

Earthquake Hazard Mitigation

**Mitigation Through Design
for
Nonstructural Components**



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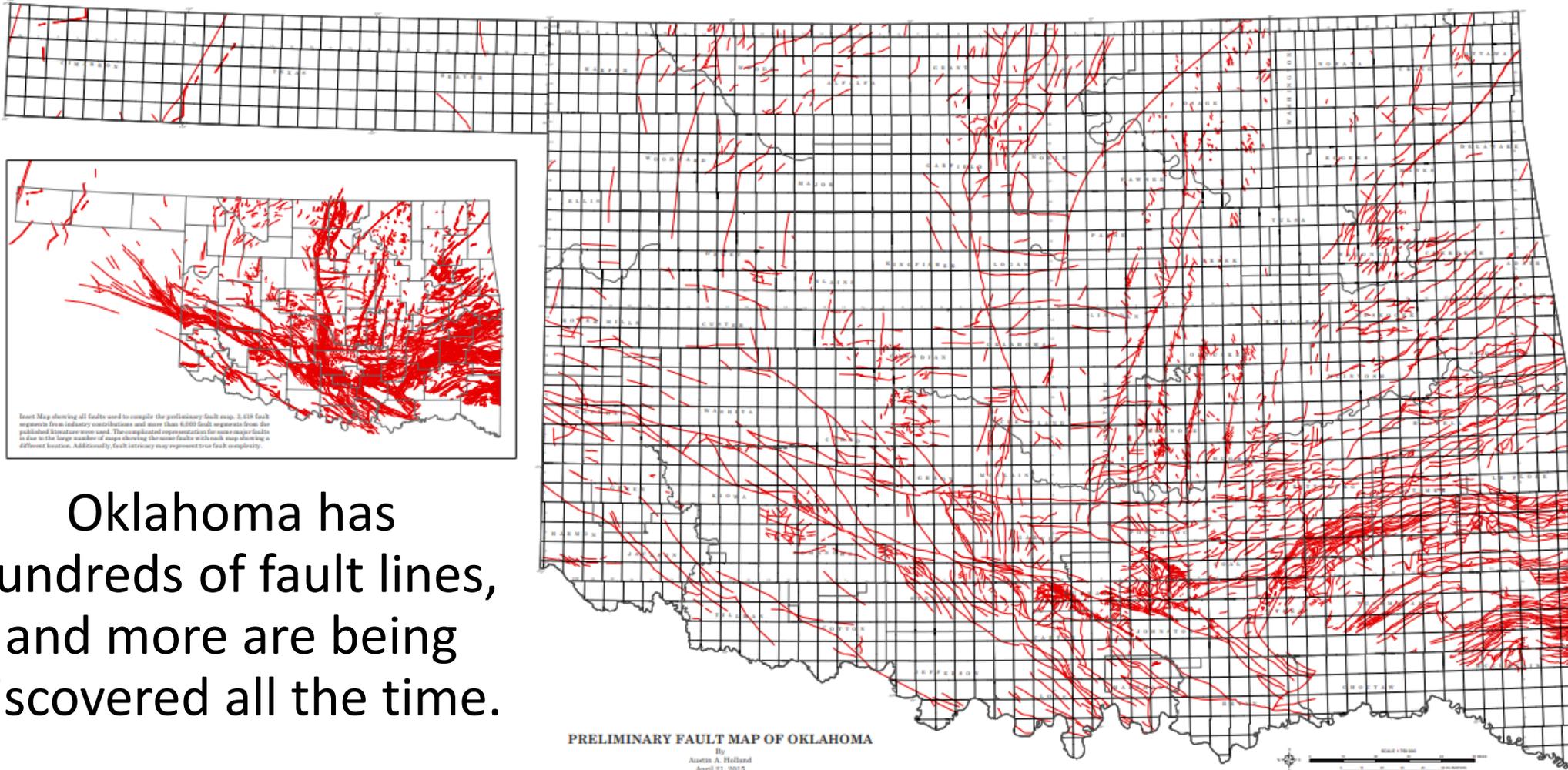


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Fault Lines in Oklahoma

OKLAHOMA GEOLOGICAL SURVEY
Richard D. Andrews, Section Director

OPEN FILE REPORT OFD-2015
Preliminary Fault Map of Oklahoma



Inset Map showing all faults used to compile the preliminary fault map. 3,438 fault segments from industry contributions and more than 4,000 fault segments from the published literature were used. The overlapping representation for some major faults is due to the large number of maps showing the same faults with each map showing a different location. Additionally, fault activity may represent true fault complexity.

PRELIMINARY FAULT MAP OF OKLAHOMA
By
Austin A. Holland
April 21, 2015

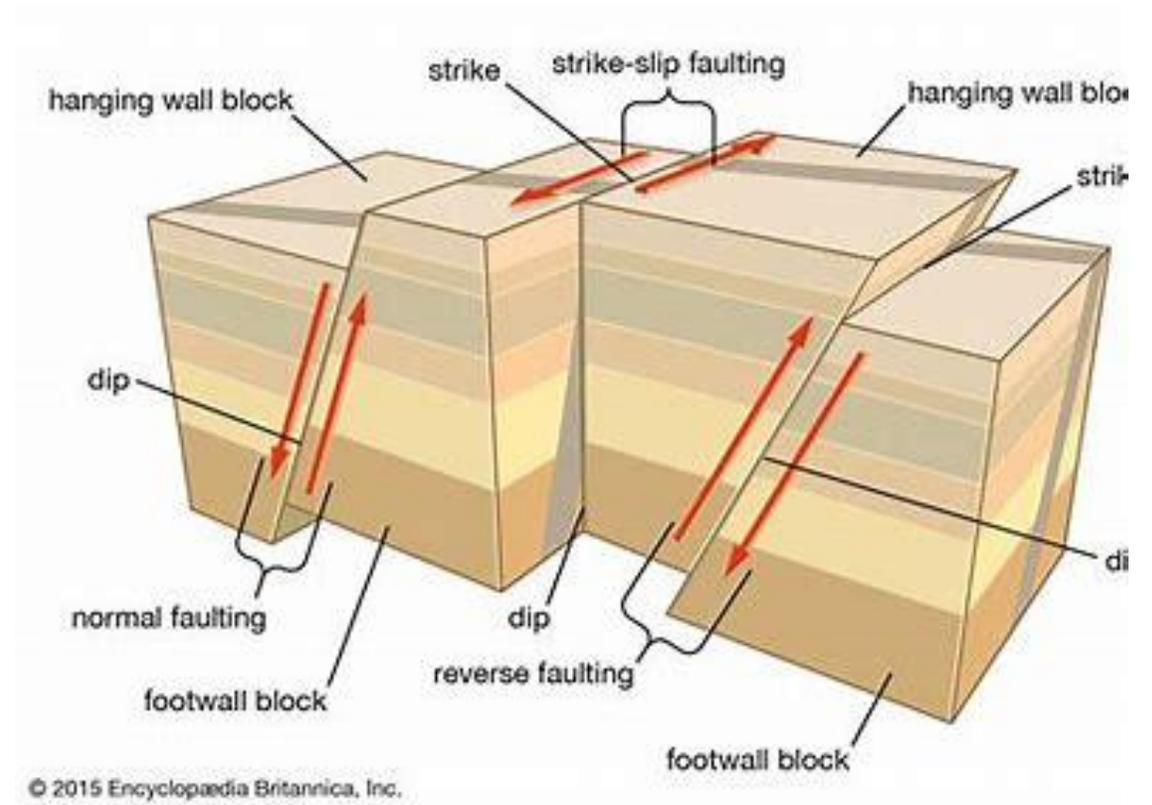
Oklahoma has hundreds of fault lines, and more are being discovered all the time.



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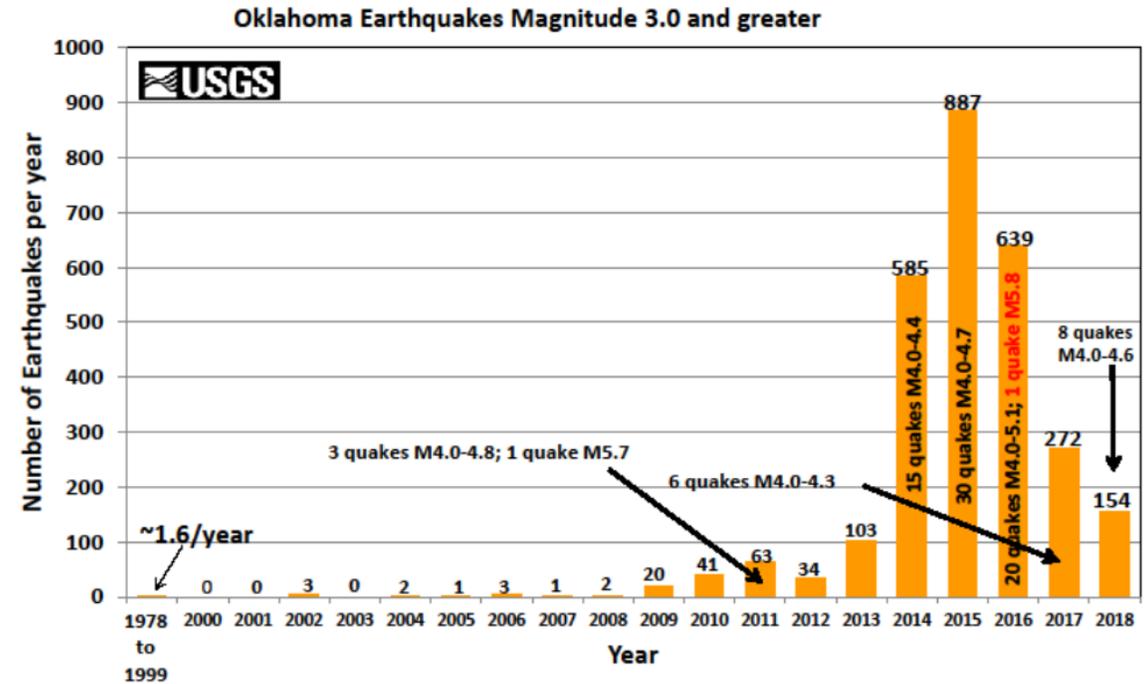
USGS Reports ...

- Oklahoma rock layers are squeezed in an east-west direction from forces at the Mid-Atlantic Ridge, San Andres and the Juan de Fuca Ridge.
- But the underground faults identified in a recent USGS study tilt to the northwest or northeast, creating an angle of about 30 to 40 degrees from this regional pressure.
- This is the optimal orientation for producing strike-slip faulting.



Earthquake Hazard Mitigation Plan

- The Oklahoma State Standard Hazard Mitigation plan was approved by FEMA in 2019.
- Evaluates and identifies mitigation efforts for all types of disasters, including earthquakes.
- Calculates probability and risk as well as vulnerabilities



Source: USGS-NEIC ComCat & Oklahoma Geological Survey; Preliminary as of Dec 3, 2018

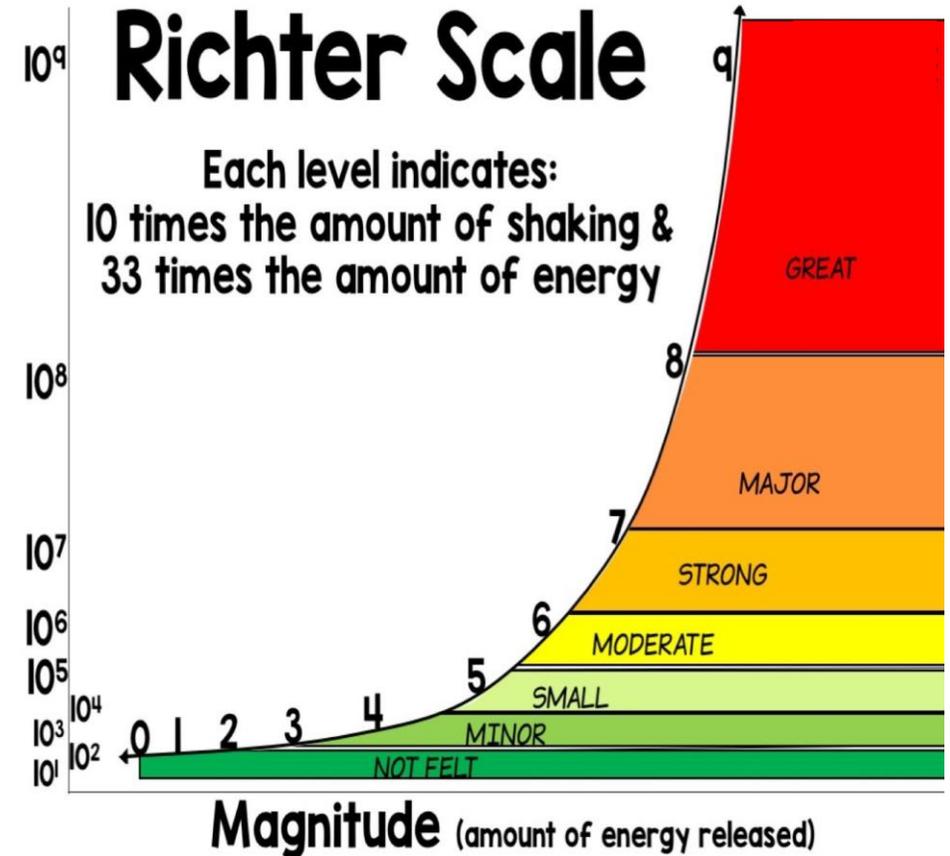
What changed in 2009?

How earthquakes cause damage

- **Ground shaking and structural failure** - the shaking triggers other hazards such as liquefaction and landslides.
 - Most earthquake damage results from the seismic waves passing beneath buildings, roads, and other structures.
- **Surface rupture and ground displacement** - it can be caused by vertical or horizontal movement on either side of a ruptured fault. Ground displacement, which can affect large land areas, can produce severe damage to structures, roads, railways and pipelines.
- **Landslides** - may result in falling rocks and debris that collide with people, trees, animals, buildings and vehicles. They also can block roads and disrupt utility lines.
- **Liquefaction** - occurs during an earthquake when saturated soil temporarily loses its strength and behaves like a liquid.
- **Tsunamis** - a series of very long waves which travel along the ocean floor and can cause significant damage when it makes landfall.
- **Fires** - start when electrical and gas lines are dislodged due to the earth's shaking. Gas is set free as gas lines are broken and a spark will start a firestorm.

At what magnitude does damage occur?

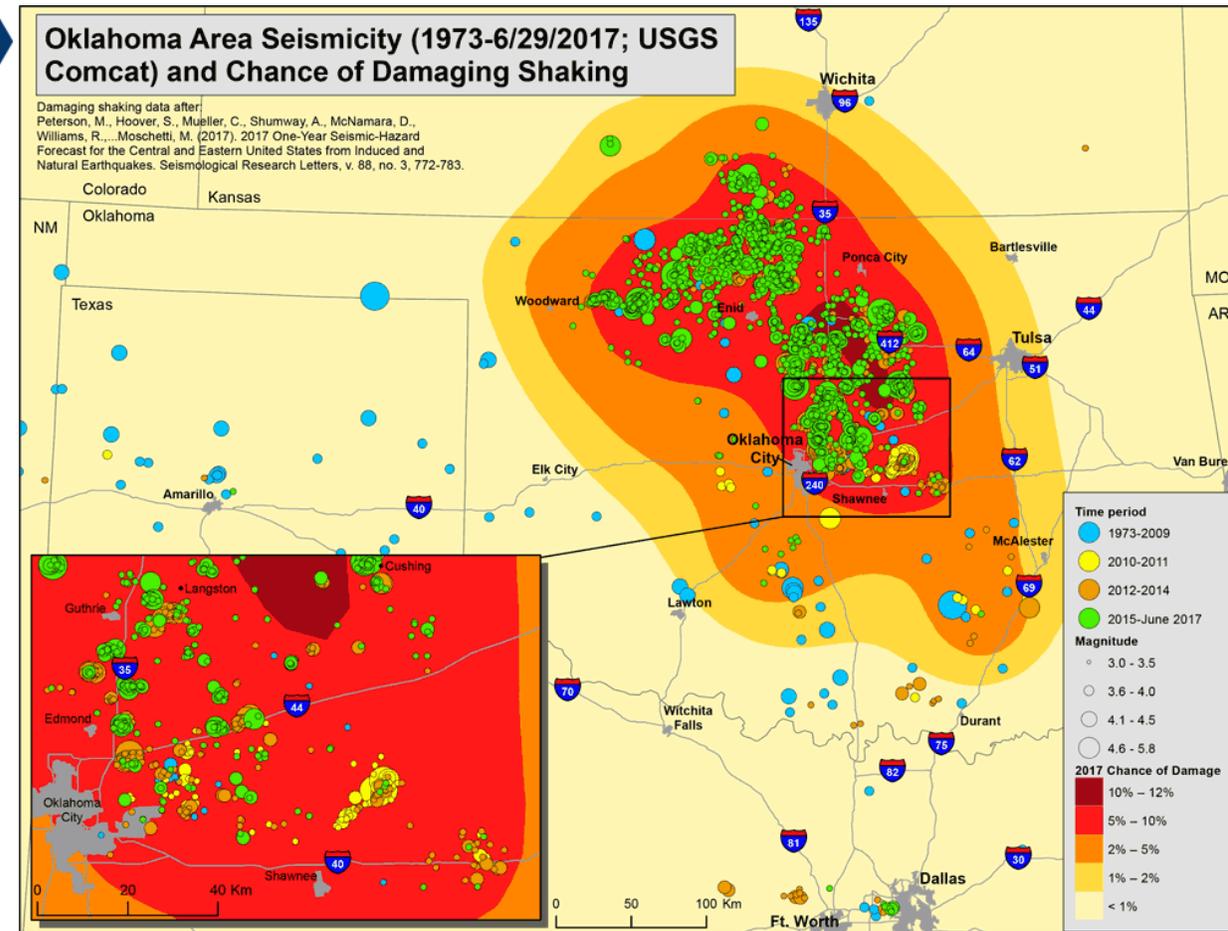
- There is not one magnitude above which damage will occur. It depends on other variables, such as the distance from the earthquake, what type of soil you are on, building construction, etc.
- However, damage does not typically occur until the earthquake magnitude reaches somewhere above 4 or 5.
- Emergency Managers in Oklahoma have long been preparing for - and working on mitigation efforts for - a 6.5 earthquake.



Earthquakes? In Oklahoma?

- 7M – Meers Fault - ~1,100
- 5.8M – Pawnee – Sept. 3, 2016
- 5.7M – Prague – **Nov. 6, 2011**
- 5.7M – Fort Gibson – Oct. 22, 1882
- 5.5M – El Reno – April 9, 1952
- 5.0M – Cushing – Nov. 7, 2018
- 5.1M – Fairview – Feb. 13, 2016
- 4.8M – Sparks – **Nov. 5, 2011**
- 4.8M – Sparks – **Nov. 8, 2011**
- Etc...

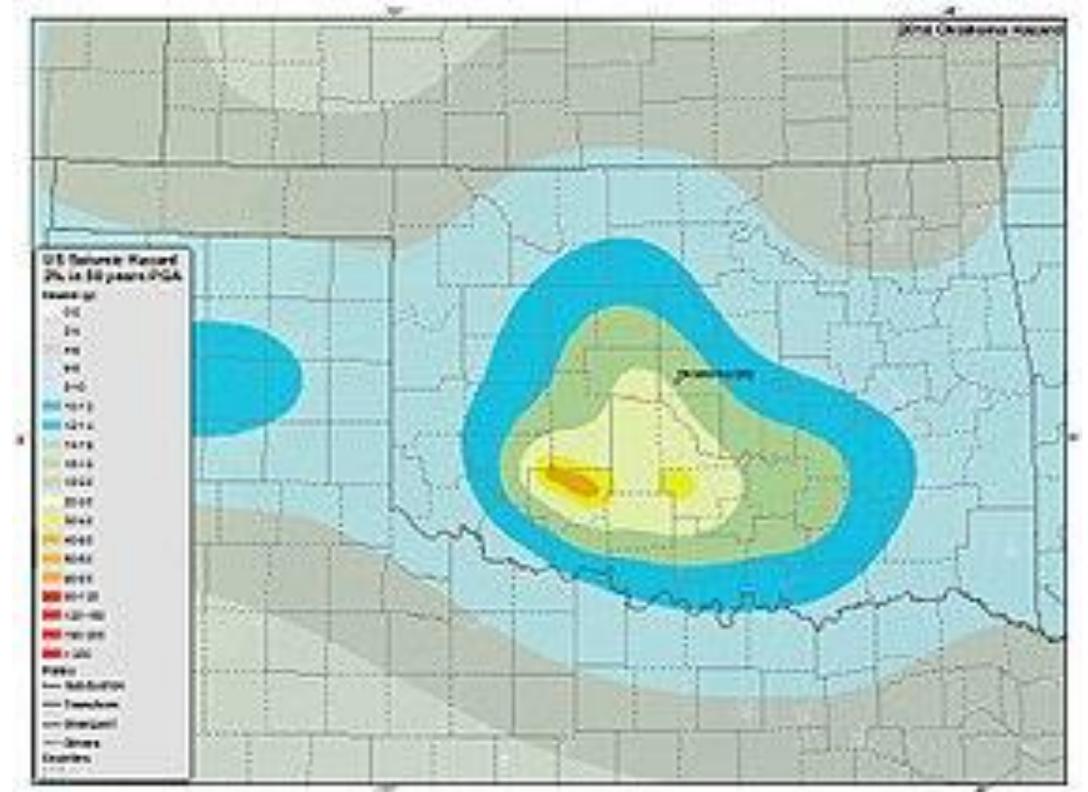
“Earthquakes don’t kill people, buildings do.”





Areas Most Vulnerable

- According to the ***Oklahoma Office of Emergency Management***, areas predominantly from the central area north extending to the northwest, including:
 - Oklahoma City
 - Edmond
 - Guthrie
 - Stillwater
 - Enid
 - Cushing



Industry in Oklahoma

- Per the Tulsa World New Article from February 21, 2016;
- *“Cushing may be home to less than half of a percent of Oklahoma’s total population, but the city with just fewer than 8,000 residents is arguably more important to the energy industry than any other point in North America. And if anything, the importance of the self-proclaimed “Pipeline Crossroads of the World” is only growing. The Cushing Interchange, just south of the city’s downtown along Linwood Avenue, is one of the largest crude-oil marketing hubs in the U.S. Dotted with tanks that together could hold nearly 90 million barrels of crude oil, Cushing is the designated point of delivery for the commodity’s New York Mercantile Exchange’s futures contracts. It’s also the price settlement point for the central United States’ oil benchmark, the light sweet crude West Texas Intermediate.”*

Specific Vulnerabilities

- Infrastructure vulnerabilities include, but are not limited to:
 - Highways, bridges and overpasses
 - Transportation
 - Dams
 - Water treatment facilities
 - Power transmission distribution
 - Chemical manufacturing
 - Petrochemical facilities and pipelines
 - Human vulnerabilities



Why should businesses care about earthquakes?

- 40% of businesses effected by a disaster won't reopen
- 25% more businesses will close within a year
- 75% of business without a continuity plan fail within three years
- The average daily loss to businesses can range from \$3,000 to \$23,000 for small- to medium-sized businesses
- 99% of all companies are “small businesses”
- Small businesses employ 50% of all the private sector workforce

Source: 2014 data from the Federal Emergency Management Agency (FEMA) and US Department of Labor

Think about YOUR facilities...

- What makes your organization valuable?
- What makes your business vulnerable?
- Preparation and mitigation begin by conducting a risk/vulnerability assessment



RISK ASSESSMENT

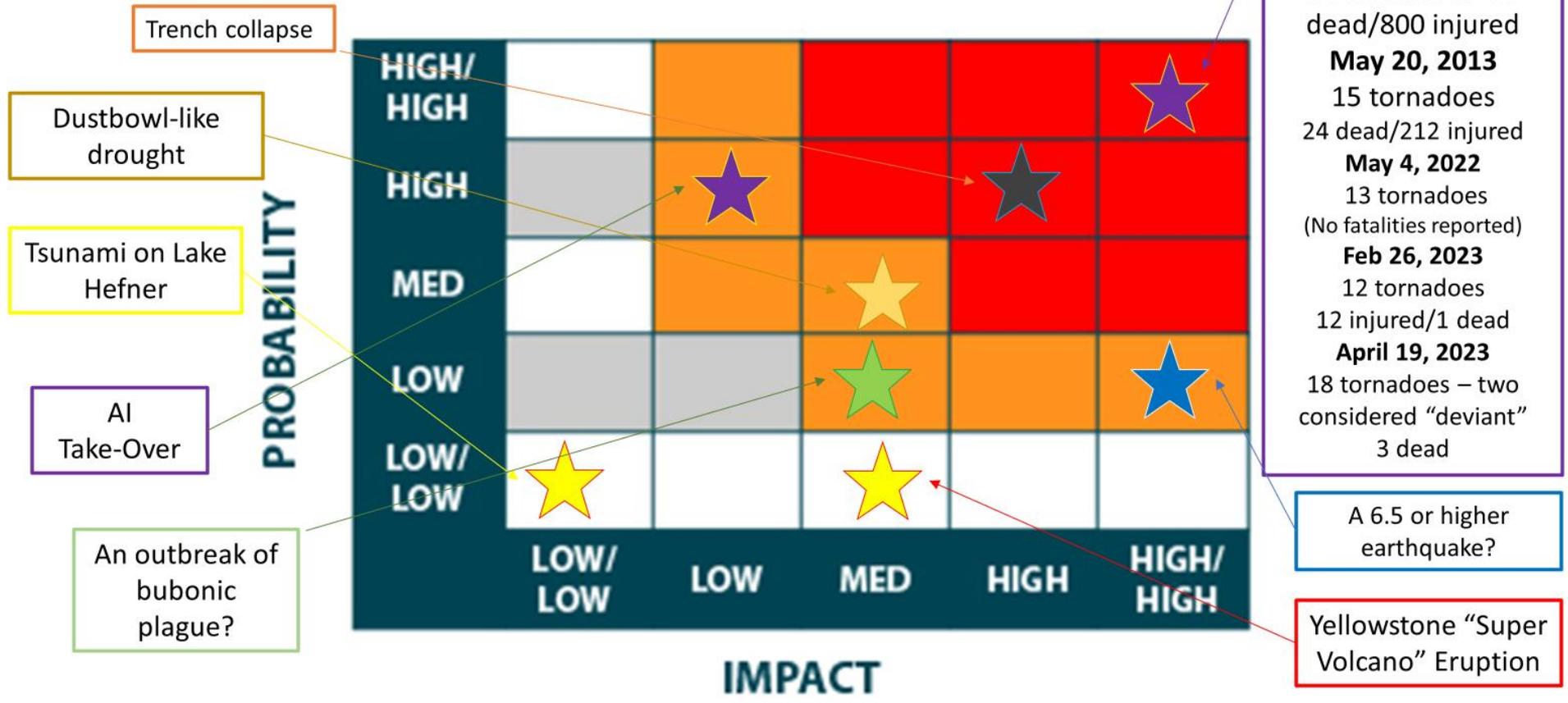
- HAZARD x VULNERABILITY = RISK
 - Building age and construction methods
 - Building contents
 - Geography & Geology
 - Processes on-going internally
 - Processes and hazards surrounding your property
 - Occupancy

IDENTIFY
THE HAZARDS

ASSESS
VULNERABILITIES

REDUCE
THE RISKS

Probability vs. Impact

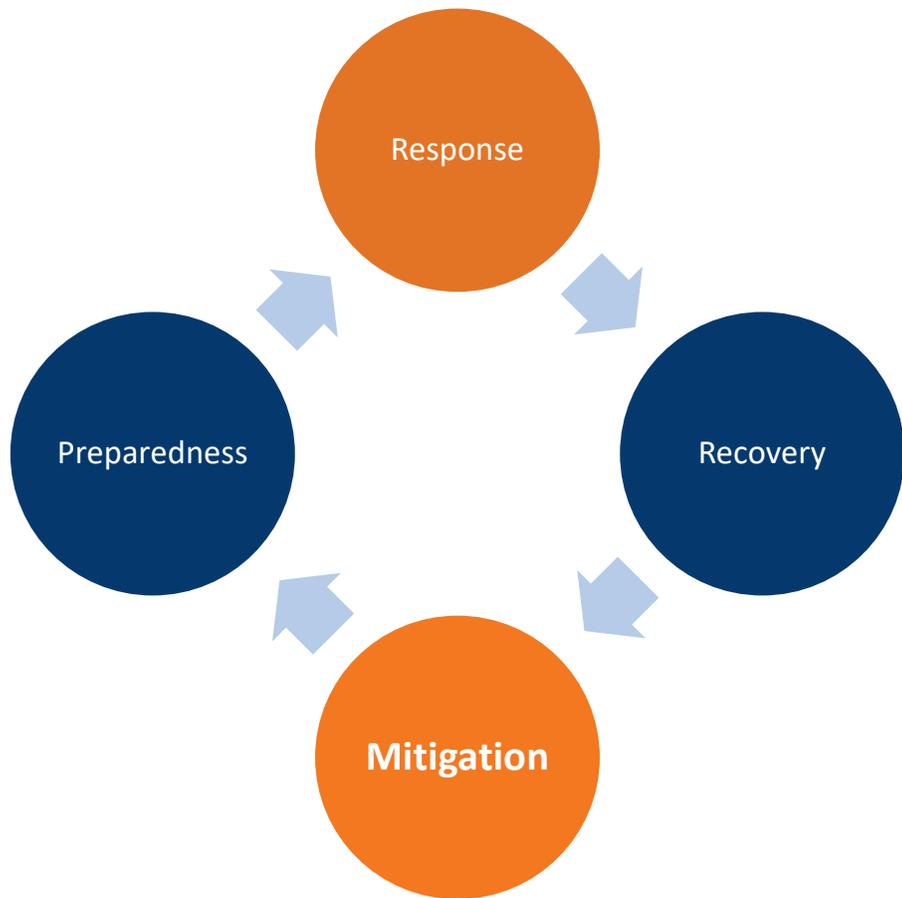


May 3, 1999
74 tornadoes -46 dead/800 injured
May 20, 2013
15 tornadoes
24 dead/212 injured
May 4, 2022
13 tornadoes
(No fatalities reported)
Feb 26, 2023
12 tornadoes
12 injured/1 dead
April 19, 2023
18 tornadoes – two considered “deviant”
3 dead

A 6.5 or higher earthquake?

Yellowstone “Super Volcano” Eruption

The Four Phases of Emergency Management



- Preparedness – anything you do to prepare for a disaster before it occurs
- Response – what you do during/immediately after
- Recovery – any efforts to get back to normal or “new normal”
- **Mitigation** – efforts to reduce exposure to, probability of, or potential loss from hazard events – the *Forgotten Phase of EM*

Why Mitigation?

- Consider mitigation actions and projects to help your facility better withstand an earthquake, minimize damage and rapidly recover from disruptions to service. Mitigation should be part of your management of change process
- When you replace aging equipment after its design life, install seismic upgrades, which are typically not major added costs.
- Earthquake mitigation saves up to \$12 per \$1 invested.

Source: The National Institute of Building Sciences

Resilience Through Design

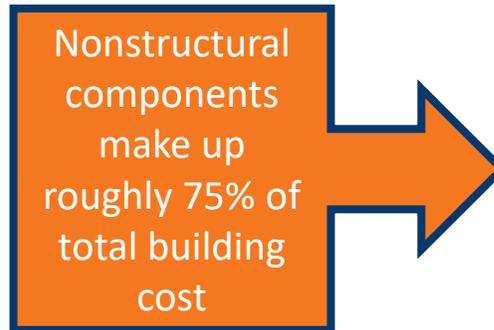
- Eliminating hazards and controlling risks to workers to an acceptable level “at the source” or as early as possible in the life cycle of items or workplaces.
- Including (mitigation) design, redesign and retrofit of new and existing work premises, structures, tools, facilities, equipment, machinery, products, substances, work processes and the organization of work.
- Enhancing the work environment through the inclusion of prevention (aka mitigation) methods in all designs that impact workers and others on the premises

There are two sides to hazard mitigation for earthquakes

- Structural

- The building itself:
- Roof
- Floors
- Beams
- Columns
- Braces
- Concrete or masonry walls,
- Etc.

Nonstructural components make up roughly 75% of total building cost



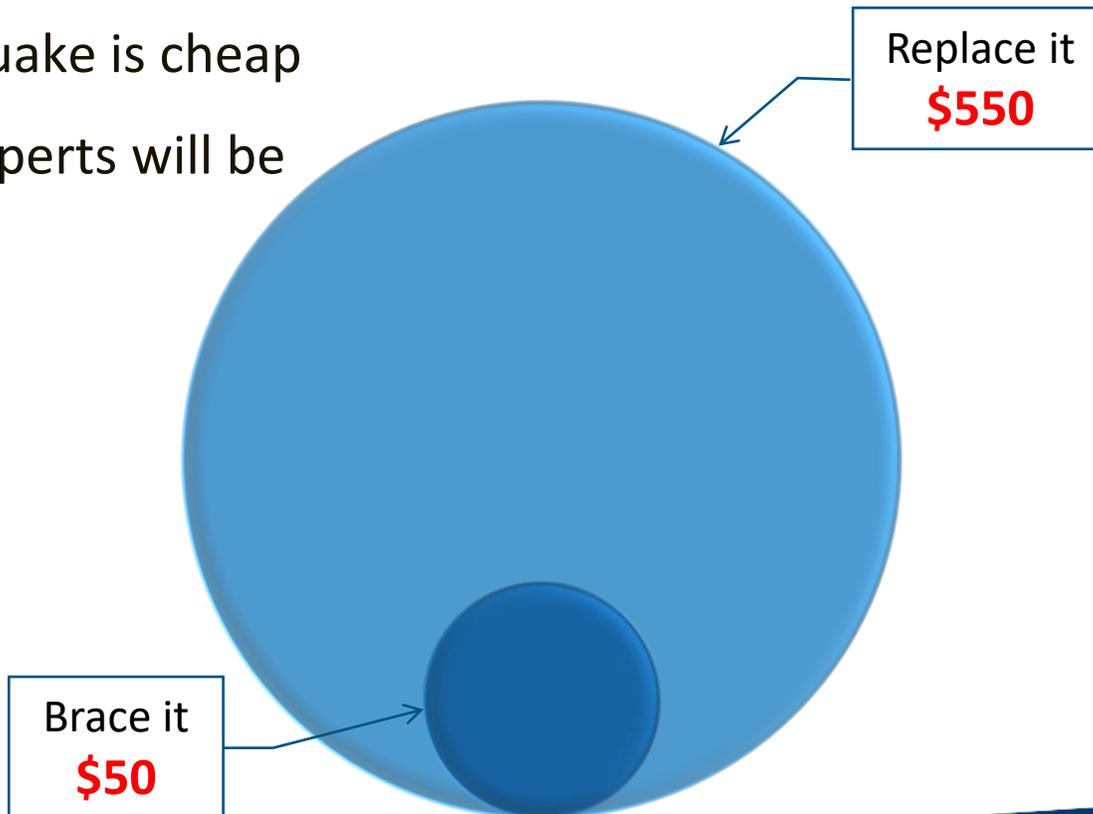
- Nonstructural

- Architectural components
- Mechanical, electrical and plumbing components
- Fixtures, furniture, equipment, contents
- Processes
- Etc.

Brace it or replace it?

- Retrofitting before an earthquake is cheap
- Repairs are expensive, and experts will be busy after an event

*The cost to replace a water heater is **10 times** more than the cost to brace it.*



What is earthquake mitigation?



ANCHOR PLATE
Installation Instructions

Tools Required
Power Drill
Ratchet Wrench

NOTE: The Haworth anchor plate is designed to be used with PLACES®, UniGroup®, and PREMISE® furniture systems. The anchor plate mounts to the floor with two (2) 5/8" diameter x 2-9/16" long anchor bolts, complying with the latest ICBO report No. 2895 installation specifications.

1. Before setting panels in place, extend the glide stem an additional 1/4" to provide clearance for the anchor plate.
2. Follow the appropriate PLACES, UniGroup or PREMISE panel installation procedures.
3. Determine location for anchor plates.
NOTE: Local code may dictate cubicle configuration and anchor locations.
4. Slide anchor plate around glide stem and use holes in anchor plate as a template to mark floor for location of bolt holes (**Fig. 1**).
5. Remove the anchor plate from the glide stem and follow instructions from the anchor bolt manufacturer for drilling anchoring holes (**Fig. 2**).
6. Replace anchor plate and install anchor bolts (**Fig. 3**).
7. Repeat the above procedure for furniture configuration as required by the appropriate regulatory agency.

OSHPD Approval
The California Office of Statewide Health Planning and Development (OSHPD) requires furniture systems in excess of 5' 9" tall to be anchored in an approved method. Contact your local Haworth Field Sales Engineer or Design Consultant for specific design and installation requirements and the OSHPD pre-approval documentation.

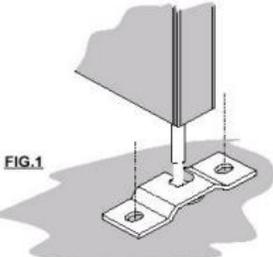


FIG.1

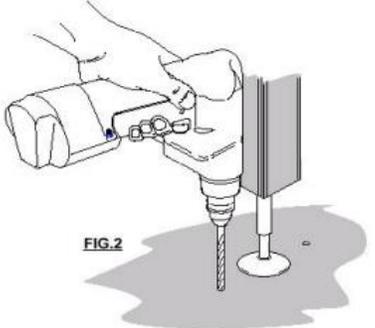


FIG.2

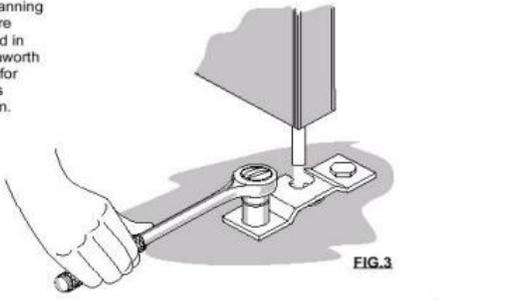


FIG.3

CUSTOMER SERVICE PHONE: 1-800-426-8562

HAWORTH	E.C.O. No: 209-870	Page: 1 of 1	Part No: 7021-6883	Rev. B
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Office Areas

- The following manufacturers of office furniture claim their products performed well in earthquake simulations:

- Haworth
- Herman Miller
- Steelcase



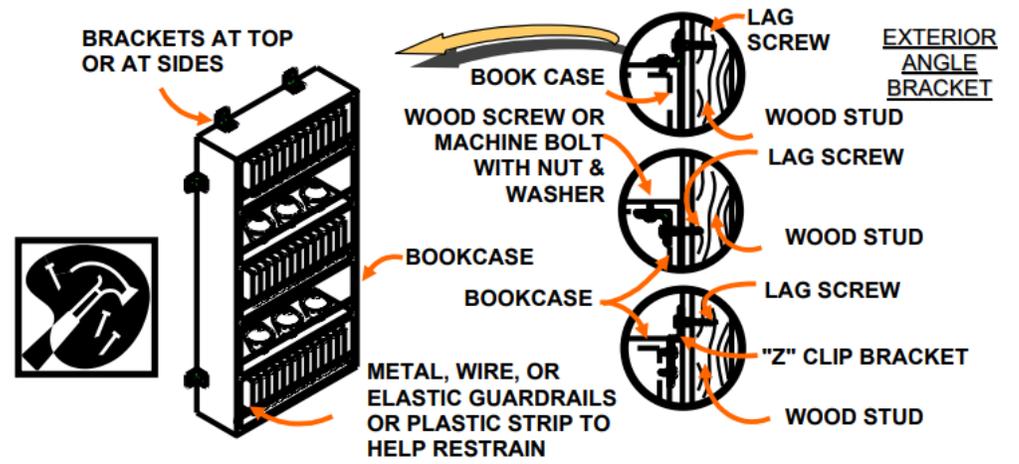
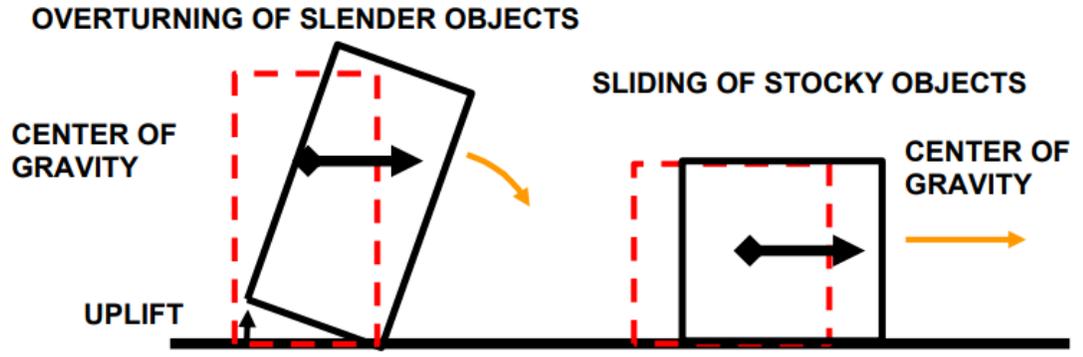
“Minor damage” to property in the building



A bookcase overturned onto a desk, spilling the contents

Degenkolb Engineers

Bookcases and tall slender objects



Paintings/Mirrors/Picture Frames

- Chose the right hardware
- Tremor Hooks or closed loop hangers are best practice
- Hook hangers and secure anchor wires can also be used in some instances
- Use 'no-shatter' materials instead of standard glass



Suspended Ceiling Tiles



- Bracing wires inclined at 45-degree angles to brace the grid horizontally.
- Vertical compression posts to brace the grid vertically
- Separate suspension wires for heavy ceiling mounted objects such as light fixtures.

Plate Glass Windows



- To prevent injuries from flying glass, apply safety film to windows and glass doors.
- Install tempered glass.
 - Tempered glass reduces the seismic hazard because it breaks into smaller fragments rather than large shards.

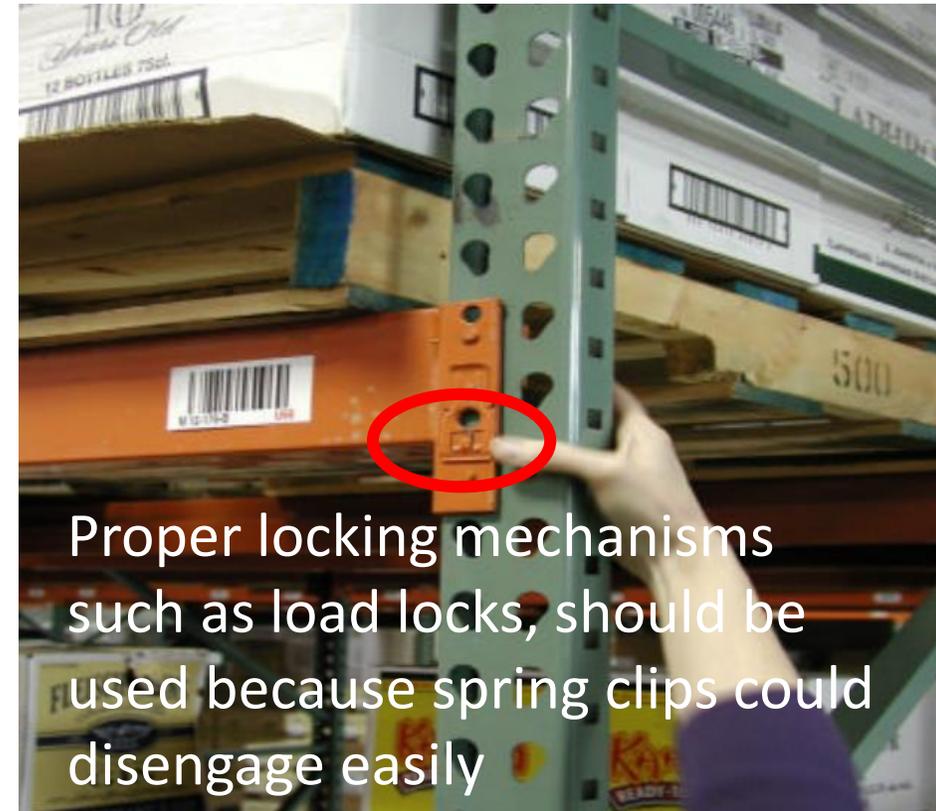
Loss of inventory



Mitigation Efforts in Warehouses

- Prepare employees and secure items before quake hits.
 - Bolted feet and horizontal bars at shelf-tops prevent racks from collapsing
 - Secure boxes on shelves
 - Keep heavier items on lower shelves
 - Keep gas cylinders in secure housing with flammable gases separate from oxygen
 - Chose racks and shelving with appropriate seismic ratings

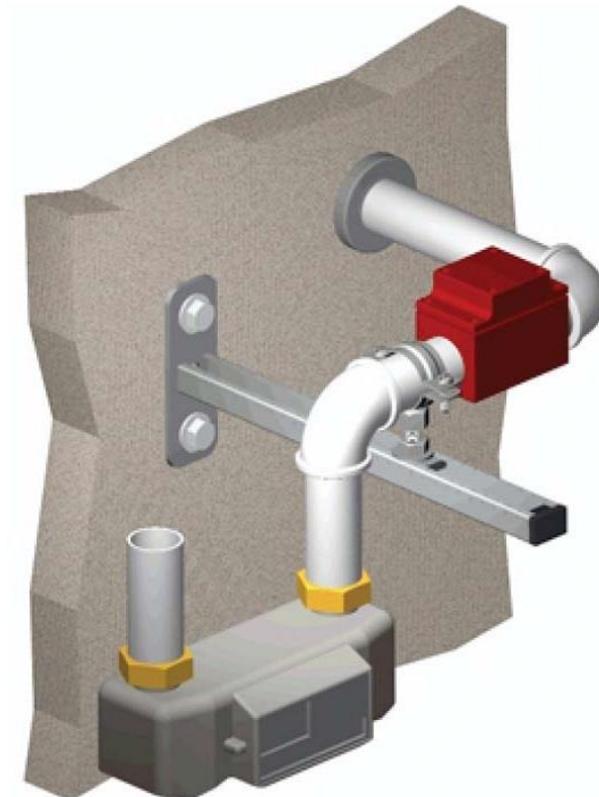
Warehouse Controls



Protecting Gas Lines

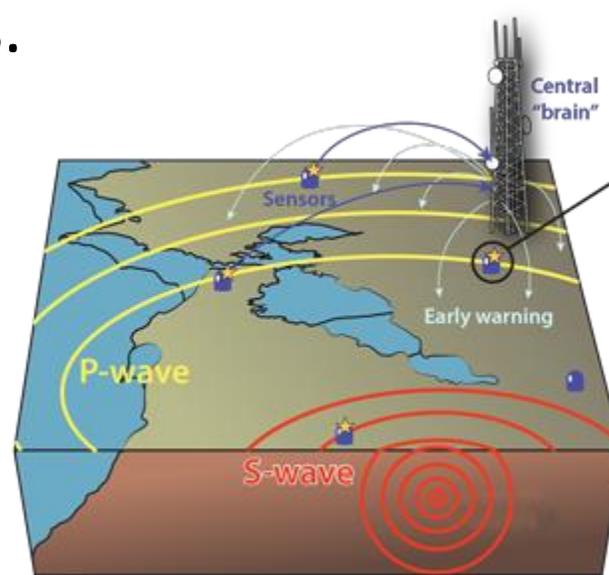


Seismic Gas Valve



Earthquake Early Warning Systems

- By detecting the initial seismic signals of an impending earthquake, EEW systems can provide crucial time for preventive measures such as shutting down operations, securing hazardous materials, and evacuating affected areas.
- USGS ShakeAlert®
- ShakeCast
- AI-supported EWS



ShakeAlert:

- 1) When an earthquake begins, non-damaging P-waves are detected by sensors throughout the region.
- 2) Information about shaking is sent to a central processing center, where the size and location of the event are determined.
- 3) A forecast of the shaking intensity at locations away from the epicenter is sent out seconds to minutes before the damaging S-waves arrive.

ZINA

Utilities, Appliances & Furnishings

- Propane & other fuel tanks – securely chained to the foundation or across several studs in the wall
- Flexible connectors between appliances and gas/electrical supply.
- Easily accessible shut off valves at the gas and water meters
- Secure large appliances using heavy duty nylon-wrapped guide wires or chains to keep them in place and functioning.
- Bookshelves, cabinets and large furnishings can be secured with angle iron, eye hooks and similar hardware, properly anchored to the wall studs.
- “Child proof” latches can ensure cabinet doors remained closed and contents not spilled out.
- Televisions & computer screens can be secured with special hooks, Velcro, or similar products.

Other things to consider

- Permanence
- Redundancy
- Building Interaction
- Building Performance
- Anchorage to Structural Framing
- Limitations



Anchorage – Special Considerations

Structural Framing Material	Types of Anchorage	Considerations
Steel	Welding	Welding should be done by qualified welders in compliance with applicable codes and standards. For older structures it may be necessary to check the existing steel for weldability.
	Bolts and screws	Bolts should be installed in drilled holes. Self-tapping screws should be installed according to manufacturers' recommendations.
	Clamps	Clamps should only be used to restrain lightweight items.
Concrete or Masonry	Cast-in-place anchors	Cast-in-place anchors can only be installed when new concrete elements are placed.
	Epoxy anchors	Holes for epoxy anchors need to be thoroughly cleaned.
	Expansion anchors	Expansion anchors need to be tightened to verify that the wedges are properly set. Expansion anchors should not be used for overhead applications or for vibrating equipment.
Wood	Bolts	Bolts should be installed into drilled round holes.
	Lag screws	Lag screws should be installed into holes that are predrilled in the wood to reduce the possibility of splitting the wood. Lag screws should not be forced into the wood using a hammer. Nails should not be used for anchorage.

- When anchoring nonstructural elements, the structural framing must have sufficient strength to resist the forces due to the nonstructural elements.
- For nonstructural items that weigh more than 100 pounds, it is recommended that an **engineer be consulted** to determine whether the structural framing can support the forces of the nonstructural element.
- Building codes typically require engineering calculations for anchorage or support of items weighing more than 400 pounds.

What can we do in-house?

- Brace suspended ceilings
- Secure bookshelves
- Brace a water heater
- Anchor TVs, computers, and other appliances
- Secure heavy furniture
- Reinforce foundation anchorage and strengthening cripple walls
- Anchor demountable partitions (cubicles)

Expert
Tip

*FEMA posts free
resources on
their website*

When do I need a professional's help?

- Installing flexible gas lines
- Anchoring boilers and furnaces
- Bracing unreinforced masonry
- Anchoring solar panels
- Securing transformers, switch gear, and emergency generators
- Anchoring industrial storage racks
- Securing HVAC equipment
- Any structural changes where a registered engineer is necessary



Take Action

START NOW! Here are three easy things you can do **today** to get started:

1. Make sure that exit paths are clear of clutter and hazardous materials.
2. Secure heavy equipment, shelves, bookcases and their contents so they don't collapse into exit paths.
3. Create and train staff on earthquake action plans and mitigation efforts.



Resources

- https://mitigation.eeri.org/files/FEMA74_FieldManual.pdf
- https://www.fema.gov/sites/default/files/documents/fema_fema-331-protecting-business-operations.pdf
- https://www.fema.gov/sites/default/files/2020-07/fema_earthquake-resistant-design-concepts_p-749.pdf
- <https://www.usglassmag.com/what-fema-says-about-glass-behavior-during-an-earthquake/>
- <https://www.ehs.washington.edu/system/files/resources/earthquake-plan-chem-storage.pdf>
- <https://www.epa.gov/sites/default/files/2018-02/documents/180112-earthquakeresilienceguide.pdf>

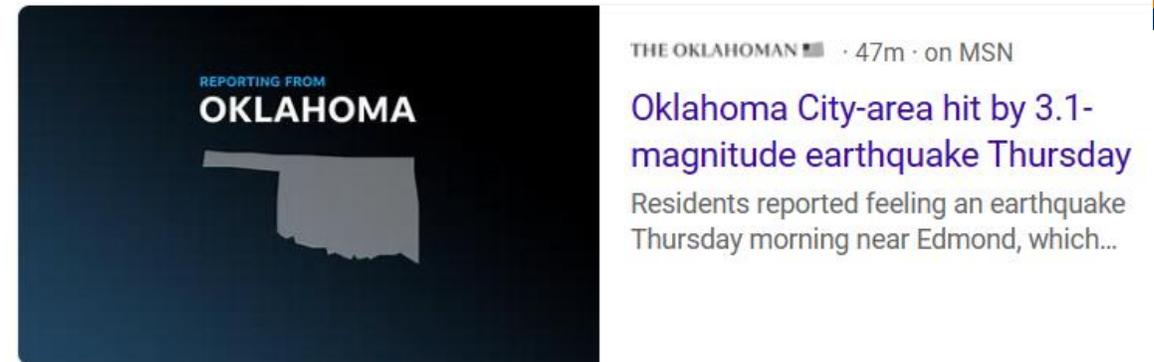
Resources

- <https://readytorecover.org/episode-7-disaster-recovery-challenges-and-solutions-for-small-businesses/>
- <https://readytorecover.org/r2re5/>
- <https://www.agilityrecovery.com/article/earthquake-safety-preparedness>
- https://www.fema.gov/sites/default/files/2020-07/fema_earthquake_other-business-tools.pdf
- https://www.fema.gov/pdf/about/org/ncp/coop_brochure.pdf
- https://www.fema.gov/pdf/plan/prevent/rms/397/fema397_a.pdf

Resources

- https://www.fema.gov/sites/default/files/2020-10/earthquake-resistant-design-concepts_nehrp-seismic-provisions.pdf
- <https://www.epa.gov/sites/default/files/2018-02/documents/180112-earthquakeresilienceguide.pdf>

Oh, the irony! While working on this presentation, we got a new piece of equipment we were working to secure so it wouldn't topple over in an earthquake. When I returned to my desk, this was in my newsfeed.



**BETSEY KULAKOWSKI, CSHO, COSS
EXECUTIVE DIRECTOR**

Thank You
For Your Attention



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