What We Know About Earthquakes in the New Madrid Fault Zone in Mid-America

Arthur Frankel
Coordinator for Earthquake Effects Research
U.S. Geological Survey
New Madrid Area has the highest rate of earthquakes in the U.S. east of the Rocky Mountains. Map shows earthquake epicenters from 1990-2000

Source: USGS National Earthquake Information Center
New Madrid Area has the highest rate of earthquakes in the U.S. east of the Rocky Mountains. Map shows earthquake epicenters from 1990-2000.

Source: USGS National Earthquake Information Center
Why Are There Earthquakes in the New Madrid Region?
This Region is Far From Boundaries of North American Tectonic Plate
Animation of plates showing opening of Atlantic Ocean basin starting 200 million years ago

Faulting in the New Madrid region was produced during the previous cycle when the continent was torn apart by the opening of the ocean basin prior to the Atlantic
The New Madrid area was near a plate boundary about 500 million years ago: green lines

Slide from William Thomas
GSA Today Feb. 2006
New Madrid faults: within failed rift from opening of ocean basin prior to Atlantic Ocean about 500 million years ago; this was near a plate boundary at that time.

Now these ancient faults have been reactivated by compression within the plate.
USGS employs four-part strategy to reduce risk in the region

1. Monitor and report on the seismicity; rapid reporting of magnitude, location, and shaking of earthquakes
2. Develop and distribute products to reduce earthquake losses
3. Educate people in the use of these products
4. Continue the long-term research that will lead to improvements in these products and reduced levels of uncertainty
1811-1812 three earthquakes, magnitude 7.5-8.0 struck the New Madrid region within 2 months; thousands of aftershocks followed.

Examples of damage:
Houses were destroyed in New Madrid, houses damaged in Cape Girardeau, chimneys toppled in St. Louis, Vincennes, Nashville, and other locations.

Tops of trees sheared off in area of epicenters

USGS funds studies of historical earthquakes
Riverbanks caved.
Vast tracts of land sank and were uplifted …

Reelfoot Lake

Movement of the Reelfoot fault in the Feb. 1812 earthquake also produced waterfalls on the Mississippi River
Landslides occurred all along the bluffs.
In the central & eastern U.S., earthquakes affect much larger areas than in the west.

Intensity VII: moderate damage to non-engineered buildings

1811-12 earthquakes felt as far as New England

USGS funds studies on how seismic waves travel through the Earth’s crust.
What remains today…
(Blytheville, Arkansas)

sand blow
Liquefaction and Sand Blow Formation

During strong shaking, pore water pressure in saturated, loose sand increases until the sand loses its strength and acts like a liquid, finally erupting to the surface through fissures, forming sand blows.
Sand blows are the smoking guns that prove the occurrence of past large earthquakes.
How often do 1811-12 type earthquakes occur? Sand blows show that previous large earthquakes occurred around 1450 and 900 A.D.; about 500 years between M7.5-8.0 earthquakes, on average.
Probabilities of large earthquakes in the next 50 years in the New Madrid Zone

- Repeat of 1811-1812 (magnitude 7.5-8.0) - Approximately 7-10%

- Magnitude 6.0 or greater (such as the 1843 Marked Tree, AR and 1895 Charleston, MO earthquakes) - Approximately 25-40%

From studies of instrumental, historical, and prehistoric earthquakes
Earthquakes continue today in New Madrid and Wabash Valley seismic zones and scattered over Illinois, Indiana, Missouri, Arkansas, Tennessee, Kentucky, Alabama, and Mississippi.
Monitoring Earthquakes

- Network upgraded as part of Advanced National Seismic System (ANSS)
- In addition to National Backbone, over 120 stations operated by local universities and USGS
  - 20 new strong-motion stations monitoring urban areas and region: St. Louis, Memphis, Evansville
- National Earthquake Information Center (NEIC) now 24/7
Monitoring Ground Deformation

- 10 continuously operated Global Positioning System (GPS) stations operated by the University of Memphis and the University of Arkansas
ShakeMaps

About 5 minutes after the earthquake, the USGS and CERI (Univ. of Memphis) notify local, state, and federal emergency management officials and others with the epicenter and preliminary magnitude of the earthquake.

15 minutes after the earthquake, an initial set of Shakemaps of the earthquake is released by the USGS showing areas of expected higher ground shaking for emergency response, utilities, business recovery, public awareness.
60 minutes after the earthquake, seismograms have been analyzed to determine the geometry of the fault and an improved ShakeMap is released.
PAGER

Prompt Assessment Of Global Earthquakes For Response

Available about 15 minutes after earthquake; Improved version released about 60 min. after earthquake

Currently prototype; Publicly operational in September

The population exposure estimates are NOT a direct estimate of earthquake damage. Comparable shaking intensities will result in significantly lower losses in regions with well built and engineered structures than in regions with vulnerable structures. Users should consider the preliminary nature of this information when making decisions relating to public safety.

This information was automatically generated and has not been reviewed by a seismologist.

http://earthquake.usgs.gov/pager
Anticipating the Effects of the Next Large New Madrid Earthquake

USGS partnering with the Central U.S. Earthquake Consortium (CUSEC), Center for Earthquake Research and Information (CERI), emergency managers and State Geologists, USGS Mid-Continent Geographic Science Center, FEMA, the Coast Guard and other federal and state agencies on SONS07 exercise
Scenario
ShakeMaps
We make and distribute maps of expected ground shaking for possible earthquakes on specific faults. These are used for emergency planning and loss estimation. We are working with the MAE Center, FEMA, CUSEC, and Earthquake Engineering Research Institute by providing maps of expected shaking for a M7.7 New Madrid earthquake scenario.
The USGS makes **national seismic hazard maps** based on the best available science: research conducted by the USGS, state geological surveys, universities, and the private sector, funded through NEHRP.

These maps are used to guide various practical measures that reduce the loss of life and property from earthquakes.
The USGS works in cooperation with FEMA to incorporate the national seismic hazard maps into model building codes. The national seismic hazard maps are the basis for seismic design maps in the International Building Code and the International Residential Code.

One set of the USGS National Seismic Hazard Maps, shaking with a 2% chance of being exceeded in 50 years, is used in building codes in 47 states and DC; will be enacted in 3 more states next year.
From Earthquake Monitoring and Research To Improving Public Safety

- **Seismic hazard maps** have improved building codes and the design of bridges and other structures; they help to save lives and reduce property losses (for example, Northridge, Loma Prieta, and Nisqually earthquakes)
- They are also used in the design of critical facilities (DOE), dams (Army COE), landfills (EPA) and in the evaluation of nuclear power plants (NRC)
- They are used in loss estimation studies
- They are used to set premiums for earthquake insurance
Urban Seismic Hazard Maps

- Include the effects of the local geology
- Need detailed maps of surficial geology and knowledge of sub-surface geology
- Useful for: prioritizing retrofitting of unreinforced masonry buildings, initial seismic design of structures, screening studies, urban planning
Computer Simulation of M6.5 Earthquake near Seattle Showing How Shallow Soils Amplify and Trap Seismic Waves
Urban hazard mapping in the Central U.S. involves local and state partners.

St. Louis

Evansville

Memphis

Missouri Dept
Of Natural Resources
Research Questions on Mid-America Earthquakes To Reduce Uncertainties and Improve Risk Mitigation

- What is the full extent of the New Madrid seismic zone? Search for more geologic evidence. Use seismic and geophysical exploration methods to identify active fault systems.

- Are there other areas in mid-America besides the New Madrid zone that can produce large earthquakes? How often do they occur? We know that Wabash Valley zone has $M \geq 6.5$ with about 4000 yr recurrence. Search for geological and geophysical evidence of prehistoric earthquakes and active fault systems.

- Can we identify areas of high hazard using GPS measurements of ground deformation?

- What level of ground shaking can we expect from future large earthquakes? Use data from the Advanced National Seismic System; map the properties of soils that amplify ground shaking; need more instruments to improve Shakemap and urban hazard maps.
From Earthquake Monitoring and Research To Improving Public Safety

- **Scenario ground-shaking maps** provide information on expected shaking for future large earthquakes to emergency managers, engineers, government officials, businesses, and the public, so that they can plan for these earthquakes and ensure community resilience.

- **ShakeMaps** provide rapid information on observed and expected ground shaking when an earthquake occurs; key to situational awareness and emergency response to reduce loss of life and property and speed business recovery.

- **Seismograms from ANSS** are used in the design of buildings and critical facilities; they tell us how strong the ground will shake in future large earthquakes.
What we can do before the earthquake to reduce its effects on communities: the USGS makes national seismic hazard maps based on geoscience research conducted by the USGS, state geological surveys, universities, and the private sector, funded through NEHRP.
Urban Hazard Maps in the Central U.S.
Urban Hazard Maps in the Central U.S.
Urban hazard maps involve state and local partners
Making Seismic Hazard Maps

- Use fault information, evidence of prehistoric earthquakes, instrumental and historical earthquake catalog (ANSS), and ground deformation measurements to estimate probabilities of large earthquakes
- Estimate the level of ground shaking if these earthquakes occur (ANSS data)
- Hazard maps show the ground shaking to be expected with a certain probability
USGS makes ground-motion maps for earthquake scenarios:

**M 7.7 Southwest Segment**

**New Madrid Seismic Zone**

Here we have converted ground motion values to intensities. These types of maps are used to estimate losses given inventory of buildings.
From Science to Mitigation of Risk

Earth Science Information

Seismological: earthquake monitoring, ground-motion studies (ANSS)

Geological: studies of prehistoric earthquakes, fault studies, geologic mapping

Geophysical: crustal deformation GPS, studies to determine subsurface properties

Quantitative Assessment Of Hazard

USGS national seismic hazard maps

Urban seismic hazard maps

Scenario ground motion maps

Mitigation of Earthquake Risk

Seismic provisions in building codes

Design standards for bridges

Land-use planning

Loss estimation

Earthquake insurance

Emergency management
Educate people in earthquake hazard

- Building shaking scenarios for state and local exercises
- Hosting field trips
- Local earthquake town hall meetings
- Fact sheets
- Public Earthquake Resource Center
- Preparing educational and informational materials
- Working with state emergency management agencies, departments of transportation, and geological surveys through Central U.S. Earthquake Consortium
How Often Do 1811-12 Type Earthquakes Occur?

USGS funds studies to identify and date sand blows from prehistoric earthquakes.
In some states, building codes are adopted on a local level:

Shelby County (Memphis) has recently amended its building code to allow non-essential buildings to be designed to lower ground-shaking levels than used previously. They reduced the force levels for 10 story buildings by 45%, compared to the Standard Building Code that was used prior to 2006.
Two GPS studies: one finds significant deformation across New Madrid zone, the other doesn’t. We need a longer observation time; also some models of intra-plate processes predict little deformation in the time between earthquakes.

In any case, there is clear geologic evidence of repeated large earthquakes and high seismic hazard.
Over 450,000 Individual Responses Nationally!

Yellow $\approx$ MMI 6  
Slide provided by D. Wald, USGS
Slide composed by D. Wald

National Hazard Map (50 years)