BUILDING INNOVATION
Conference

Recovering from Earthquakes

Why the 2024 New Jersey earthquake is an important reminder of how the National Earthquake Hazards Reduction Program works to protect lives and the Nation's economy

Panelists

Dr. Jay Harris

Acting NEHRP Director

National Institute of Standards & Technology

Dr. Nicolas Luco

Supervisory Research Civil Engineer

U.S. Geological Survey

Robert Pekelnicky

Senior Principal

Degenkolb Engineers

Moderators

Dr. Roberto Leon

Via Professor of Civil and Environmental Engineering

Virginia Tech

Sara Barrett

Project Manager

National Institute of Building Sciences

National Earthquake Hazards Reduction Program

Supporting the Nation's Earthquake Resilience

Dr. Jay Harris

NEHRP Provisions Update Committee NIST Liaison

Acting NEHRP Director, NIST

National Earthquake Hazards Reduction Program (NEHRP, "*nee-herp*")

2024 Building Innovation Conference

May 23, 2024

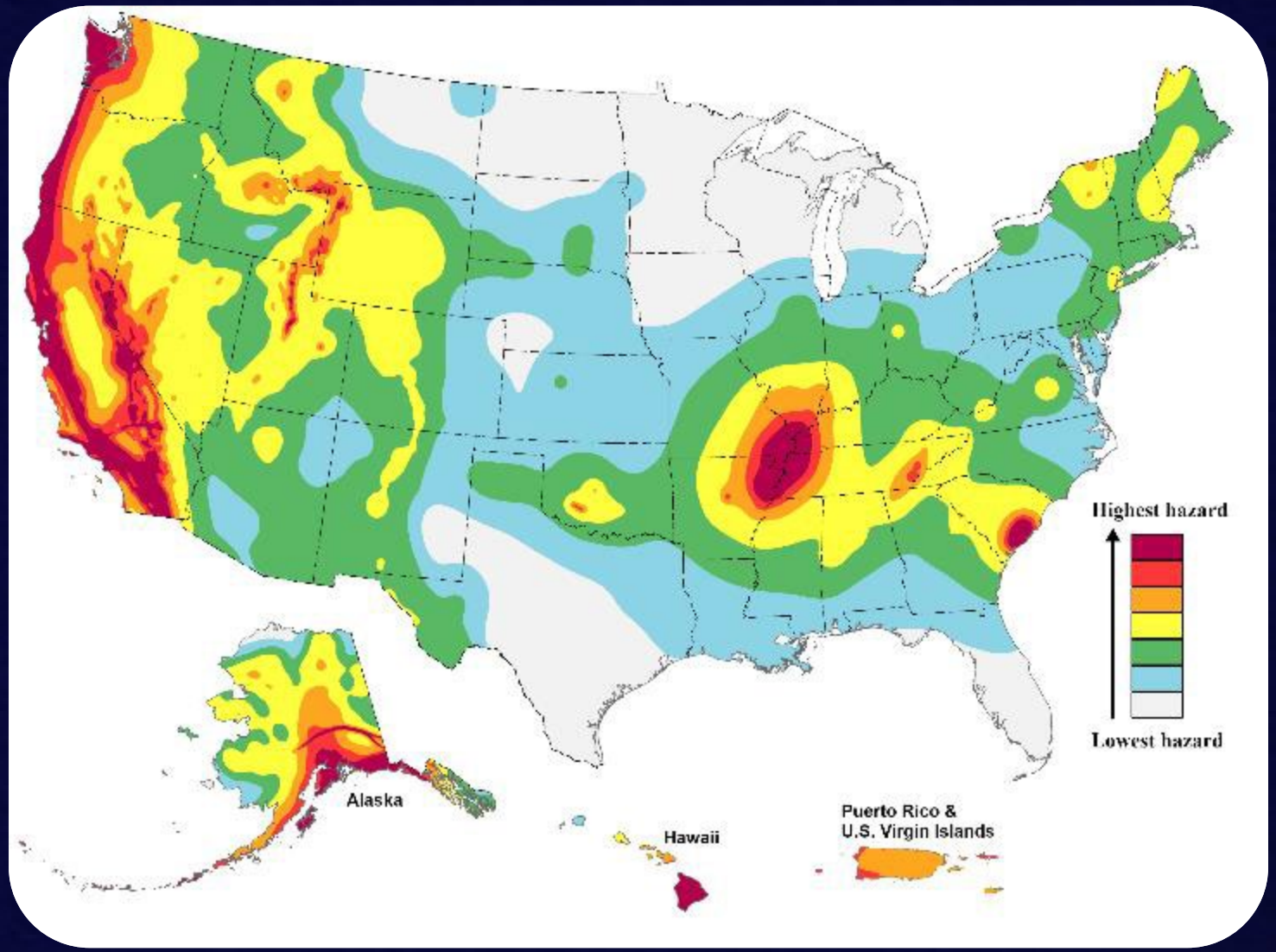
Jay Harris – Jay.Harris@nist.gov
Acting NEHRP Office Director
National Institute of Standards and Technology
Engineering Laboratory

Earthquake Hazard

42 states and all territories in the Pacific Ocean and Caribbean Sea have some degree of earthquake hazard.

Today, about half of the U.S. population resides in areas with moderate to high earthquake hazard.

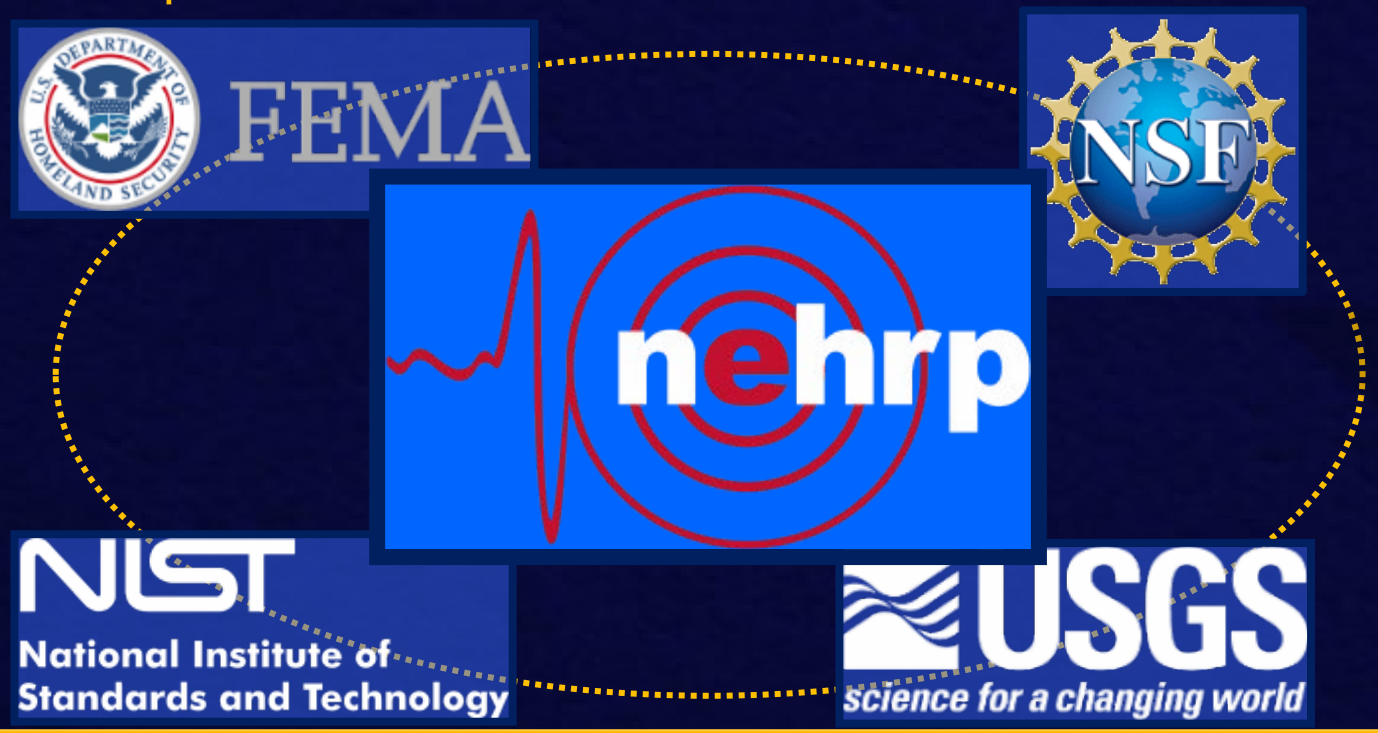
https://www.usgs.gov/programs/earthquake-hazards

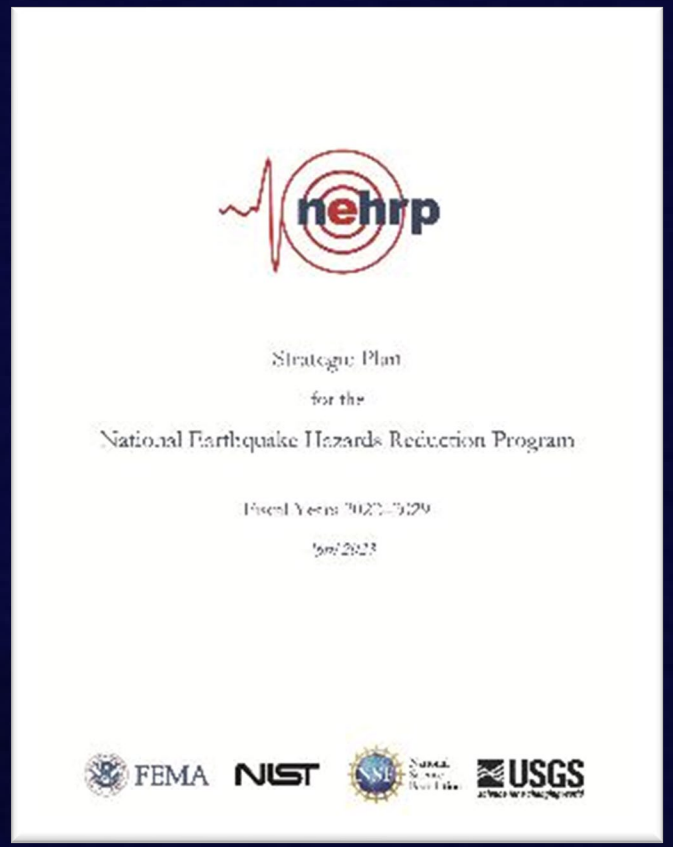


What is NEHRP?

National Earthquake Hazards Reduction Program (NEHRP)

- Established by Public Law 95-124, Oct. 7, 1977
- Overall purpose: "…to reduce the risks of life and property from future earthquakes in the United States…"
- In its current form, NEHRP is a multi-agency coordinating partnership



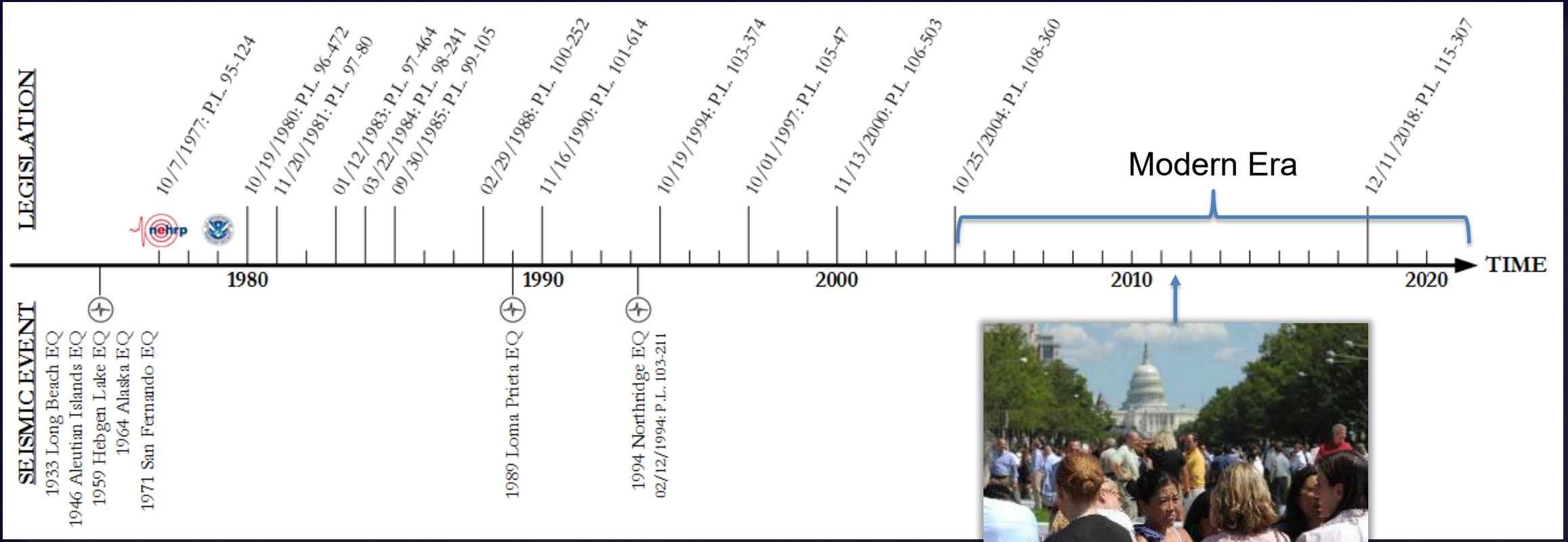


Available on NEHRP.gov

What is NEHRP?

Timeline of the Earthquake Reduction Act of 1977 and Amendments

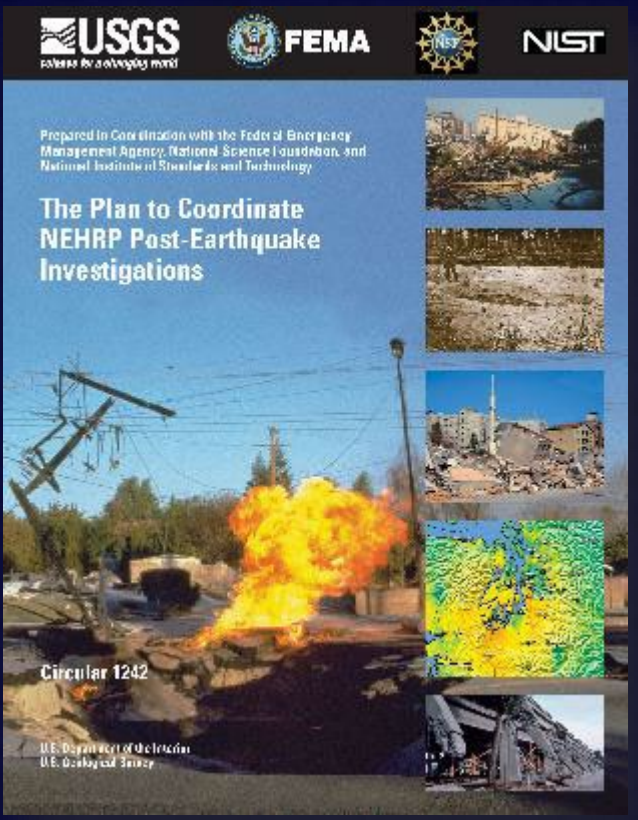
- Program has been reauthorized by Congress at various times, latest was Dec. 2018 (P.L. 115-307) – approved funding for 2019 through 2023



NEHRP Agency Synergies (= Mission of the Program)

Supporting the Mission of the Program

- Monitor earthquake activity and hazard characterization (USGS, NSF)
- Conduct interdisciplinary fundamental and applied research on earthquakes and their consequences on the built environment and communities (NSF, USGS, NIST)
- Develop earthquake-resistant design and construction practices (NIST, FEMA)
- Develop and promote adoption of effective model building codes and practices for earthquake resilience (FEMA, NIST)
- Public education on earthquake risks and mitigation (All)
- Conduct post-earthquake investigations (All, Program-level chaired by USGS)



Please visit NEHRP.gov for more information

Thank You!

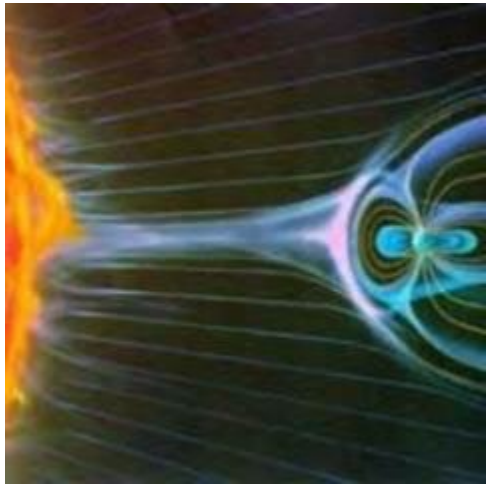
VA Hospital in Sylmar, CA before and after the 1971 San Fernando Earthquake

Earthquake Hazard and Risk of Damage in the Eastern and Central U.S.

Dr. Nicolas Luco
NEHRP Provisions Update Committee USGS Liaison
Functional Recovery Task Committee Voting Member
Supervisory Research Civil Engineer, USGS

USGS Natural Hazards Mission Area Programs

Geomagnetism



Landslide

Volcano

Coastal & Marine

Earthquake

+ GSN

Mission Statement

USGS Earthquake Hazards Program

The USGS Earthquake Hazards Program of the U.S. Geological Survey (USGS) is part of the National Earthquake Hazards Reduction Program (NEHRP) led by the National Institute of Standards and Technology (NIST).

The USGS role in NEHRP is to provide Earth sciences information and products for earthquake loss reduction. The goals of the USGS' Earthquake Hazards Program are:

1. Improve earthquake hazard identification and risk assessment methods and their use;
2. Maintain and improve comprehensive earthquake monitoring in the United States with focus on "real-time" systems in urban areas;
3. Improve the understanding of earthquakes occurrence and their effects and consequences. **(research)**

Example of USGS Earthquake Monitoring

https://earthquake.usgs.gov/earthquakes/eventpage/us7000ma74/executive

Earthquake Hazards Program
In cooperation with: US

- Latest Earthquakes
- **Overview**
  - Interactive Map
  - Regional Information
- Impact
  - Felt Report - Tell Us!
  - Did You Feel It?
  - ShakeMap
  - PAGER
  - Ground Failure
  - Aftershock Forecast
- Technical

M 4.8 – 2024 Tewksbury, New Jersey Earthquake

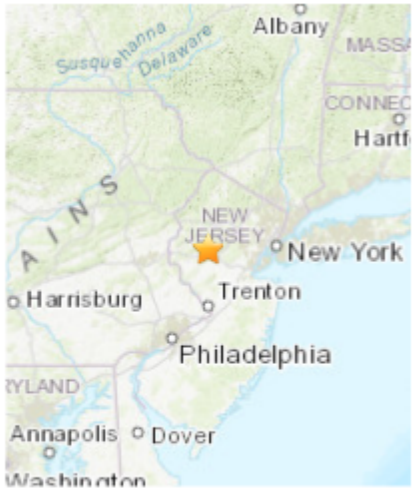
2024-04-05 14:23:20 (UTC) | 40.696°N 74.760°W | 2.6 km depth

On 4-22-2024, the USGS changed the name of this earthquake from "Whitehouse Station" to "Tewksbury" to be more in line with local geography. The decision was made in consultation with local experts.

Interactive Map

Contributed by USGS[3]

Regional Information



Contributed by USGS[3]

Felt Report - Tell Us!

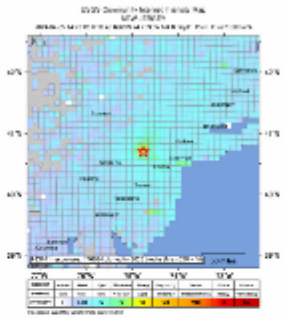
1 8 3 7 4 1

Responses

Contribute to citizen science. Please tell us about your experience.

Citizen Scientist Contributions

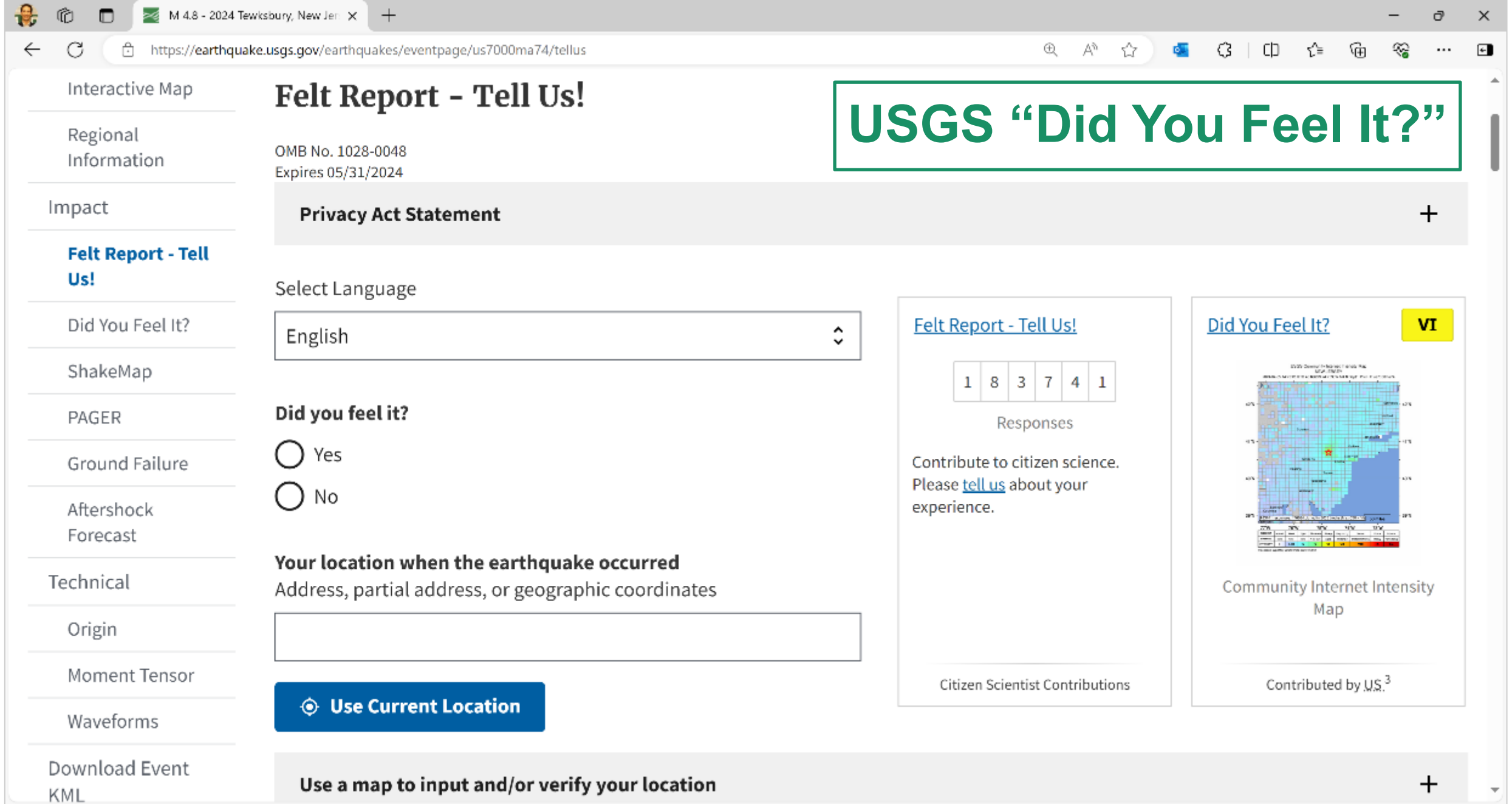
Did You Feel It? VI



Community Internet Intensity Map

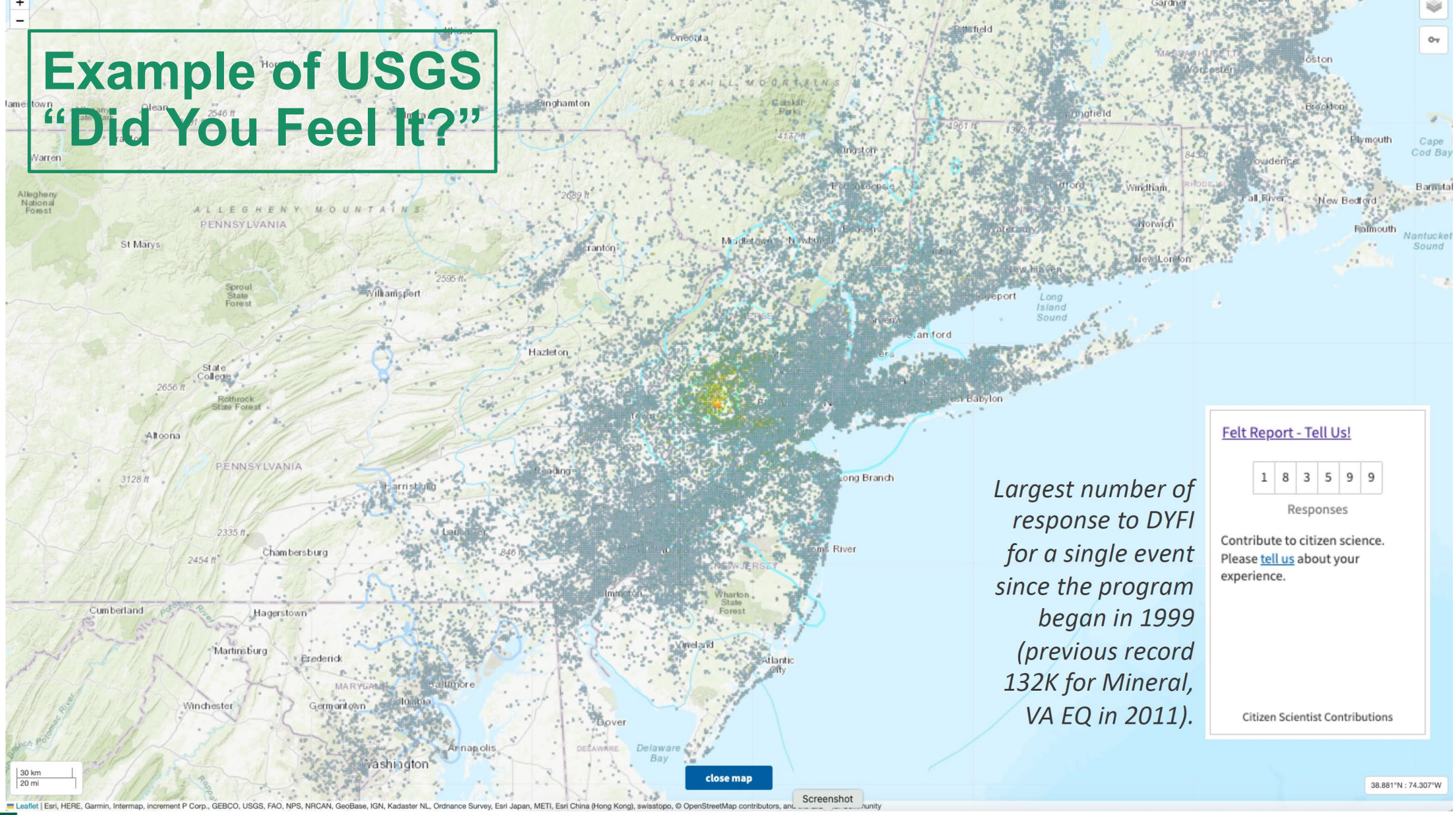
Contributed by USGS[3]

USGS “Did You Feel It?”



(Screenshot from https://www.usgs.gov)

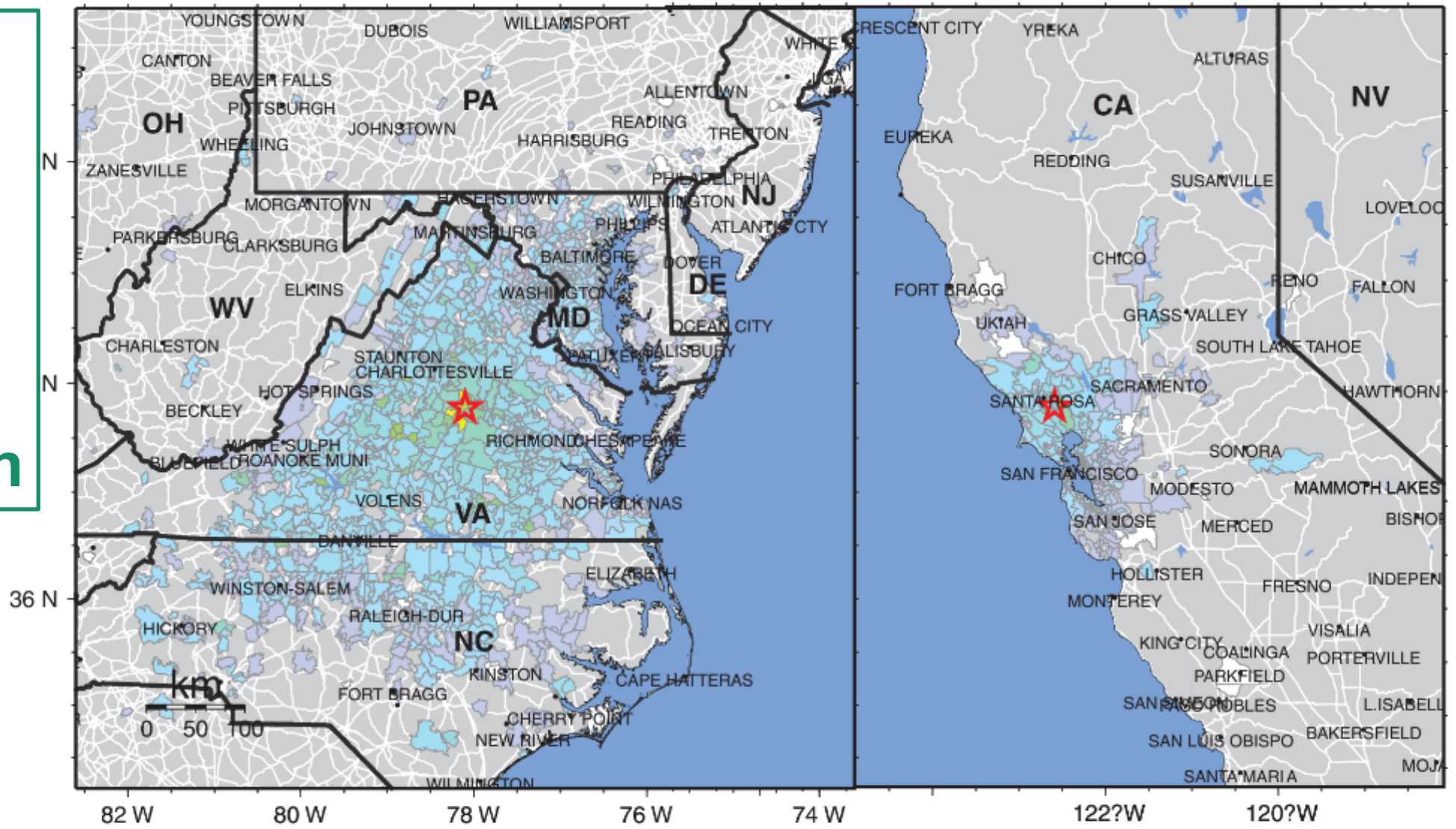
Example of USGS "Did You Feel It?"



Largest number of response to DYFI for a single event since the program began in 1999 (previous record 132K for Mineral, VA EQ in 2011).

(Map from Gavin Hayes, USGS Senior Science Advisor for Earthquake & Geologic Hazards)

Example of Eastern vs. Western Shaking Attenuation

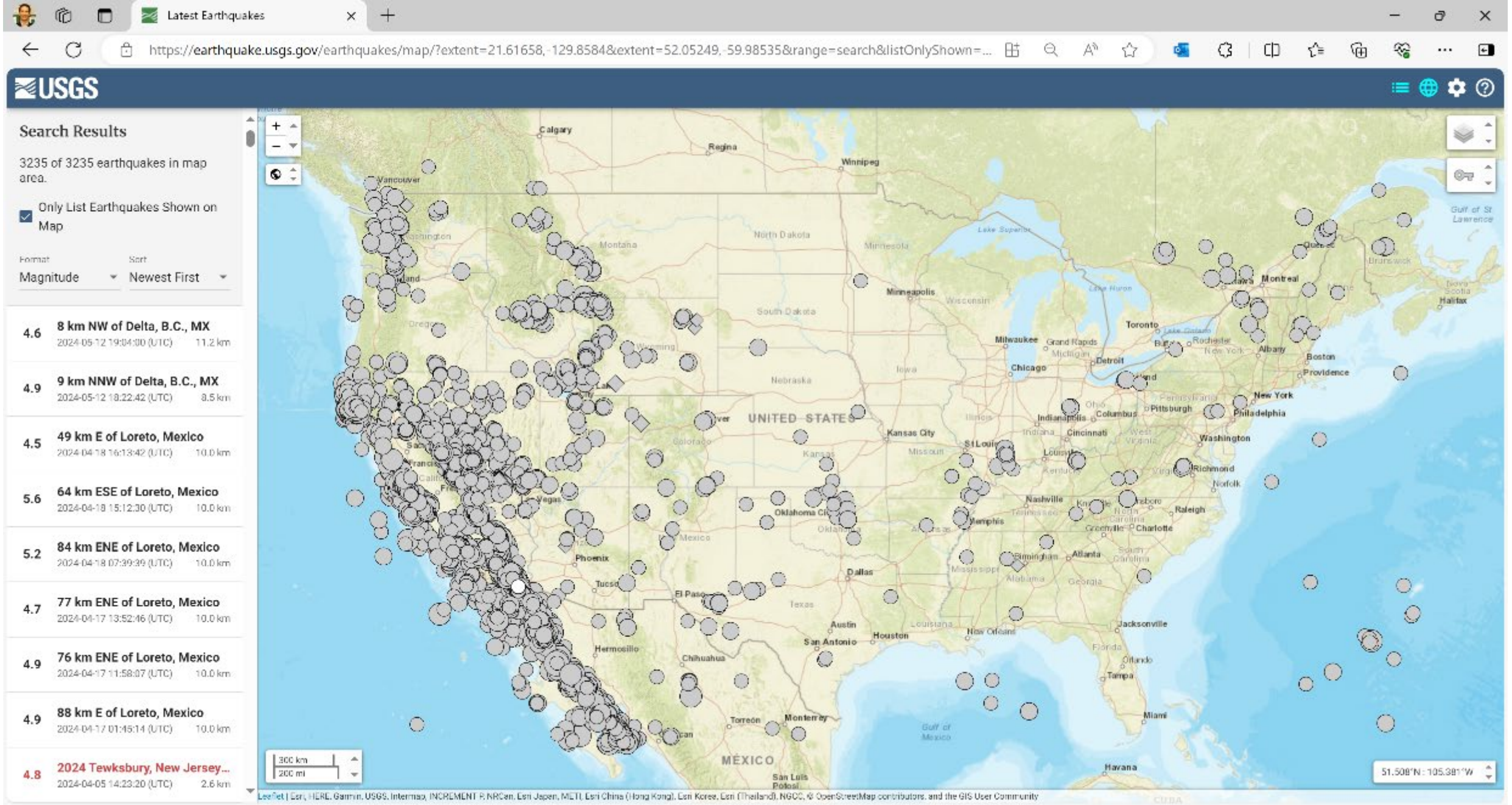


INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+
SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy

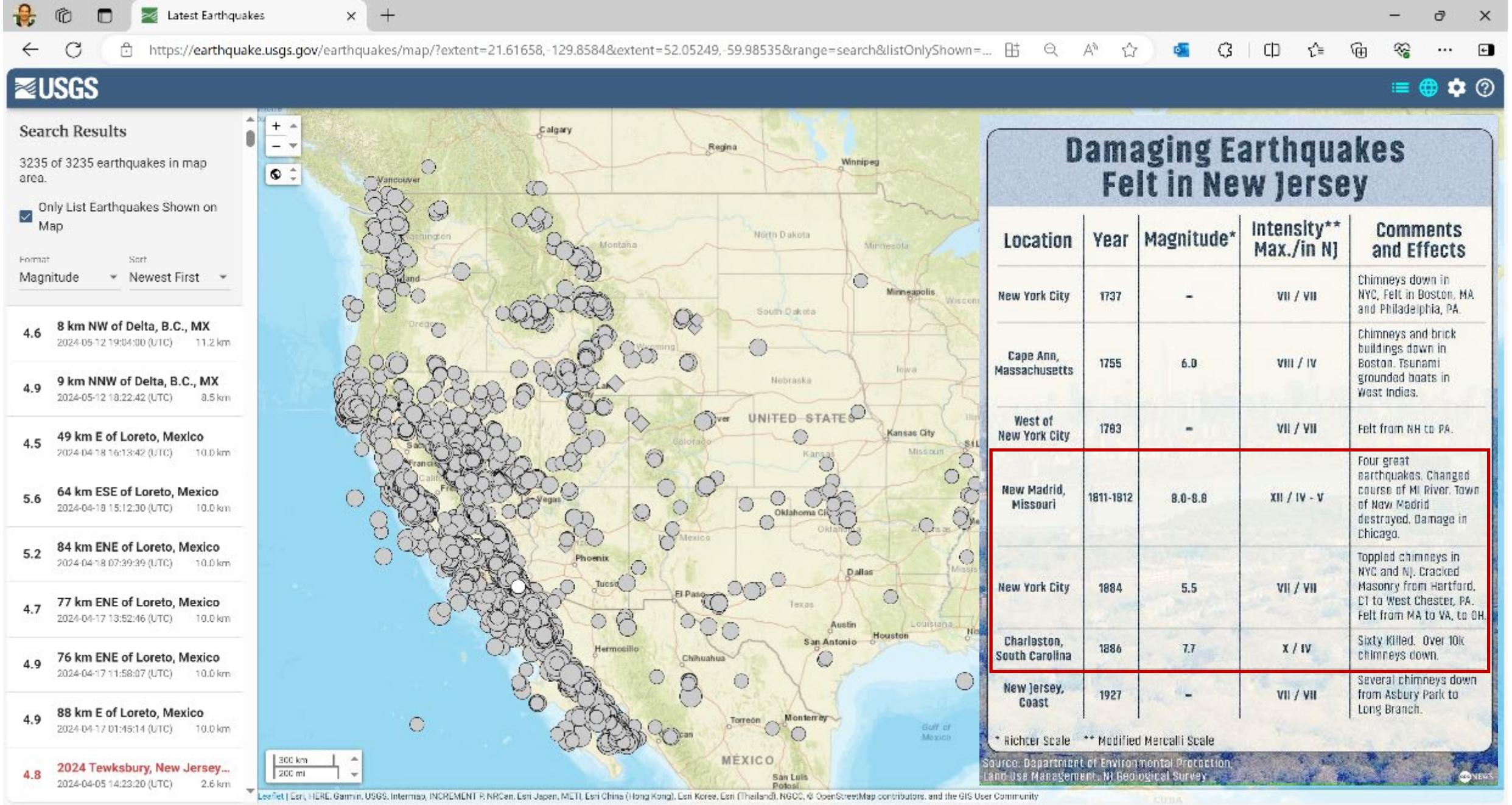
▲ **Figure 6.** Comparison of felt area and intensities for the 9 December 2003 M 4.2 Columbia, Virginia, earthquake (left) with the 2 August 2005 M 4.4 Santa Rosa, California, earthquake (right). Note the dramatic difference in the overall felt area and difference in epicentral intensity (see also figure 6). Maps scales are approximately the same.

(Figure from Atkinson & Wald paper in *Seismological Research Letters* journal, 2007)

INTERNATIONAL CODE COUNCIL



Eastern vs. Western Earthquakes (1924-2024)



Eastern vs. Western Earthquakes (1924-2024)

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3. Improve the understanding of earthquakes occurrence and their effects and consequences. **(research)**

Example of USGS Earthquake Hazard Identification

Earthquakes can strike faster tha

https://www.usgs.gov/news/science-snippet/earthquakes-can-strike-faster-a-new-york-minute-what-do-when-ground-shakes

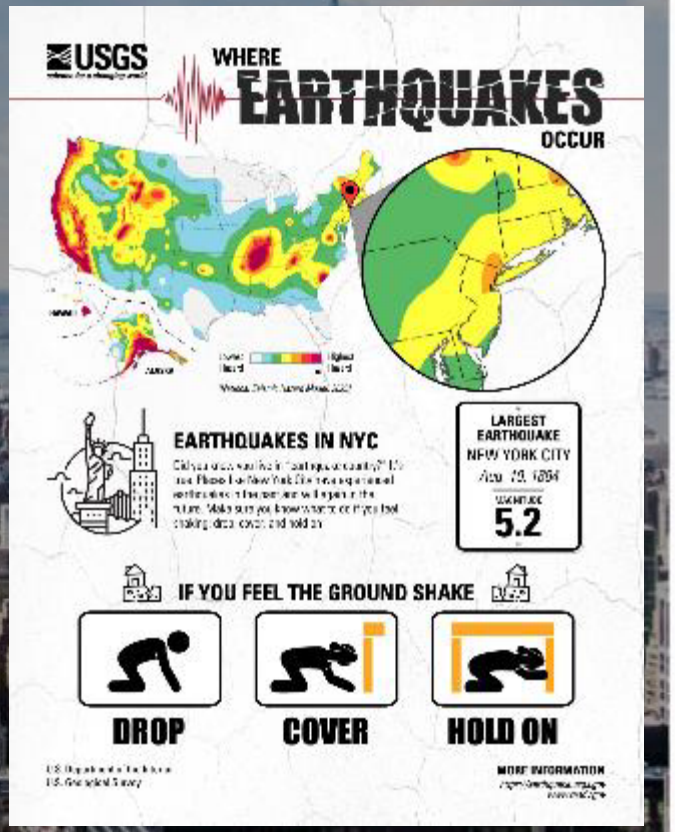
USGS science for a changing world

SCIENCE PRODUCTS NEWS CONNECT ABOUT

Latest Earthquakes

SCIENCE SNIPPET

Earthquakes can strike faster than a New York minute – What to do when the ground shakes...



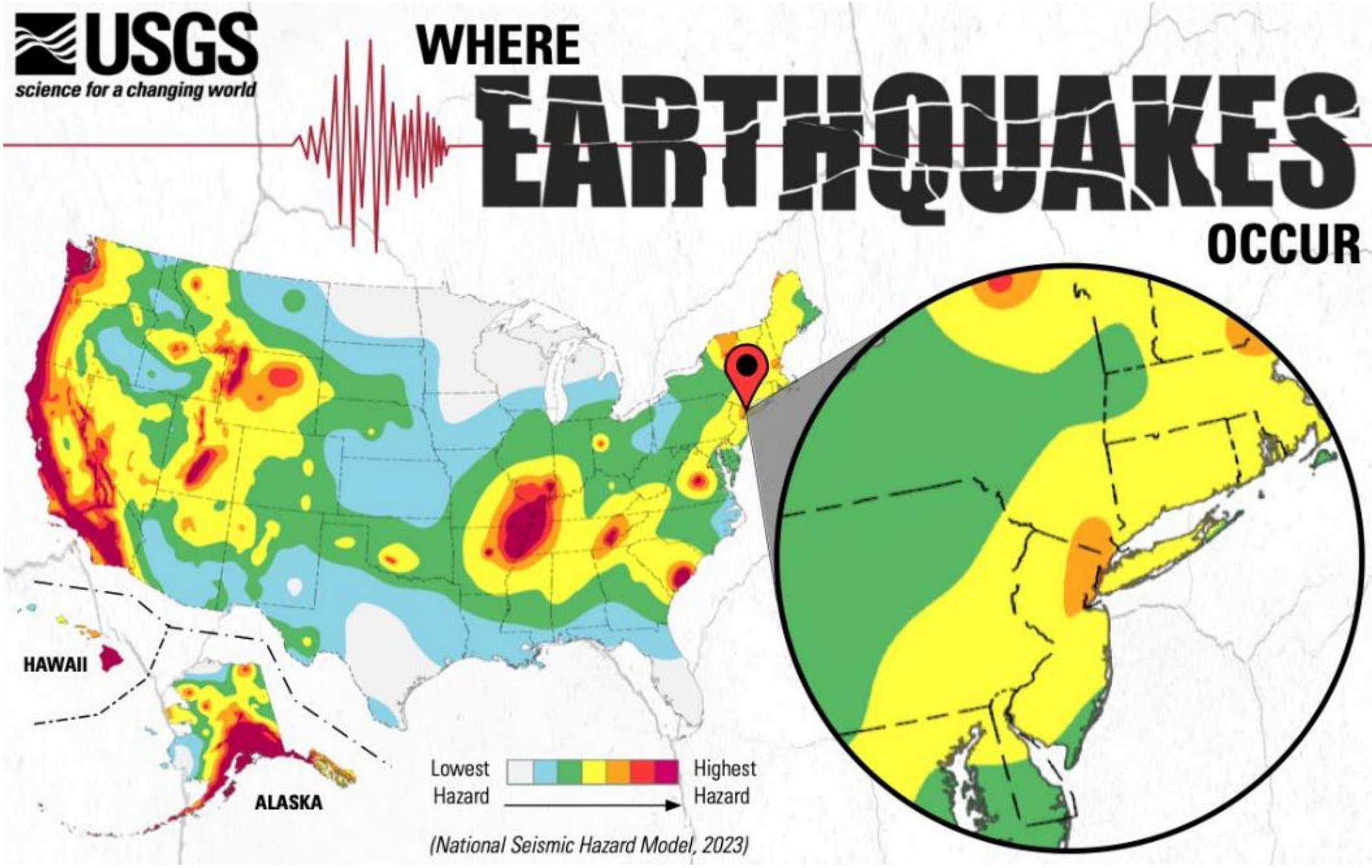
By Communications and Publishing February 12, 2024 ← 2 months before New Jersey earthquake

Nearly 75 percent of the U.S. could experience damaging earthquake shaking, including the possibility of damaging earthquakes

(Screenshot from https://www.usgs.gov)

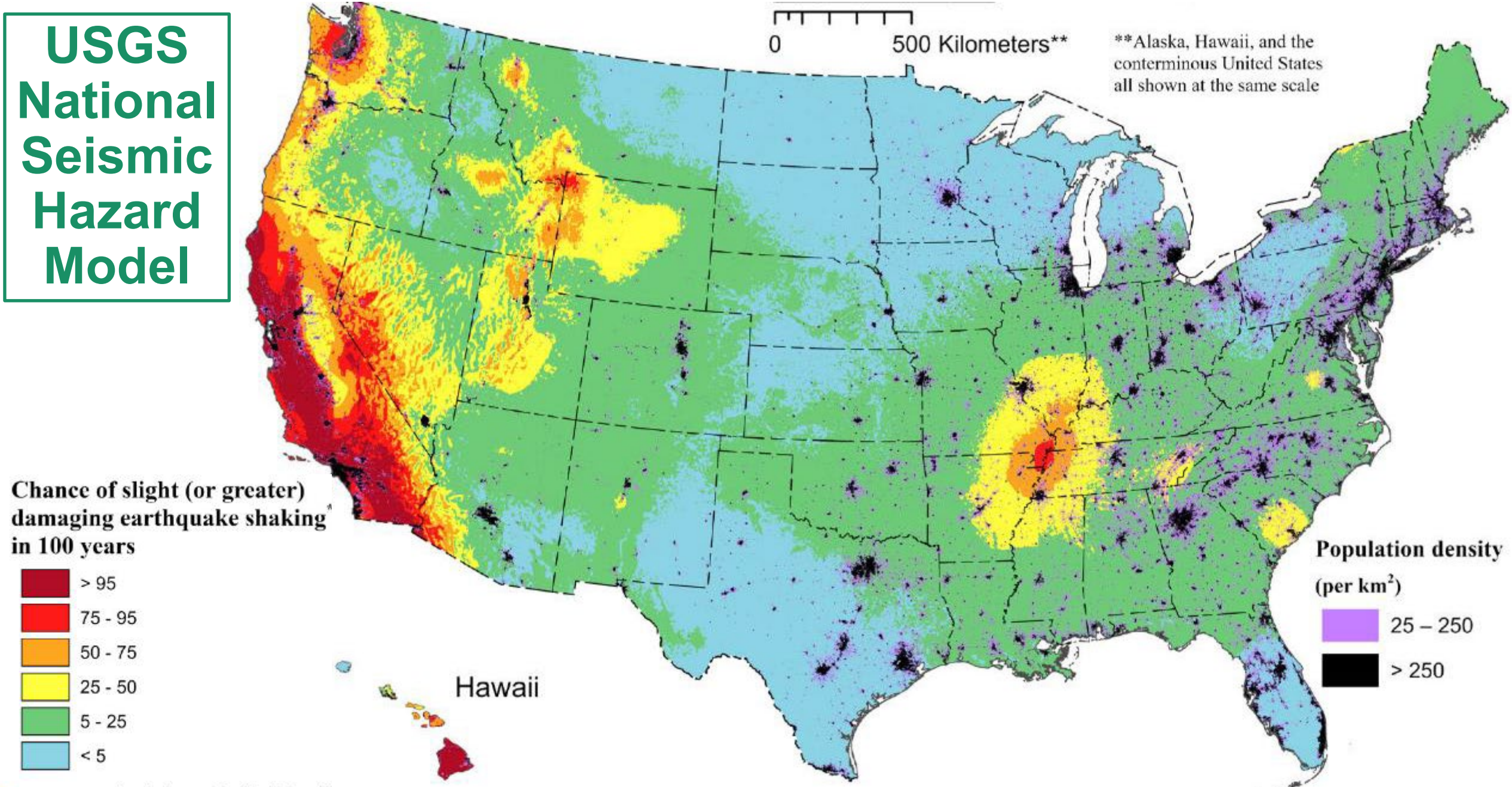
USGS National Seismic Hazard Model

A forecast of the earth-quake shaking hazard



(Map based on Petersen et al. paper in *Earthquake Spectra* journal, 2024)

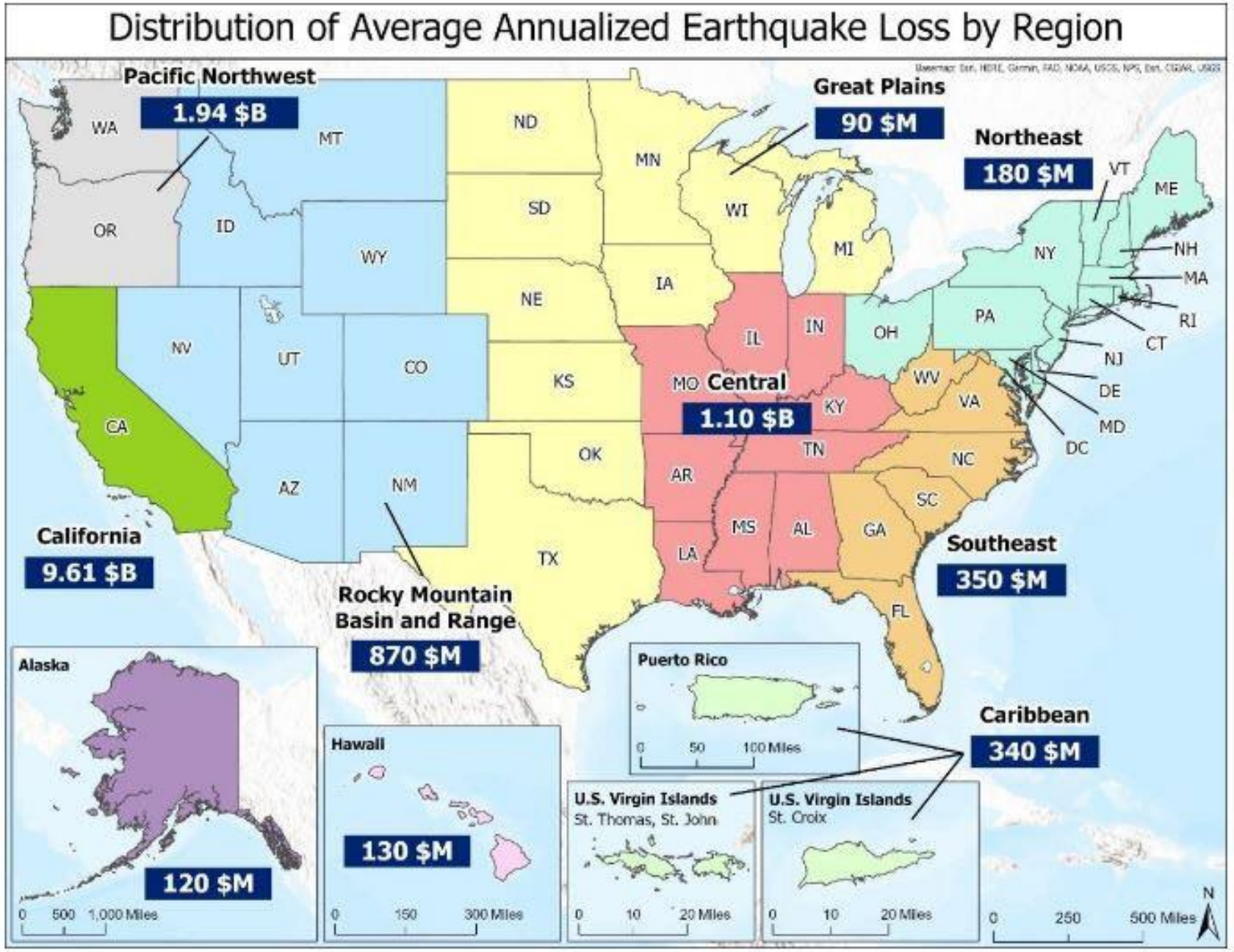
USGS National Seismic Hazard Model



"nearly 75% of the U.S. could experience damaging earthquake shaking"

USGS National Seismic Hazard Model

FEMA P-366: "Hazus Estimated Annualized Earthquake Losses for the United States"



"earthquakes cost the nation an estimated $14.7 billion annually"

USGS National Seismic Hazard Model

Building Codes

NEHRP Recommended Seismic Provisions for New Buildings and Other Structures

Volume I: Part 1 Provisions, Part 2 Commentary

FEMA P-2082-1 / September 2020

FEMA

nehrp

ASCE STANDARD

ASCE/SEI

7-22

Minimum Design Loads and Associated Criteria for Buildings and Other Structures

ASCE
AMERICAN SOCIETY OF CIVIL ENGINEERS

SEI
STRUCTURAL ENGINEERING INSTITUTE

2024
INTERNATIONAL CODES®

IBC®

A Member of the International Code Family®

INTERNATIONAL BUILDING CODE®

ICC
INTERNATIONAL CODE COUNCIL

ICC INTERNATIONAL CODE COUNCIL

+ other design specification, e.g., AASHTO for bridges

Recovering from Earthquakes

Recovery-based Design Provisions for the Next Generation Building Codes

Robert Pekelnicky

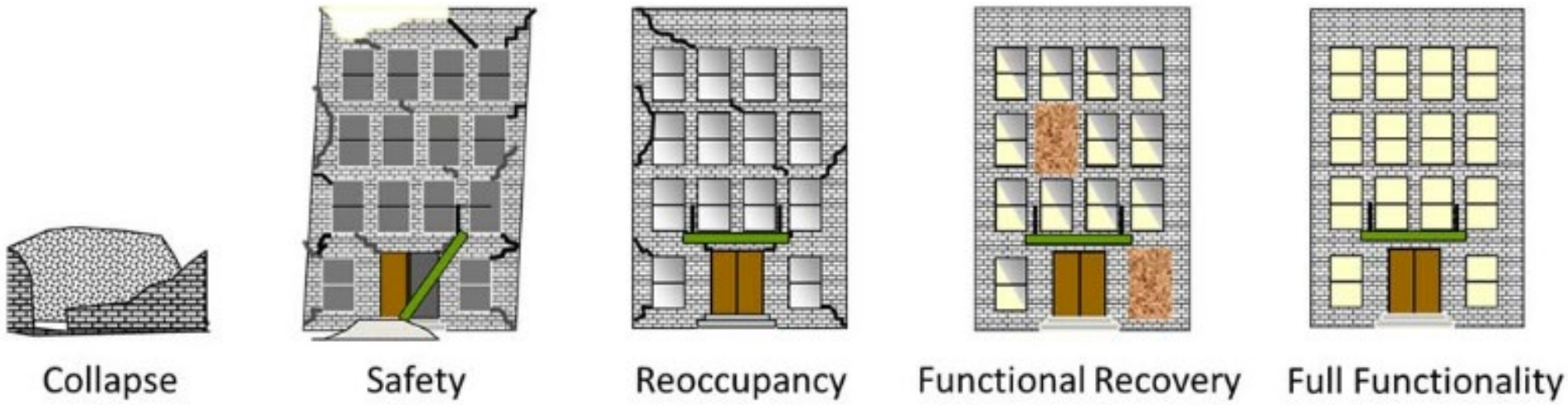
NEHRP Provisions Update Committee Vice Chair

Senior Principal, Degenkolb Engineers

What is Functional Recovery?

Definitions from FEMA-NIST Special Publication (FEMA P-2090 / NIST SP-1254):

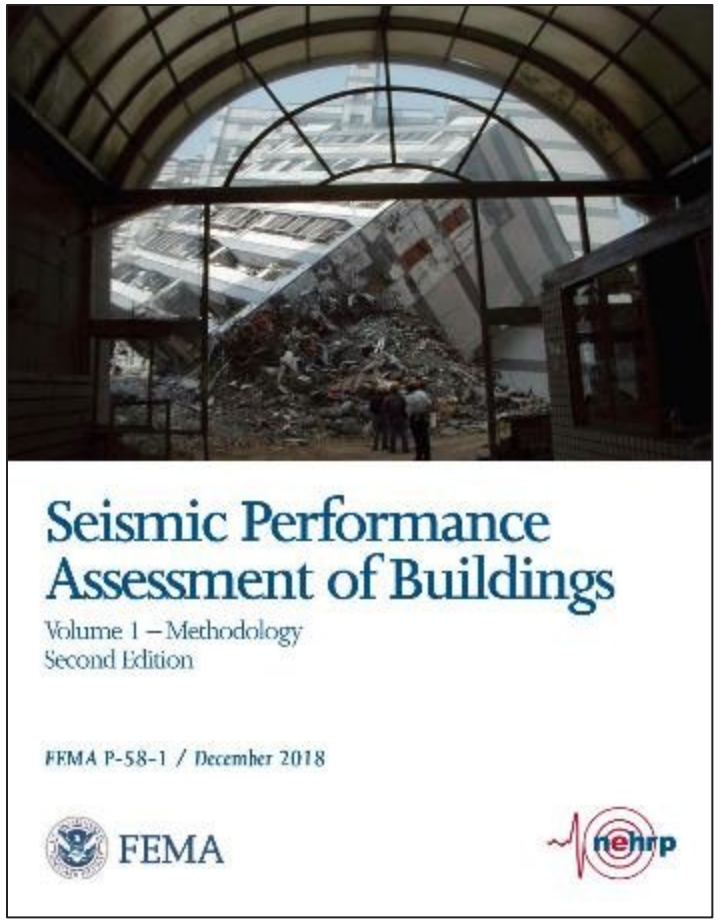
Functional recovery is one of three recovery milestones beyond basic safety, which include reoccupancy, functional recovery, and full functionality (or full recovery).



Functional Recovery - How did we get here?

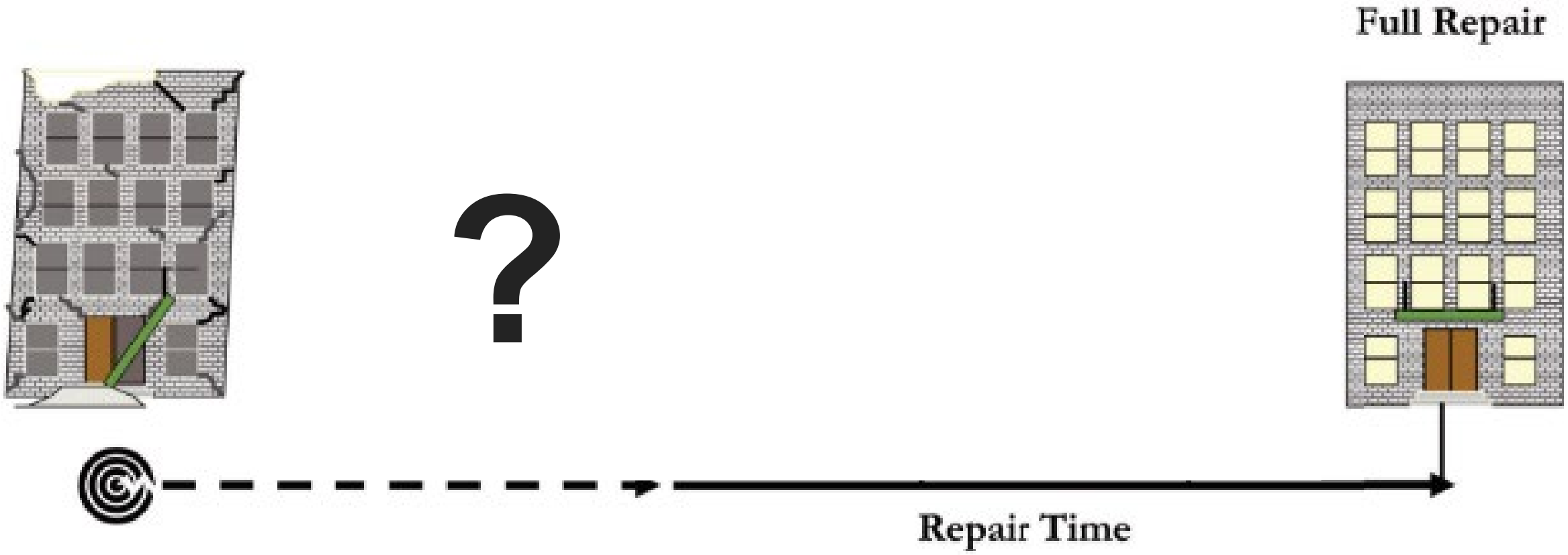
FEMA P-58 Project

- Significant investment of NEHRP resources and attention over the last +/- 20 years
- “Next Generation” Performance-based Seismic Design
- Quantify seismic building performance in understandable metrics:
  - Safety
  - Repair Cost
  - Repair (and Recovery) Time
  - Carbon Impact of Repair

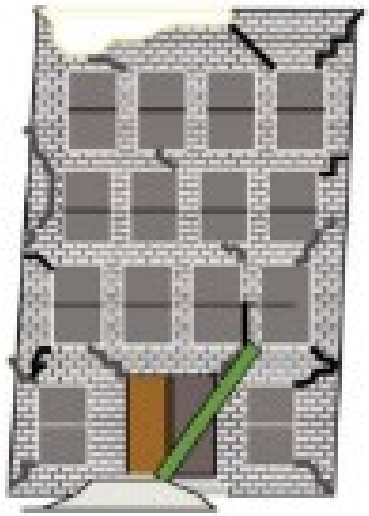


https://femap58.atcouncil.org/documents/fema-p-58/24-fema-p-58-volume-1-methodology-second-edition/file
https://femap58.atcouncil.org/documents/fema-p-58/27-fema-p-58-volume-5-expected-performance/file

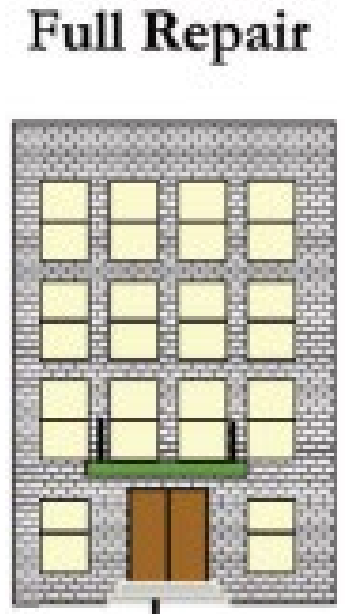
FEMA P58 – Repair Time



ATC 138 – Impeding Factors

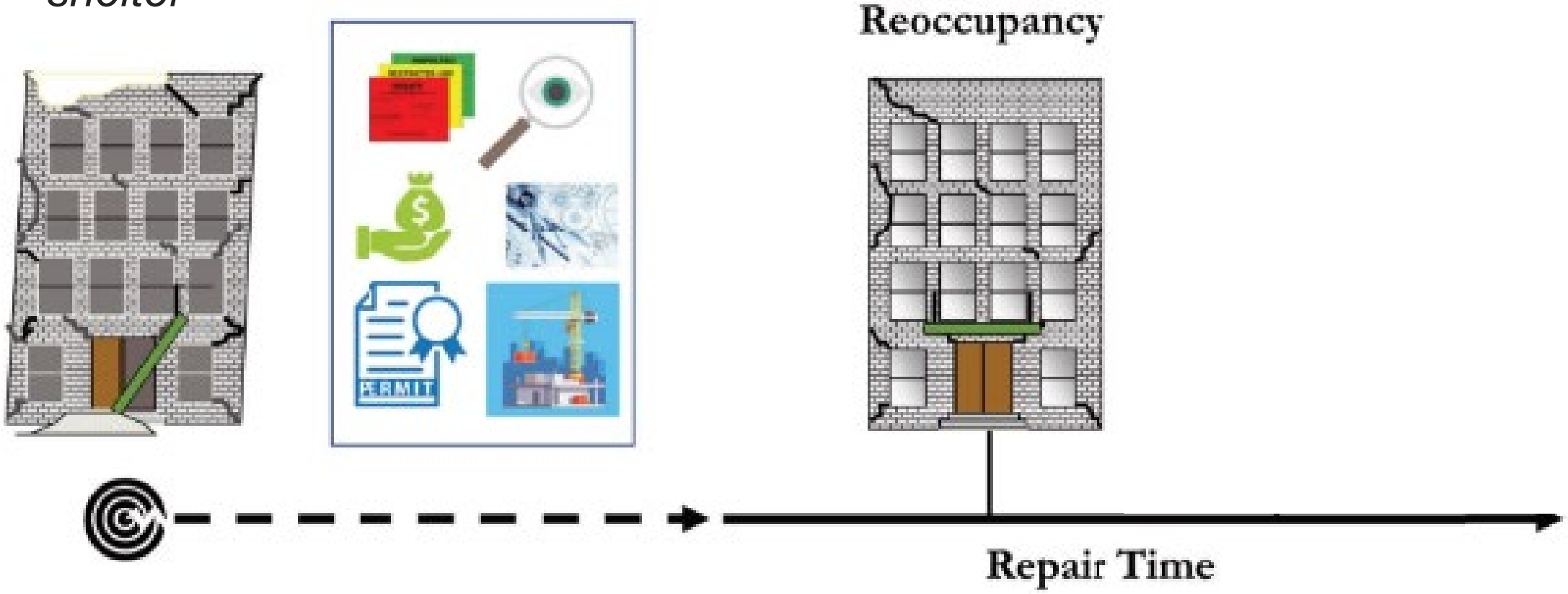


- Inspection
- Repair Design
- Repair Permitting
- Repair Financing
- Contractor Retention
- Material Procurement



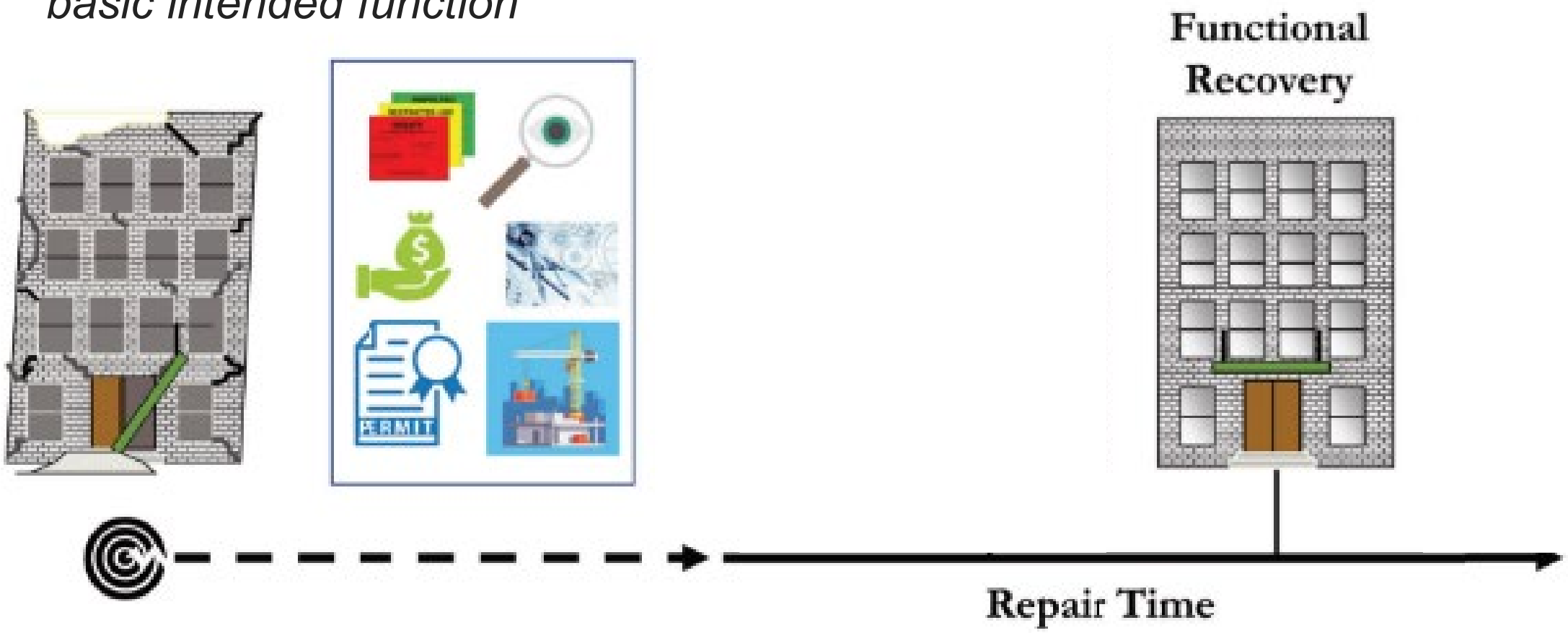
ATC 138 – Reoccupancy

The structure is maintained or restored to allow safe re-entry or provide shelter



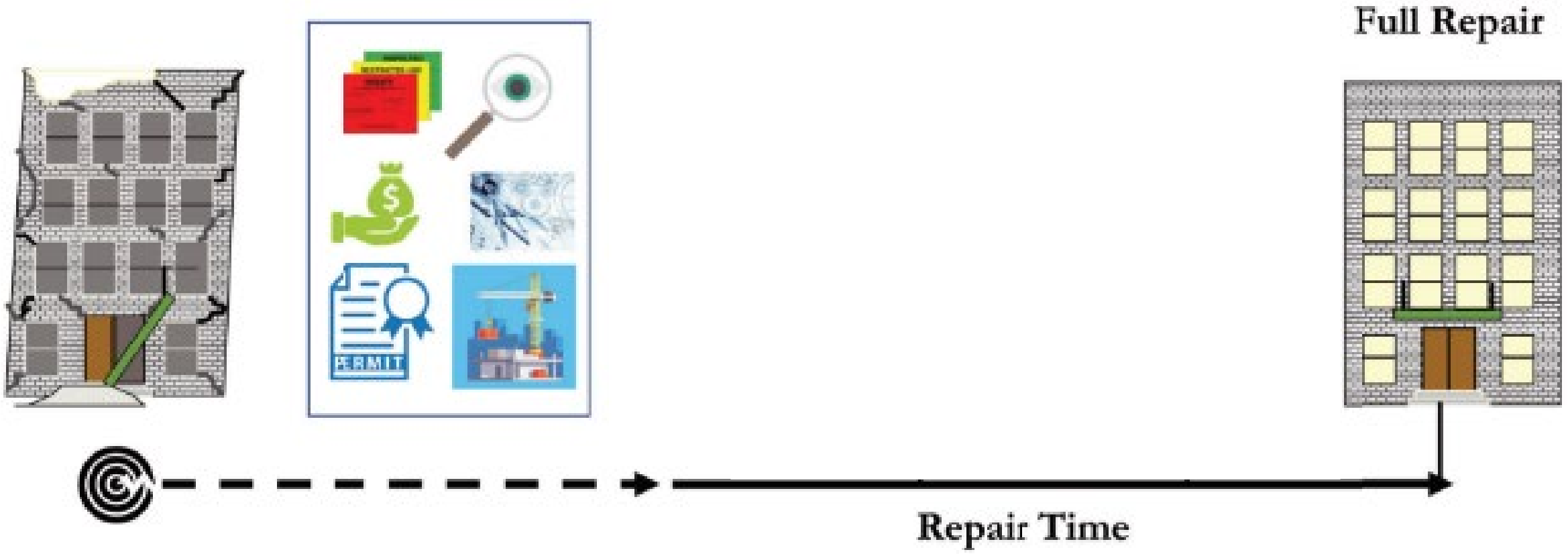
ATC 138 – Functional Recovery

The structure is maintained or restored to safety and adequately support basic intended function



ATC 138 – Full Recovery

The structure is maintained or restored to its pre-earthquake condition



Disclaimer

Work on the *2026 NEHRP Recommended Seismic Provisions* is ongoing.

The final content of the proposals for the *2026 NEHRP Recommended Seismic Provisions* will depend on the technical and policy deliberations of the Task Committee and the PUC.

All proposals will be balloted through the consensus review process, and any concepts discussed herein are subject to change depending on further development of proposals and deliberations during balloting.

PUC Functional Recovery Task Committee (FR TC)

Overarching Goals:

Set the stage to ultimately support community resilience through seismic building code provisions that recognize performance impacts across the community

Near-term:
Transition philosophy and language of seismic code provisions to address functional recovery time, in addition to safety
Standardize what is meant by functional recovery and functional recovery time
Develop “1st-generation” code language, including seismic design provisions that improve recovery time compared to current provisions and initial recommendations for recovery priorities
Explore strategies for strengthening links between community needs and technical code provisions, including broadening input

Longer-term:
Develop strategies and refined seismic code provisions to achieve specific seismic performance targets, not just improved performance, where these performance targets directly reflect community needs / priorities

DRAFT Functional Recovery Provisions

Functional Recovery Categories

Functional Recovery Earthquake

Basic Intended Function Determination

Structural Design Provisions

Nonstructural Design Provisions

Functional Recovery Coordinator

Quality Assurance / Quality Control Provisions

Functional Recovery Plan

Performance-Based Provisions

Functional Recovery Categories

Functional Recovery Category	Target Functional Recovery Time
A	0 hours
B	72 hours
C	2 months
D	6 months

Functional Recovery Categories

Functional Recovery Category	Community Functions Supported by Structures
A	Community functions that provide essential and urgent safety and survival needs. Functions in this category include but are not limited to: - Emergency response and communication - Emergency and acute healthcare - Housing of non-ambulatory populations, persons incapable of self-preservation, and persons under custodial care
B[1]	Community functions that provide safety, survival, basic well-being, and essential everyday needs and prevent the escalation of adverse disaster consequences. Functions in this category include but are not limited to: - Emergency services not included in FRC A - Essential food and water services - Healthcare providing regularly scheduled life sustaining treatments - Housing of vulnerable populations - Housing of transient persons for sleeping - Urgent veterinary services - Water and wastewater treatment - Power generation - Telecommunication - Petrochemical - Mining
C	Community functions that provide basic human needs, self- and group-preservation, and that sustain short- and long-term economic, educational, and governance activities and services. Functions in this category include but are not limited to: - Essential governance - Custodial care of vulnerable populations - Housing of nontransient populations - Education (PK-12) - Services critical to regional economic stability - Veterinary services
D	Community functions that enhance a community's general well-being and expedite the return to normalcy. Functions in this category include but are not limited to: - Post-secondary education - Non-essential governance - Recreation
E	Community functions that enhance general well-being and amplify people's quality of life. The recovery timeline of these functions may not be essential in overall recovery of the community.

Basic Intended Function

Define required systems for functional recovery:

Structural system

Fire suppression (?)

Electrical power (?)

Exterior enclosure (?)

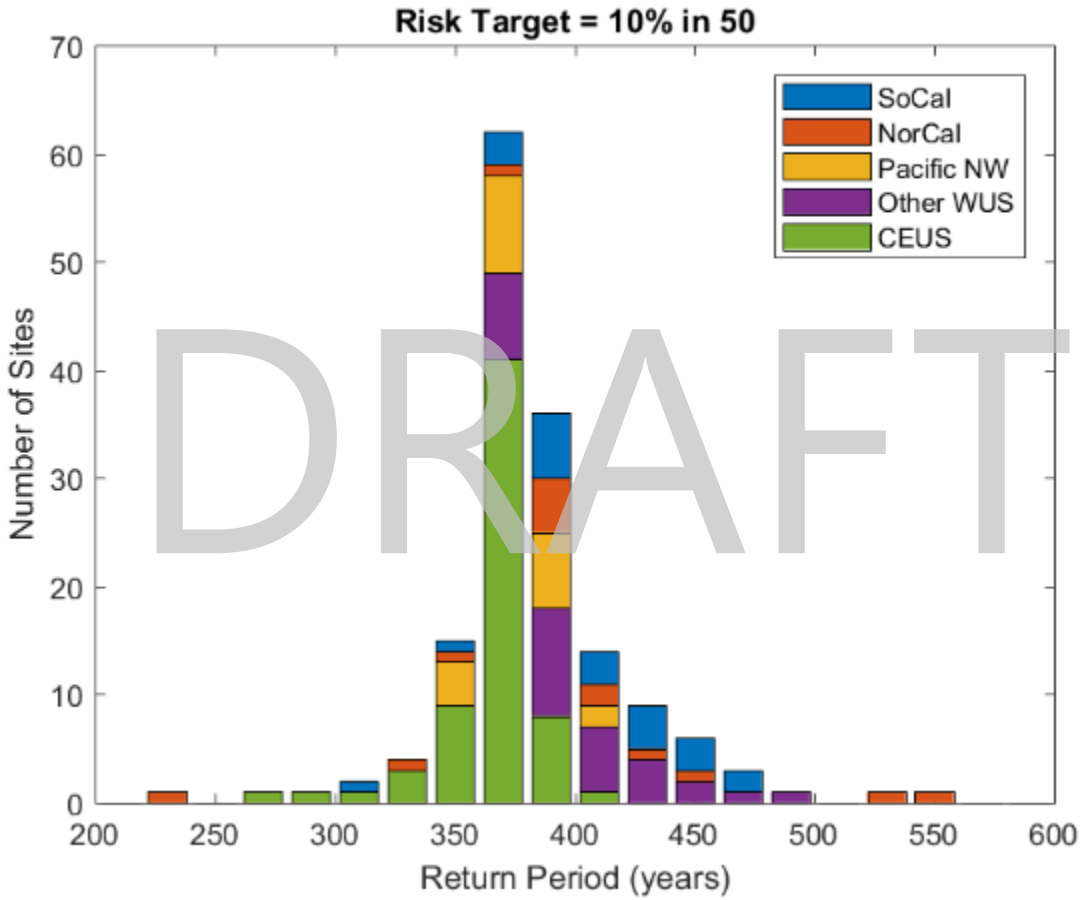
Water / wastewater

HVAC systems (?)

Etc…

Functional Recovery Earthquake Hazard

Risk targeted to a 10% probability of not meeting target recovery time



Structural Design Provisions

- Functional Recovery R-factors
- Functional Recovery Drift Limits
- Irregularity prohibitions
- Design requirements
- Nonlinear analysis criteria
- Requirements for Non-Building Structures

Seismic Force-Resisting System	R_{fr} and Δ_{afr} by Functional Recovery Category[a]			
	B or C		D	
BEARING WALL SYSTEMS				
Special reinforced concrete shear walls where the shear capacity is not designed for the expected flexural capacity	2	$0.01h_{sx}$	R/1.5	$0.02h_{sx}$
Special reinforced concrete shear walls where the shear capacity is designed for the expected flexural capacity	3	$0.01h_{sx}$	R/1.5	$0.02h_{sx}$
Reinforced concrete ductile coupled walls	3	$0.01h_{sx}$	R/1.5	$0.02h_{sx}$
Ordinary reinforced concrete shear walls	2	$0.01h_{sx}$	R/1.5	$0.02h_{sx}$
BUILDING FRAME SYSTEMS				
Steel eccentrically braced frames	3	$0.005h_{sx}$	R/1.5	$0.02h_{sx}$
Steel special concentrically braced frames	1	$0.005h_{sx}$	R/1.5	$0.02h_{sx}$
Steel ordinary concentrically braced frames	1	$0.005h_{sx}$	R/1.5	$0.02h_{sx}$
Special reinforced concrete shear walls where the shear capacity is not designed for the expected flexural capacity	2	$0.01h_{sx}$	R/1.5	$0.02h_{sx}$

Nonstructural Design Provisions

Force requirements

Seismic certification requirements

Table 24.10-1. Functional Recovery Nonstructural Component Importance Factors by Functional Recovery Category for Earthquake Loads

Functional Recovery Category	Seismic Functional Recovery Component Importance Factor, I_{pfr}
B	2
C	1.5
D	1.25

Table 24.10-2. Seismic Floor Acceleration Threshold

Component or Distribution System	Seismic Floor Acceleration Threshold (g) by Functional Recovery Category		
	B	C	D
MECHANICAL			
HVAC Ducting (area ≤ 6 ft2)	0.75	0.9	1.1
HVAC Ducting (area > 6 ft2)	1.5	1.75	2.0
HVAC Drops	0.5	0.6	0.7
Chilled Water Piping (diameter ≤ 2.5")	0.3	0.35	0.5
Chilled Water Piping (diameter > 2.5")	0.45	0.5	0.65
Steam Piping (diameter ≤ 2.5")	0.3	0.35	0.5
Steam Piping (diameter > 2.5")	0.5	0.6	0.7
PLUMBING			
Potable water piping (diameter ≤ 2.5")	0.5	0.6	0.7
Potable water piping (diameter > 2.5")	0.5	0.6	0.7

Functional Recovery Coordinator

Reviews and approves the criteria

Reviews all disciplines

Can be project structural engineer

Reviews all delegated design

Leads pre-construction FR conference

Reviews QA/QC plan

Reviews the Functional Recovery Plan

Quality Assurance / Quality Control Provisions

Design professional observation requirements

Quality assurance plan

Special inspection and testing

Functional Recovery Plan

Based on San Francisco BORP and FEMA Post-EQ Recovery Plan

Identify components to inspect

Arrangements for inspectors

Documentation to assist the inspectors

Next steps

Full PUC Ballot of the Provisions about to commence

PUC Ballot comments resolved and re-balloted

Concurrent ballot of PUC Member Organizations and ASCE 7 Seismic

ASCE 7 Main Committee Ballot

Case Studies

Assess the cost of the provisions on different building types

Hospital

Multi-family Residential

Medical Office Building

Laboratory

NIBS Congressional Briefing

Protecting American Lives, Infrastructure, and the Economy through Resilience

NIBS Congressional Briefing

Panel Discussion

Dr. Jay Harris

Acting NEHRP Director

National Institute of Standards & Technology

Dr. Nicolas Luco

Supervisory Research Civil Engineer

U.S. Geological Survey

Robert Pekelnicky

Senior Principal

Degenkolb Engineers

Discussion

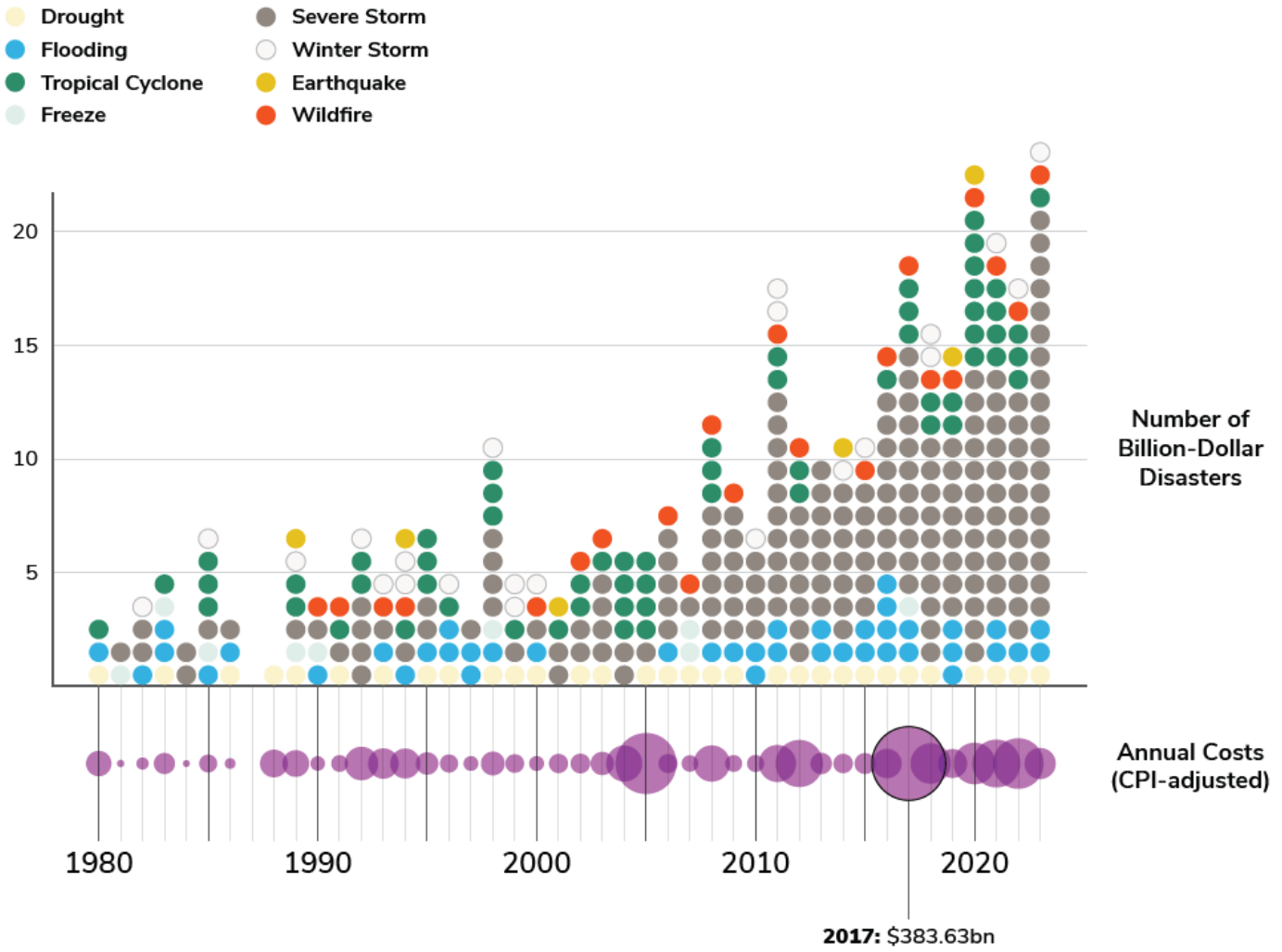
Session Objectives

1. Understand how the National Earthquake Hazards Reduction Program serves emergency managers, building officials, businesses, federal building investments, and the American public.
2. Learn about the eastern U.S. seismic hazard and risk.
3. Understand the development process of the National Seismic Hazard Model, which informs the Nation's model building codes seismic design parameter maps.
4. Enhance awareness of how the next generation of model building codes can improve community resilience.

Discussion
Question #1: Costs of Natural Disasters

Earthquakes have grown increasingly costly due to human development in risk-prone areas. Earthquakes cost the United States approximately $14.7 billion annually in building damage and associated losses.

NHERI Decadal Visioning Study: 2026-2035, https://nexightgroup.com/



Discussion

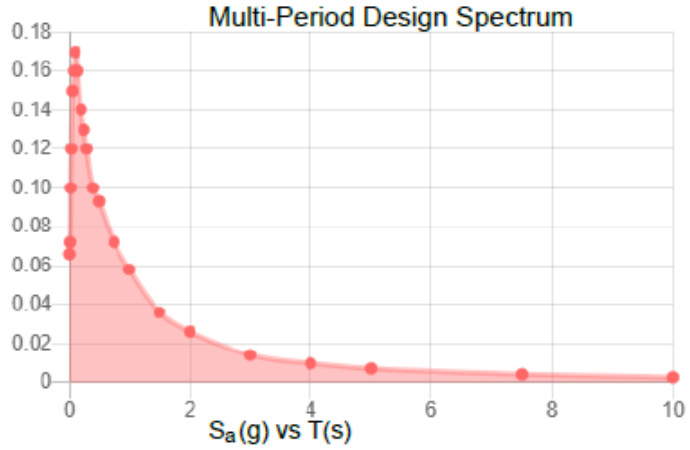
Question #2: Vulnerable Infrastructure - Baltimore Bridge

https://www.webuildgroup.com/en/media/press-notes/webuild-ready-rebuild-baltimore-bridge-collapsed-march/

- Port of Baltimore = $15M/day; 800,000 vehicles in 2023
- Travel = 35,000 vehicles/day x 10-20 miles detours
- Indirect losses = new bridge by end of 2028?
- Cost of new bridge = $1.70B- $1.90B anticipated

Minimum Design Loads

Design Speed (non-hurricane)	
Wind (50 years)	90 mph
Wind (700 years)	113 mph
Wind (3000 years)	126 mph
Seismic Design (IV, SC D)	

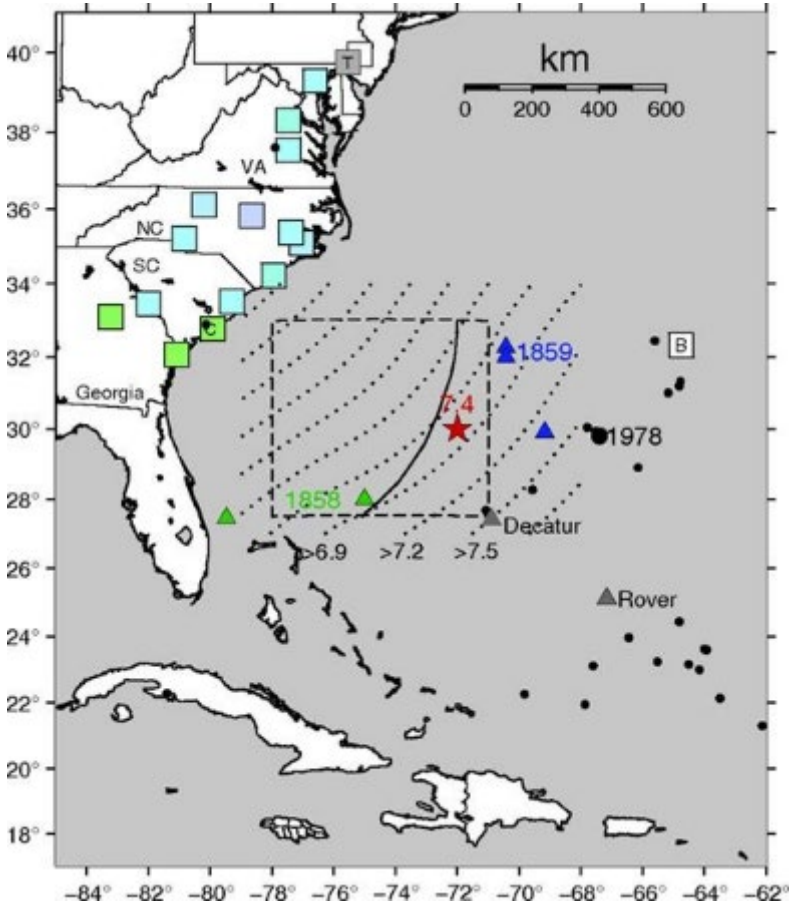


https://ascehazardtool.org/

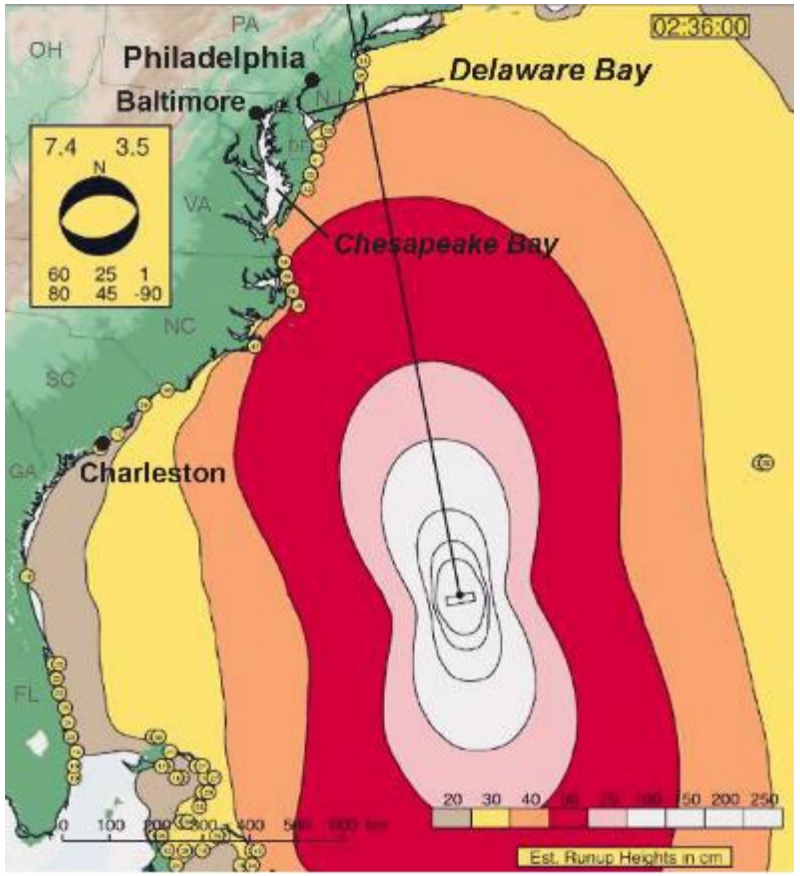
Discussion stimulants (non- THC)

Crazy question #1: Tsunamis in the East Coast

Reverberations on the Watery Element: A Significant, Tsunamigenic Historical Earthquake Offshore the Carolina Coast
Susan E. Hough, Jeffrey Munsey, and Steven N. Ward
Seismological Research Letters
Volume 84, Number 5
September/October 2013



https://doi.org/10.1785/0220120152



Discussion stimulants (non- THC)

Crazy question #2: Major Bridges – Functional Recovery

- Scenario 1 : Temporary loss of bridges and tunnels into Manhattan due to inspection need after a moderate nearby earthquake.
- Scenario 2: Loss of St. Lawrence Seaway due to bridge collapses in a large earthquake