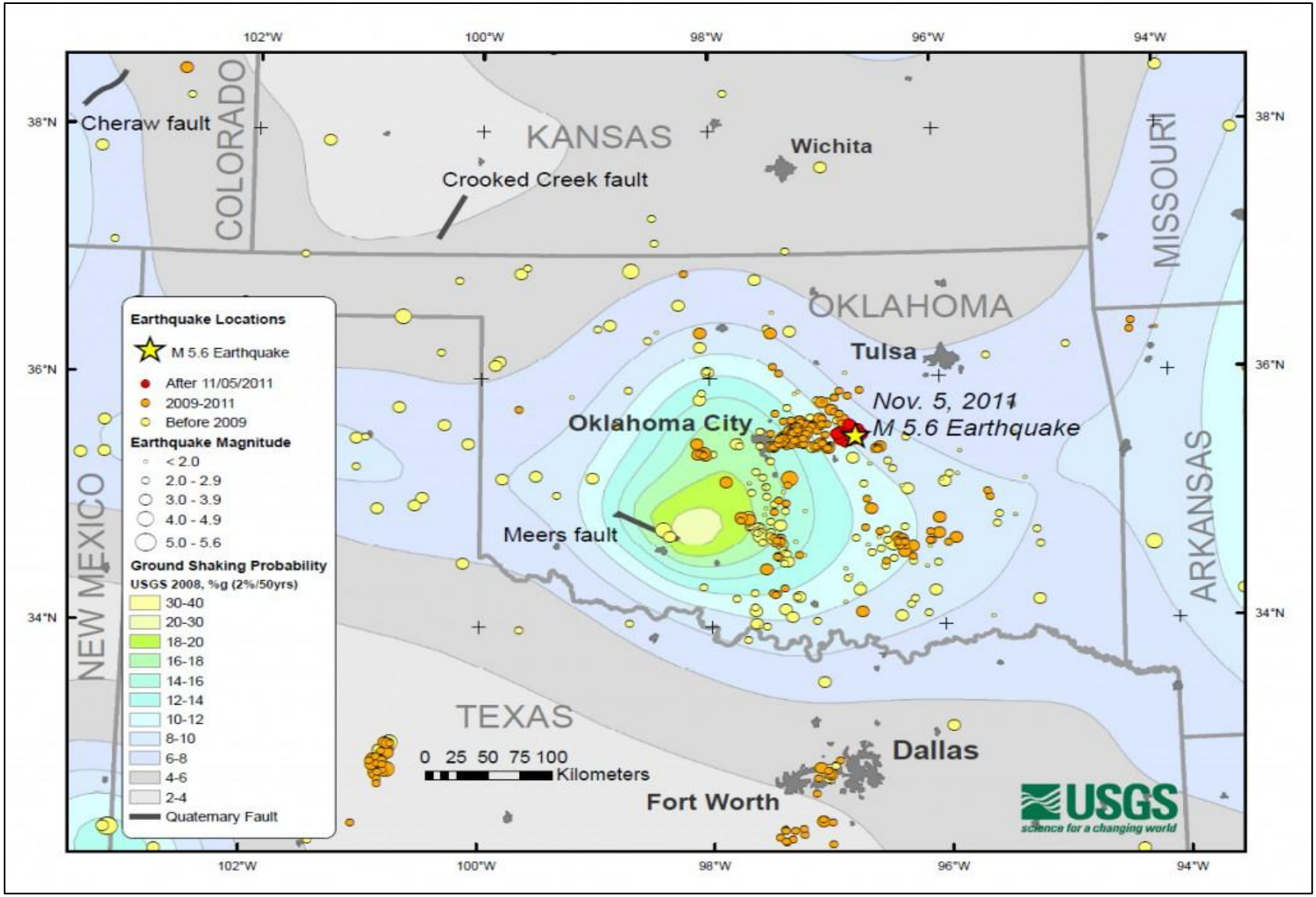
This intensity indicates a future earthquake affecting the communities in Pottawatomie County can cause moderate ground shaking with some damage possible to structures and contents. The historical impact of earthquake incidents falls in the category of slight to moderate impact in the county. Pottawatomie County officials consider any earthquake activity above 4.8 on the Richter scale as a significant event. Housing in communities throughout Pottawatomie County is generally not built to "earthquake standards."



Earthquakes occurring in the past near or in Pottawatomie County have been slight to moderate with minor to moderate damage to structures particularly in the Shawnee area.


Forecasted Frequency of Earthquake Shaking Capable of Causing Damage Within the United States
The intensity of forecasted shaking (corresponding to level VI on the Modified Mercalli Intensity scale) is capable of the following: cracking windows; knocking dishes, glassware, knickknacks, and books off shelves and pictures off walls; moving or overturning furniture; and cracking weak plaster, adobe buildings, and some poorly built masonry buildings. Data source is the USGS National Seismic Hazard Mapping Project, updated in the following years: contiguous US-2014, Alaska-2007, Hawaii-1998, Puerto Rico and the US Virgin Islands-2003; forecasted frequency of a horizontal ground acceleration on firm rock of at least 7.2% g, which is an average acceleration corresponding to an MMI of VI. In the map, all frequencies are over a 10,000 year span: very high frequency is defined as more than 50 occurrences, high is between 20 and 50 occurrences, medium is between 4 and 20, and low is fewer than 4.
Frequency
Very high
High
Medium
Low
WA
OR
CA
ID
NV
MT
WY
UT
AZ
CO
NM
ND
SD
NE
KS
OK
TX
MN
IA
MO
AR
LA
WI
IL
MS
MI
IN
OH
KY
TN
AL
GA
FL
SC
NC
VA
WV
PA
NY
MD
DE
NJ
CT
RI
MA
VT
NH
ME
AK
HI
PR
0 115 230 460 690
miles
FEMA
ORR Mapping & Analysis Center
Washington, DC
08/07/14
Sources: ESRI, HSIP, USGS
MapID 144cd3feb7f0807141341hqprod


OKLAHOMA GEOLOGICAL SURVEY
Dr. Jeremy Boak, Director
OPEN-FILE REPORT OF-X-2015
Preliminary Oklahoma Optimal Fault Orientations
EXPLANATION
Fault Orientation (Azimuth):
Optimal
[157°–167°, 172°–177° and 337°–347°]
Moderately Optimal
[147°–157°, 167°–172°, 327°–337°, 347°–352°]
Sub-Optimal
[0°–147°, 172°–327° and 352°–360°]
Summary
Maximum Horizontal Stress
Oklahoma Geological Survey
PRELIMINARY OKLAHOMA OPTIMAL FAULT ORIENTATIONS
By
Amberlee P. Darold and Austin A. Holland
2015


102°W
100°W
98°W
96°W
94°W
38°N
36°N
34°N
Cheraw fault
COLORADO
KANSAS
Wichita
Crooked Creek fault
MISSOURI
OKLAHOMA
Tulsa
Nov. 5, 2011
M 5.6 Earthquake
Oklahoma City
Meers fault
NEW MEXICO
ARKANSAS
TEXAS
Dallas
Fort Worth
0 25 50 75 100
Kilometers
USGS
science for a changing world
Earthquake Locations
M 5.6 Earthquake
After 11/05/2011
2009-2011
Before 2009
Earthquake Magnitude
< 2.0
2.0 - 2.9
3.0 - 3.9
4.0 - 4.9
5.0 - 5.6
Ground Shaking Probability
USGS 2008, %g (2%/50yrs)
30-40
20-30
18-20
16-18
14-16
12-14
10-12
8-10
6-8
4-6
2-4
Quaternary Fault

Officials of Pottawatomie County, all participating jurisdictions, the school districts and Gordon Cooper Technology Center consider an earthquake registering 5.0 on the Richter Scale as Major. Events registering above 7.0 would be considered catastrophic.

Charles F. Richter, of the California Institute of Technology, developed the Richter magnitude scale in 1935 as a mathematical device to compare the size of earthquakes. This scale is usually the one referred to by news media when broadcasting, and is the most familiar to the public. The diagram below compares the Mercalli and Richter scales, and gives a description of earthquake impact for each level.

Table 3-14 EARTHQUAKE: MERCALLI/RICHTER SCALE COMPARISON

Mercalli Scale	Richter Scale	Full Description
I.	0 - 1.9	Not felt. Marginal and long period effects of large earthquakes.
II.	2.0 – 2.9	Felt by persons at rest, on upper floors, or favorably placed.
III.	3.0 – 3.9	Felt indoors. Hanging objects swing. Vibration like passing of light trucks. Duration estimated. May not be recognized as an earthquake.

Table 3-14 EARTHQUAKE: MERCALLI/RICHTER SCALE COMPARISON		
Mercalli Scale	**Richter Scale**	**Full Description**
IV.	**4.0 – 4.3**	Hanging objects swing. Vibration like passing of heavy trucks. Standing motor cars rock. Windows, dishes, doors rattle. Glasses clink the upper range of IV, wooden walls and frame creak.
V.	**4.4 – 4.8**	Felt outdoors; direction estimated. Sleepers wakened. Liquids disturbed, some spilled. Small unstable objects displaced or upset. Doors swing, close, open. Pendulum clocks stop, start.
VI.	**4.9 – 5.4**	Felt by all. Many frightened and run outdoors. Persons walk unsteadily. Windows, dishes, glassware broken. Books, etc., off shelves. Pictures off walls. Furniture moved. Weak plaster and masonry D cracked. Small bells ring. Trees, bushes shaken.
VII.	**5.5 – 6.1**	Difficult to stand. Noticed by drivers of motor cars. Hanging objects quiver. Furniture broken. Damage to masonry D, including cracks. Weak chimneys broken at roof line. Fall of plaster, loose bricks, stones, tiles, cornices. Some cracks in masonry C. Waves on ponds. Small slides and caving in along sand or gravel banks. Large bells ring. Concrete irrigation ditches damaged.
VIII.	**6.2 – 6.5**	Steering of motor cars affected. Damage to masonry C; partial collapse. Some damage to masonry B. Fall of stucco and some masonry walls. Twisting, fall of chimneys, factory stacks, monuments, towers, elevated tanks. Frame houses moved on foundations. Decayed piling broken off. Branches broken from trees. Changes in flow or temperature of springs and wells. Cracks in wet ground and on steep slopes.
IX.	**6.6 – 6.9**	General panic. Masonry D destroyed; masonry C heavily damaged, sometimes with complete collapse; masonry B seriously damaged. (General damage to foundations.) Serious damage to reservoirs. Underground pipes broken. Conspicuous cracks in ground. In alluvial areas sand and mud ejected, earthquake fountains, sand craters.

Table 3-14 EARTHQUAKE: MERCALLI/RICHTER SCALE COMPARISON		
Mercalli Scale	**Richter Scale**	**Full Description**
X.	**7.0 – 7.3**	Most masonry and frame structures destroyed with their foundations. Some well-built wooden structures and bridges destroyed. Serious damage to dams, dikes, embankments. Large landslides. Water thrown on banks of canals, rivers, lakes, etc. Sand and mud shifted horizontally on beaches and flat land. Rails bent slightly.
XI.	**7.4 – 8.1**	Rails bent greatly. Underground pipelines completely out of service.
XII.	**> 8.1**	Damage nearly total. Large rock masses displaced. Lines of sight and level distorted. Objects thrown into the air.
Masonry A: Good workmanship, mortar, and design; reinforced, especially laterally, and bound together by using steel, concrete, etc.; designed to resist lateral forces. **Masonry B**: Good workmanship and mortar; reinforced, but not designed in detail to resist lateral forces. **Masonry C**: Ordinary workmanship and mortar; no extreme weaknesses like failing to tie in at corners, but neither reinforced nor designed against horizontal forces. **Masonry D**: Weak materials, such as adobe; poor mortar; low standards of workmanship; weak horizontally.		

PREVIOUS OCCURRENCES

On average, there are about 50 measurable earthquakes each year in Oklahoma with only a few of these with shaking strong enough to be felt. 2009 was an exceptional year for seismic activity in Oklahoma with 43 felt earthquakes.

The USGS database shows that there is a 2.087% chance of a major earthquake within 50 miles of Shawnee, Oklahoma within the next 50 years. The largest earthquake within 50 miles of Shawnee, Oklahoma was a 5.6 Magnitude in 2011 with an epicenter near Prague in Lincoln County just north of Pottawatomie County.

Local records indicate an earthquake of 5.4 was centered 17 kilometers southeast of Shawnee on Oct. 26, 2002 and was felt in Pottawatomie County although no damage was reported. On July 1, 2009 an earthquake of 3.4 struck one mile southeast of McLoud,; no injuries or damage was reported. On October 13, 2010 an earthquake measuring 4.4 occurred east of Norman, OK and was felt by many in Pottawatomie County. No damage was reported from the earthquake and no one was injured during the incident.

On November 6, 2011 a 5.6 earthquake that occurred 21 miles, NNE of Shawnee caused some significant damage in Pottawatomie County. There was damage to the spires on top of the Benedictine Hall at St. Gregory's University with one tower destroyed, another partially destroyed, and the other two with minor cracks. There was also damage reported at one commercial structure in downtown Shawnee, 15 residential structures with minor damage and one residence destroyed. Other damage was reported at St. Benedicts Church, Romulus Baptist Church, and Eaton Hydraulics. The City of Shawnee water treatment facilities and public works building also received minor damage, but remained in operation in the following days.

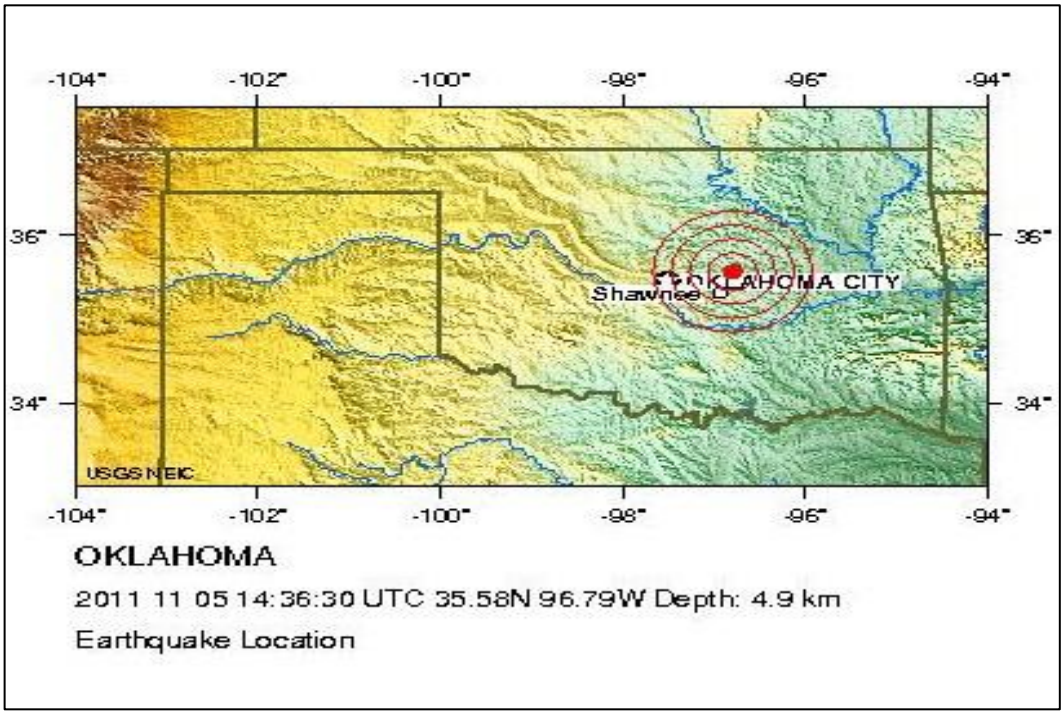


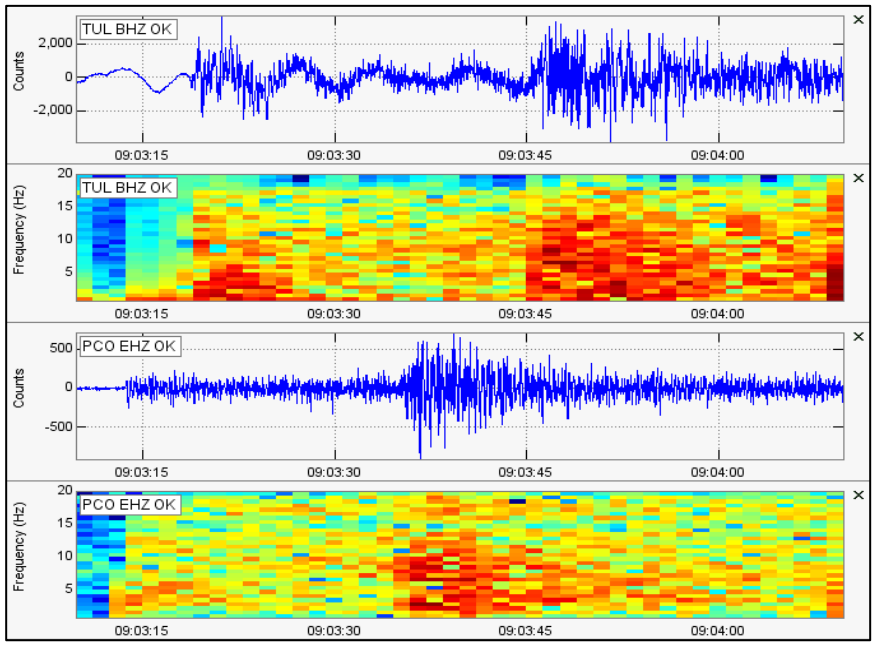
Table 3-15 POTTAWATOMIE COUNTY EARTHQUAKE EVENTS January 1, 2012-August 31, 2012 Information provided by the Oklahoma Climatological Survey					
Date	**Time**	**Depth**	**Magnitude**	**Latitude**	**Longitude**
August 13th	08:46:40	5.0	1.3	35.4656	-96.8140
August 10th	02:39:23	5.0	1.4	35.4275	-97.0084
August 9th	23:23:25	5.0	1.8	35.4476	-97.0220
July 31st	14:24:11	5.0	1.8	35.4580	-96.7962
June 13th	22:44:32	3.0	3.1	35.4597	-96.7003
June 2nd	22:11:48	5.0	2.3	35.4681	-96.7089
May 30th	22:15:43	5.0	2.5	35.4573	-96.6993
May 16th	13:22:11	5.0	0.9	35.4657	-96.6230
April 29th	11:50:23	5.0	2.0	35.4432	-97.0269
April 16th	10:59:39	5.0	2.1	35.4041	-96.6663
Feb 19th	08:12:39	.2	.6	35.4598	-96.8567
Jan 24th	18:10:05	7.8	2.0	35.3942	-97.0950

NOTE: *Unfortunately, the usual source in Oklahoma for accurate Oklahoma earthquake data, the Geological Survey Laboratory at Leonard, Oklahoma, suffered a computer failure and has been out of service for several months. The information referenced in table 3-10 was received from other sources but may not be entirely accurate.*

PROBABILITY OF FUTURE IMPACTS

Oklahoma is at a moderate risk for an earthquake as a result of its proximity to the New Madrid Seismic Zone. Central Oklahoma is currently the most active earthquake area in the state, including all participating jurisdictions in Pottawatomie County. At highest risk are areas in the northern parts of the county.

Following are the observations included in the aforementioned study by the Oklahoma Geological Survey and the Oklahoma Corporation Commission on March 23, 2013: Based upon recent earthquake activity and data from the USGS, the probability of earthquakes in Pottawatomie County, participating jurisdictions, school districts and Gordon Cooper Technology Center is "**LIKELY".**



VULNERABILITY AND IMPACT

Buildings with foundations resting on unstable soil, trailers not tied to their foundations, or homes not properly secured to their foundations are at risk for more severe damage during an earthquake. They can shake off their mountings during even a modest occurrence and possibly displace the occupants. Roads and bridges may be damaged to the extent emergency response vehicles and motorists will need to find alternate routes. Even minor earthquakes can damage natural gas lines, water lines, pipelines, electric lines, and underground lines causing loss of services to the population.

Oklahoma Geological Survey

March 22, 2013

Dr. G. Randy Keller (405) 325-7968
Director and State Geologist
Austin Holland (405) 325-8497
Seismologist

The Prague, Oklahoma, earthquake sequence of 2011, along the Wilzetta Fault zone, included a significant foreshock, a main shock of magnitude 5.7 and numerous aftershocks. It has been suggested that this sequence represents earthquakes triggered by fluid injection. The Oklahoma Geological Survey (OGS) has been working with the Oklahoma Corporation Commission (OCC) to analyze data related to the 2011 Prague sequence, and recently the U.S. Environmental Protection Agency (EPA) has participated in reservoir pressure analysis of the formations into which water is being injected. Based on analysis of earthquake seismology, 3-D reflection seismology, geologic mapping, formation pressure data, and historical Oklahoma earthquake data, the OGS offers the following observations and conclusions:

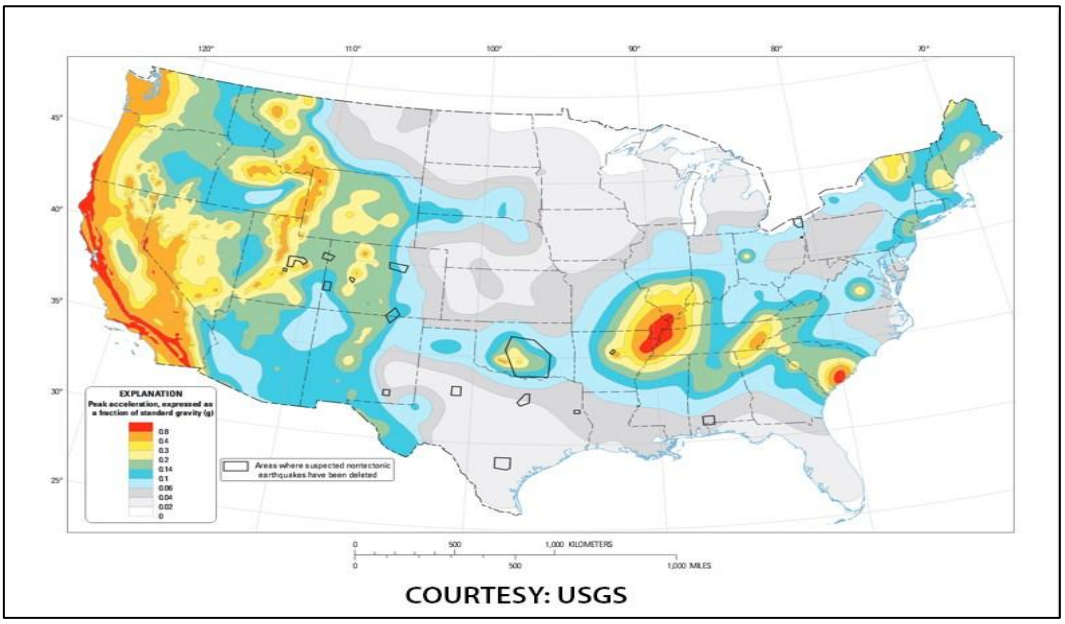
Observations:

- Relatively large, natural earthquakes occur in Oklahoma, and the U.S. Geological Survey seismic hazard map shows that the seismic hazard for the Prague/Wilzetta area was finite (not zero) prior to the Prague sequence.
- Oklahoma has experienced more than ten magnitude 4.0 or greater earthquakes since the magnitude 5.0+ El Reno earthquake of 1952. This is statistically consistent with the Gutenberg-Richter relationship, which describes the distribution of earthquakes of differing magnitude over time.
- Earthquakes in the Prague area have followed the normal Omori Law aftershock time-decay that is typical of natural seismicity.
- The earthquakes occurred on a segment of the Wilzetta Fault that is favorably oriented for earthquakes to occur as a result of the predominant crustal stress regime in Oklahoma.
- Water injection began in the Prague/Wilzetta area in 1955, increased until 2004-2005 and has remained relatively constant since then. Some researchers have observed that the earthquake activity did not increase over time as injection increased, but rather occurred in a distinct "swarm" more typical of a natural event.
- 3-D seismic recently made available demonstrates an alternative interpretation to the premise of a fault-bounded block, which is the closed compartment postulated by some researchers that would result in increased fluid pressures due to water injection. The 3-D seismic data shows that the local geological structure is not fault-bounded on all sides, which further suggests that water injection is not being restricted.
- This alternative structural interpretation is supported by recent, direct pressure measurements of the geologic formations where water injection activities are being conducted. Measurements, undertaken by the OCC, and reviewed by the EPA, show that the Hunton Formation is in fact under-pressured. Initial results from a separate test in the area of interest indicate that the Arbuckle Formation is also under-pressured.

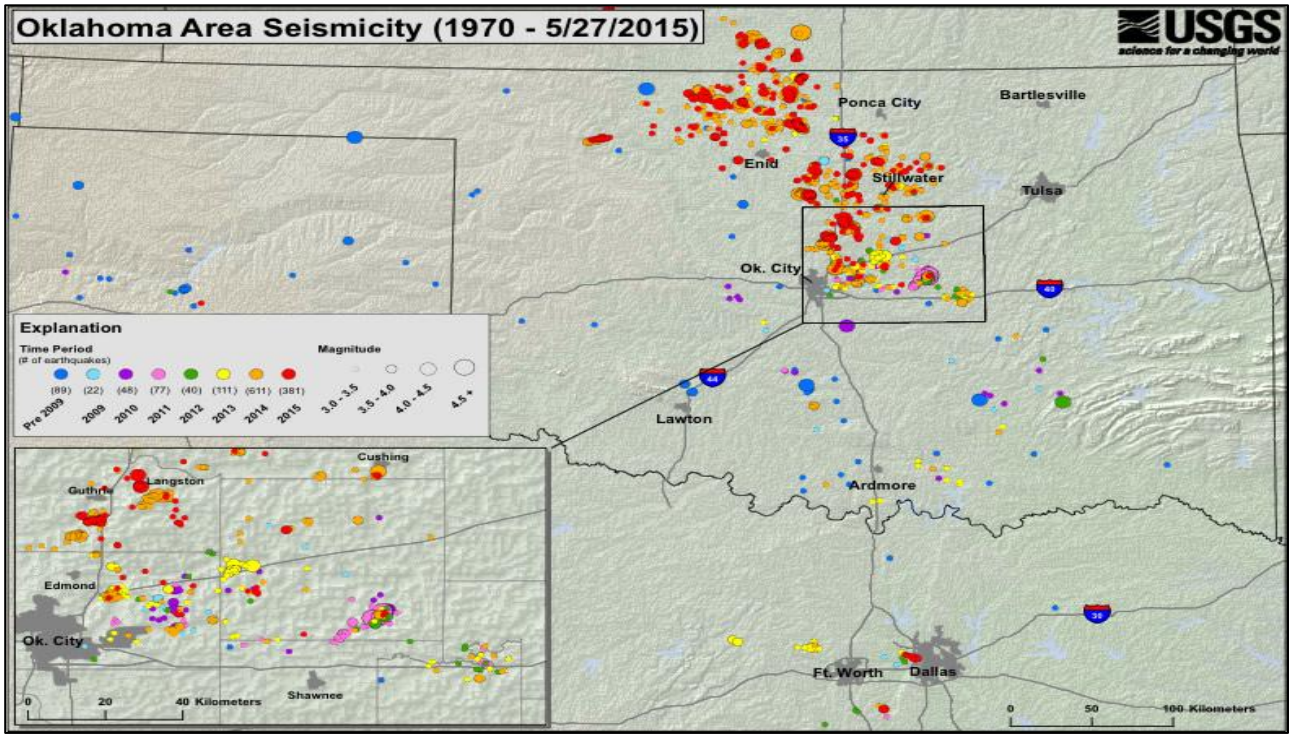
Conclusions:

- The interpretation that best fits current data is that the Prague Earthquake Sequence was the result of natural causes.
- The Prague Earthquake Sequence, as well as other current and historically active seismic areas in Oklahoma, would benefit from further study, including improved earthquake monitoring and acquisition of formation pressure data.
- Further studies of seismic activity in Oklahoma will result in a better understanding of seismicity statewide.

The Oklahoma Geological Survey is a state agency for research and public service; charged with investigating the state's land, water, mineral, and energy resources and disseminating the results of those investigations to promote the wise use of Oklahoma's natural resources consistent with sound environmental practices.



COURTESY: USGS



Environmental concerns may arise as well. Inside structures, bookshelves, hot water tanks, pictures on walls, and equipment can fall. When an earthquake occurs in a populated area, people are often injured or killed, and property is frequently damaged.

Damage to school buildings and contents could be prohibitive or even a total loss if a moderate to severe earthquake occurred.

Glass windows, appurtenances on walls or the roof could be shaken loose falling on students and staff or falling through the roof. Students and staff could be injured or killed during the earthquake. School buildings could be damaged to the point they are unusable causing classes to be moved to alternate locations until facilities can be repaired or rebuilt.

CONCLUSION

Based on available information, the potential impact of earthquakes to communities in Pottawatomie County is moderate. Pottawatomie County is in an active seismic zone with 12 earthquakes occurring in the current year alone. The earthquake that occurred in the Prague, Oklahoma, area on November 6, 2012 caused significant damage to structures throughout northern Pottawatomie County including St. Gregory's University. Large earthquakes that occur on the New Madrid fault line have the potential to cause major damage in Pottawatomie County and affect the lives of residents in the county.

SOURCES

Local Emergency Management Records

United State Geological Survey (USGS)

www.usgs.gov/

State of Oklahoma Hazard Mitigation Plan

Oklahoma Geological Survey (OGS)

Study: http://www.ogs.ou.edu/earthquakes/OGS_PragueStatement201303.pdf

United States Department of Agriculture (USDA)

http://earthquake.usgs.gov/earthquakes/states/oklahoma/seismicity.php

This page intentionally left blank