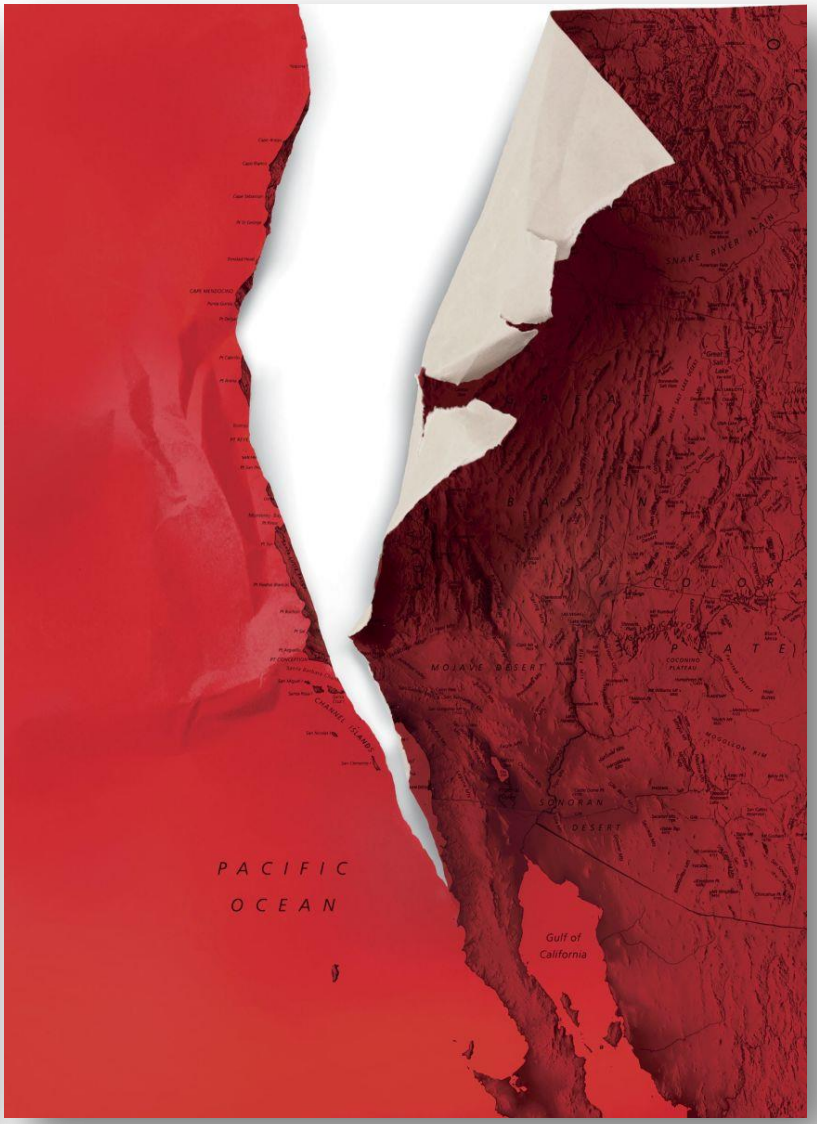
Dollars, deaths, and downtime: understand your building's seismic risk and how to evaluate it

SEAOSC Strengthening Our Cities Summit
5 Nov 2015, Los Angeles, CA

Keith Porter, PE PhD
University of Colorado Boulder

Don’t get your earthquake ideas here:



U.S. earthquakes are dangerous but

Generally don't produce devastation

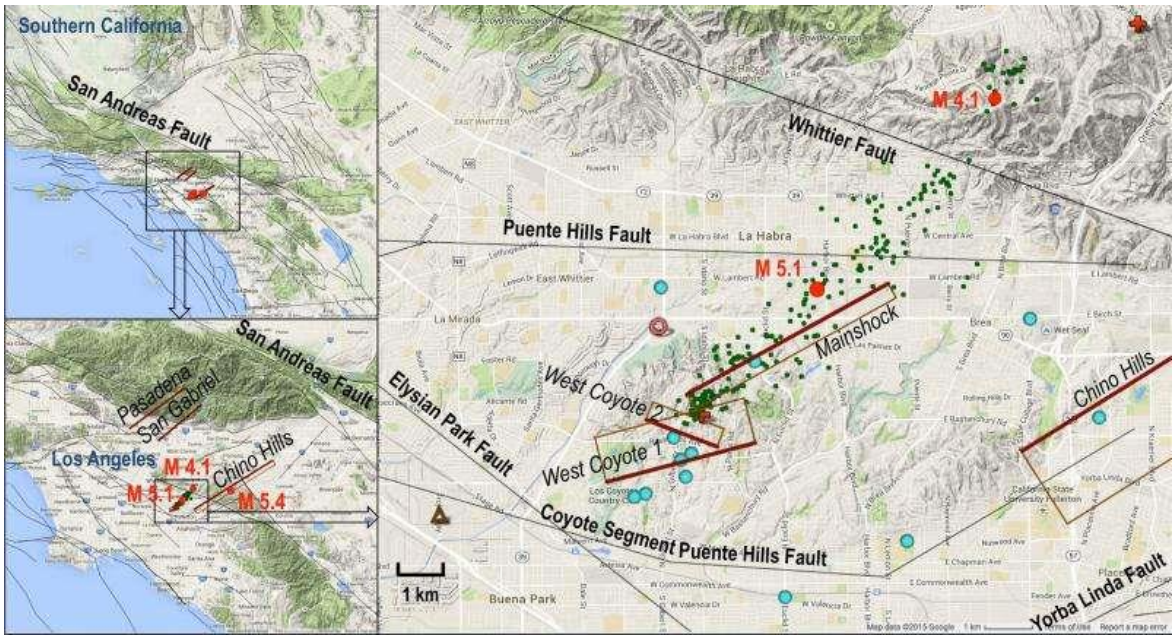
Most people and buildings survive

You can measure and cost-effectively manage seismic risk

Buildings are relatively safe

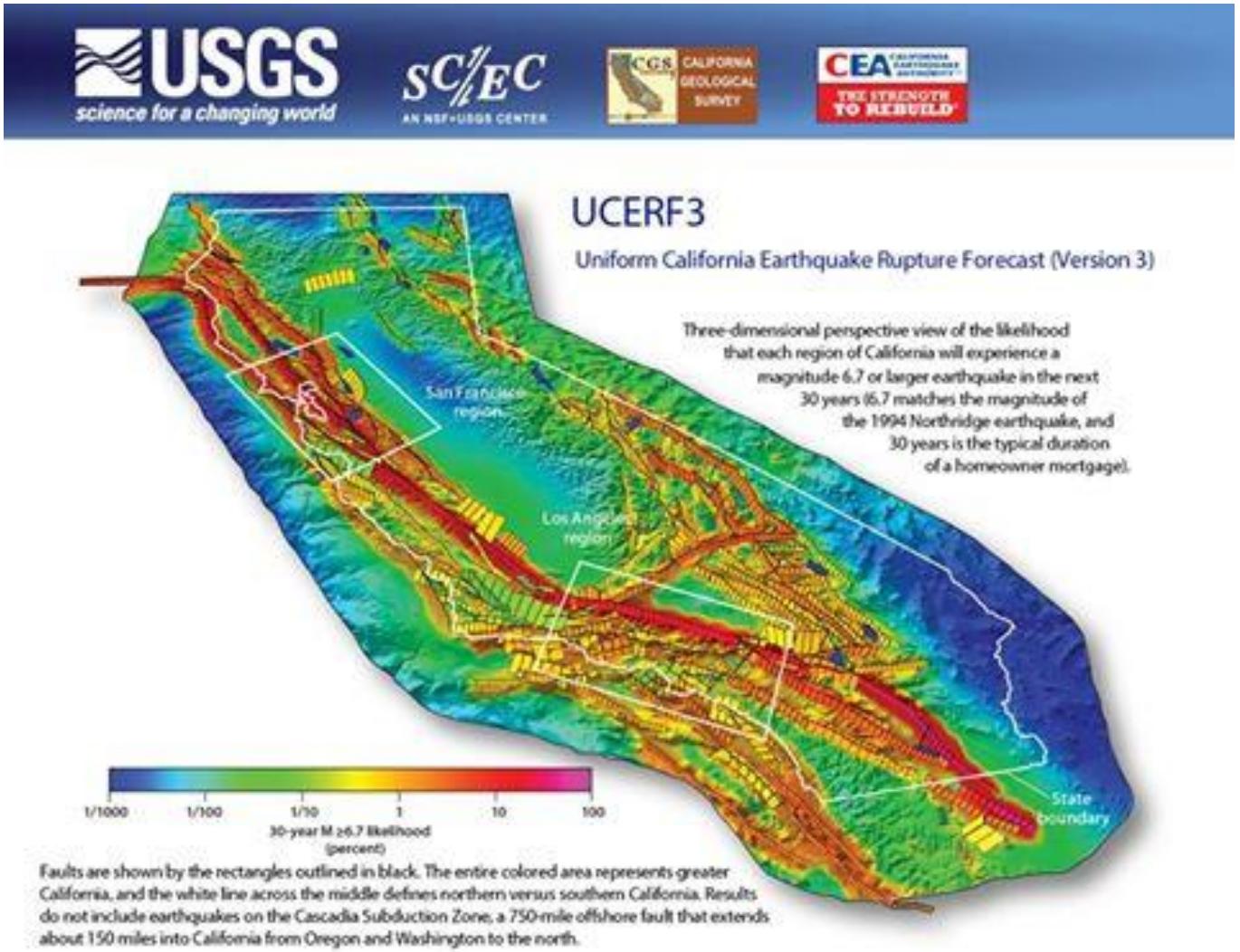
Peril	Deaths per 100,000 population per year	Where, when
Heart disease	194	US, 2010
All accidents	39	US, 2010
Occupational fatality, roofers	32	US, 2011
Auto accidents	11	US, 2009
Firearms	10	US, 2010
New buildings in earthquakes	0.1	24/7 occupancy
CA earthquakes last ~50 years	0.007	CA, 1964-2014

Scary 99.9% JPL prediction



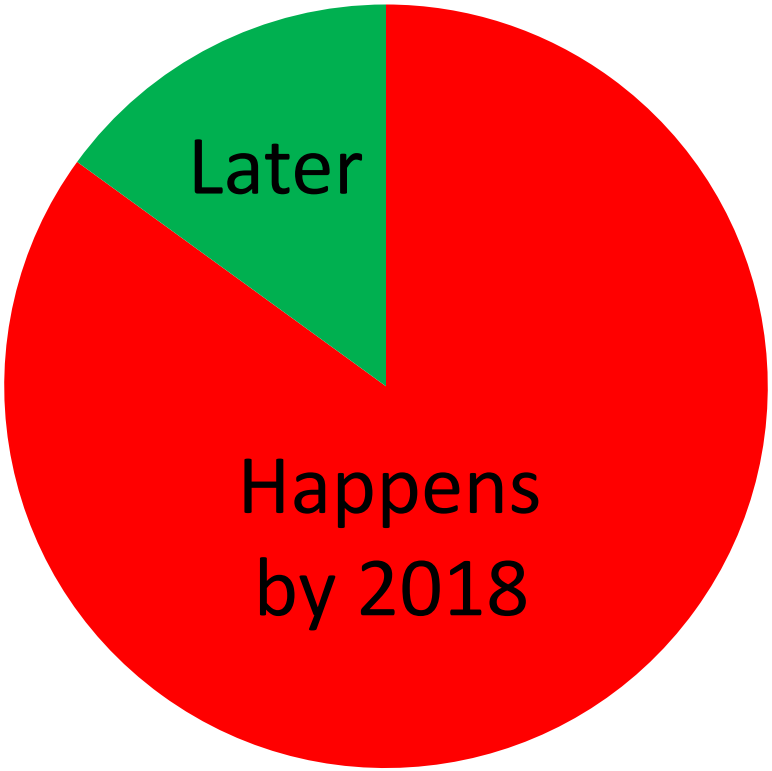
	1 Mo	1 Yr	3 Yr
M≥5	1.3%	65.3%	99.9%
M≥6	0.1%	4.8%	34.7%
M≥7	<0.1%	1.0%	8.9%
M≥8	<0.1%	0.1%	1.0%

USGS's estimate: 85%

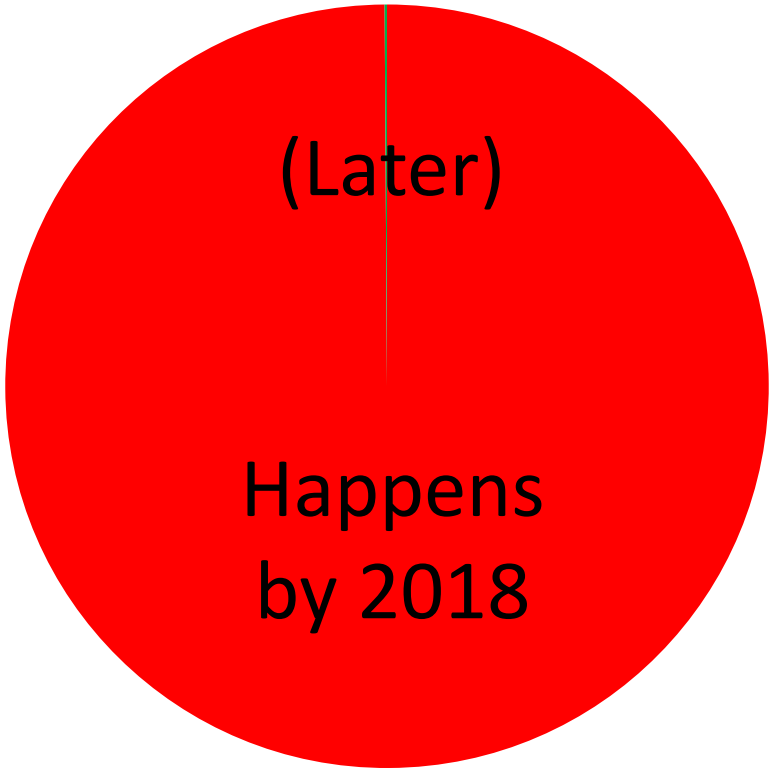


85% or 99.9%: both mean “likely”

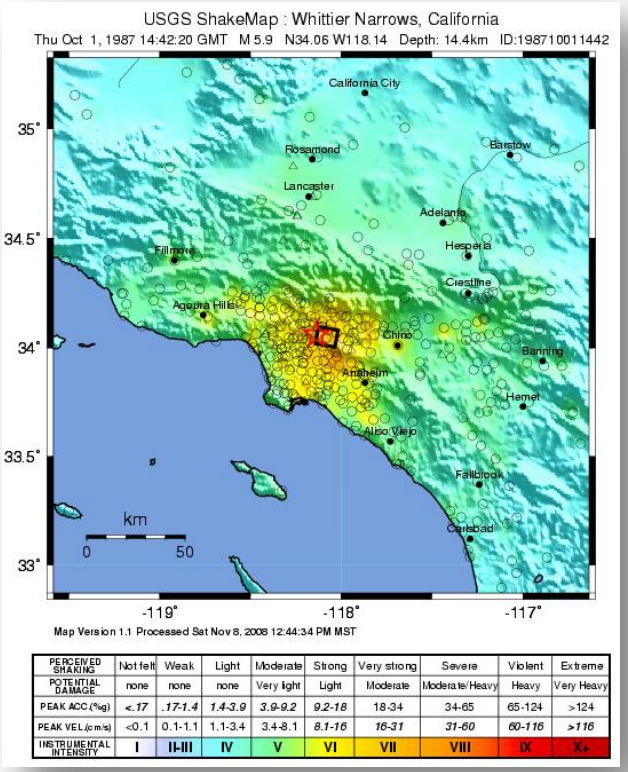
USGS



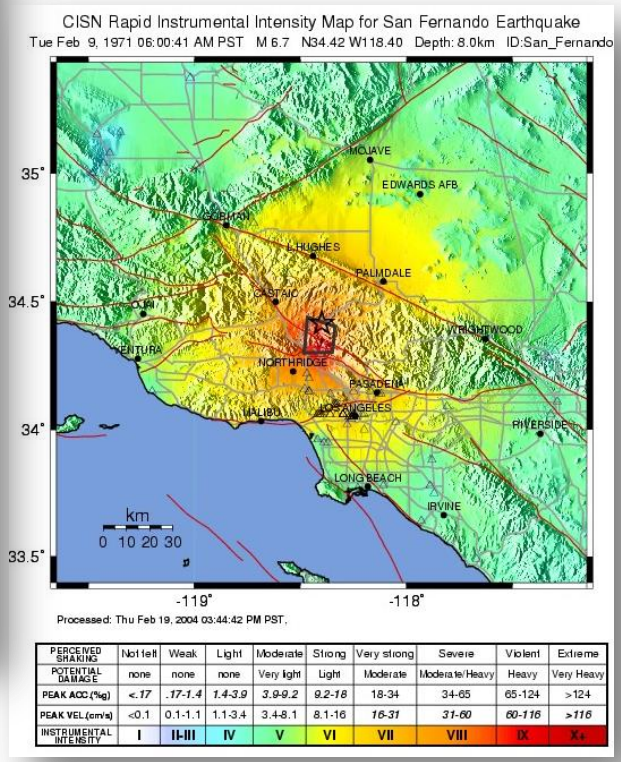
JPL



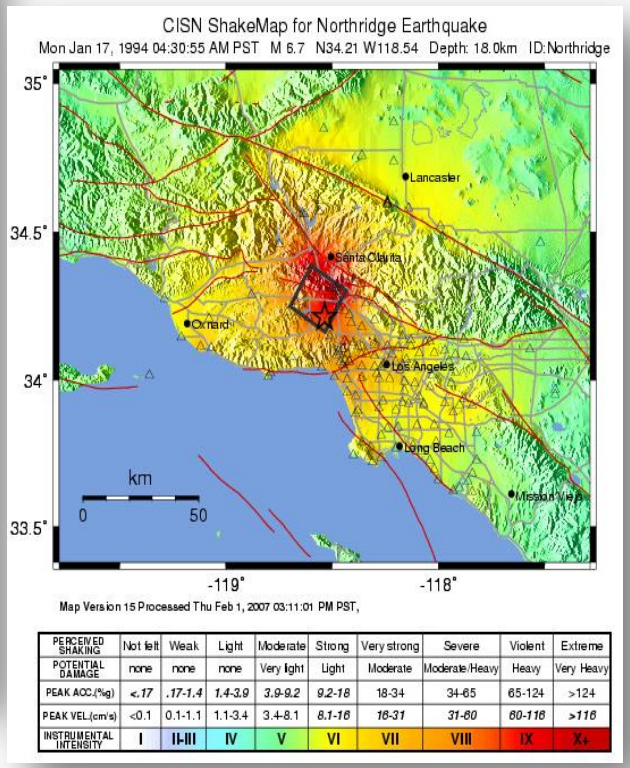
M6-7 events matter in the short run



1987 Whittier M5.9
$400 M USD
3 deaths

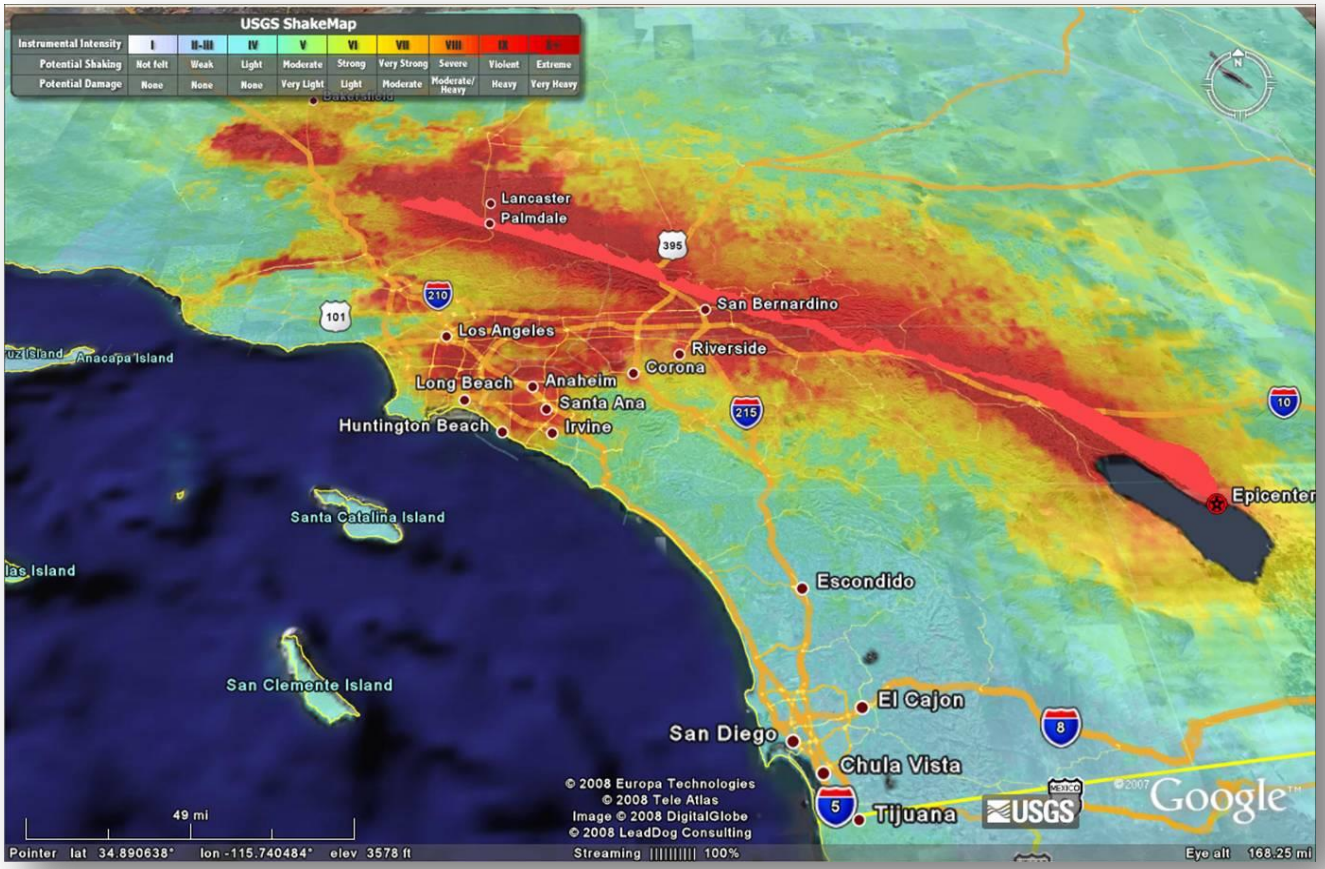


1971 San Fernando M6.7
$550 M USD
64 deaths



1994 Northridge M6.7
$40 B USD
57 deaths

M 7-8 events matter in the long run

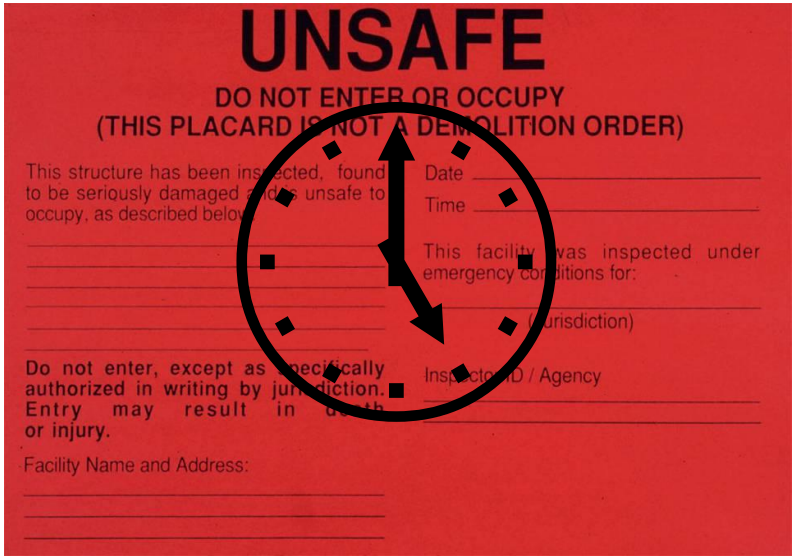


Hypothetical M 7.8 ShakeOut: a 150-year event, 150 years “overdue”

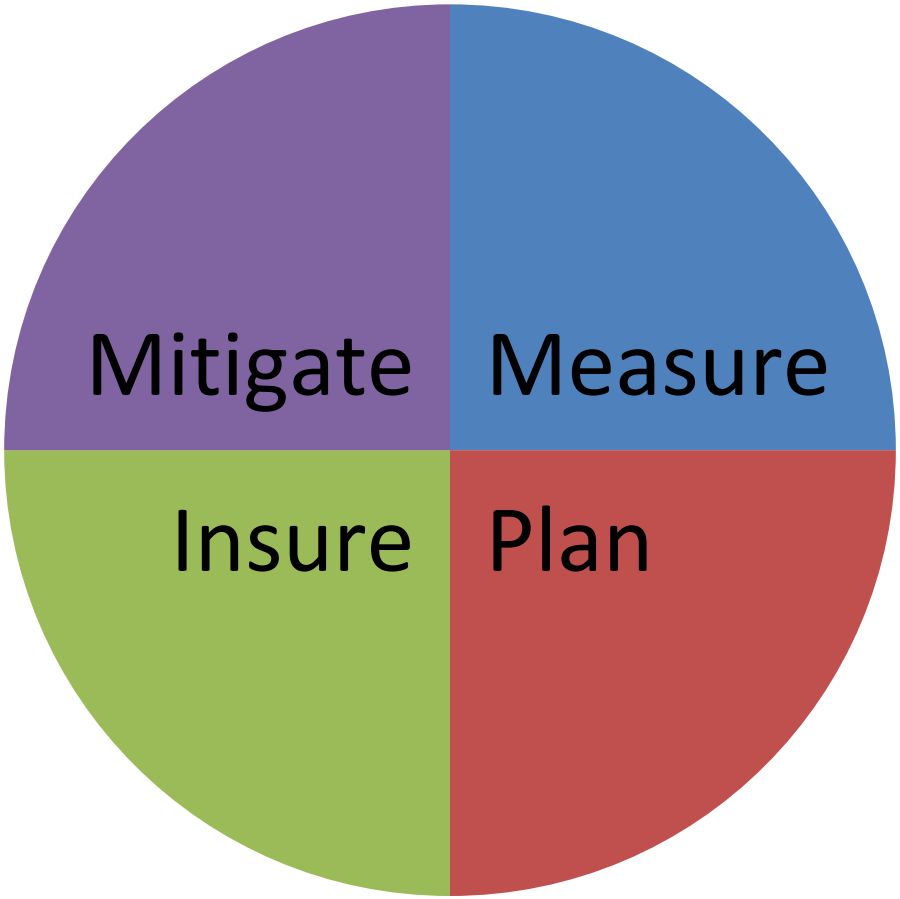
$209 B USD

1800 deaths

All are reasons to manage your risk

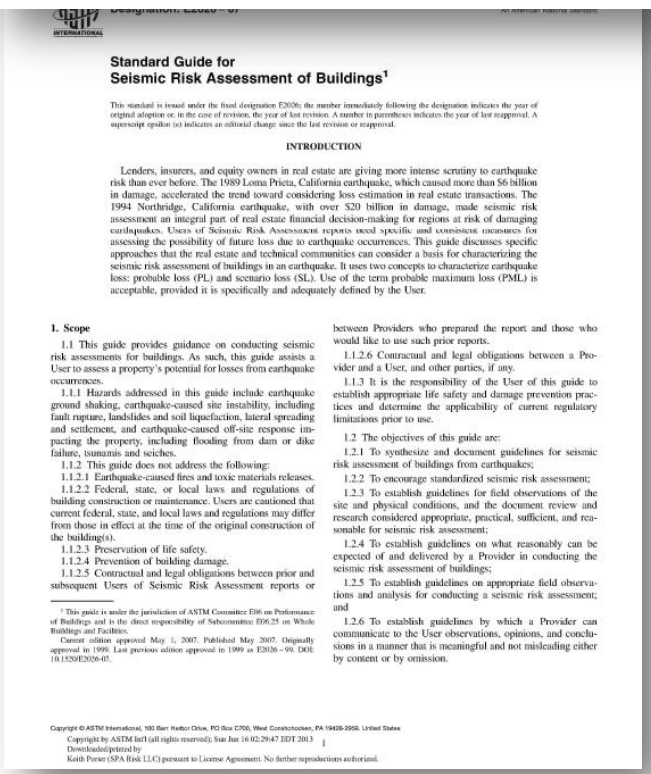


4 strategies to manage seismic risk



Strategy 1: measure

Standard Guide for
Seismic Risk Assessment of Buildings[1]



Standard Guide for
Seismic Risk Assessment of Buildings[1]

This standard is issued under the fixed designation E2026; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

INTRODUCTION

Lenders, insurers, and equity owners in real estate are giving more intense scrutiny to earthquake risk than ever before. The 1989 Loma Prieta, California earthquake, which caused more than $6 billion in damage, accelerated the trend toward considering loss estimation in real estate transactions. The 1994 Northridge, California earthquake, with over $20 billion in damage, made seismic risk assessment an integral part of real estate financial decision-making for regions at risk of damaging earthquakes. Users of Seismic Risk Assessment reports need specific and consistent measures for assessing the possibility of future loss due to earthquake occurrences. This guide discusses specific approaches that the real estate and technical communities can consider a basis for characterizing the seismic risk assessment of buildings in an earthquake. It uses two concepts to characterize earthquake loss: probable loss (PL) and scenario loss (SL). Use of the term probable maximum loss (PML) is acceptable, provided it is specifically and adequately defined by the User.

1. Scope

1.1 This guide provides guidance on conducting seismic risk assessments for buildings. As such, this guide assists a User to assess a property's potential for losses from earthquake occurrences.

1.1.1 Hazards addressed in this guide include earthquake ground shaking, earthquake-caused site instability, including fault rupture, landslides and soil liquefaction, lateral spreading and settlement, and earthquake-caused off-site response impacting the property, including flooding from dam or dike failure, tsunamis and seiches.

1.1.2 This guide does not address the following:

1.1.2.1 Earthquake-caused fires and toxic materials releases.

1.1.2.2 Federal, state, or local laws and regulations of building construction or maintenance. Users are cautioned that current federal, state, and local laws and regulations may differ from those in effect at the time of the original construction of the building(s).

1.1.2.3 Preservation of life safety.

1.1.2.4 Prevention of building damage.

1.1.2.5 Contractual and legal obligations between prior and subsequent Users of Seismic Risk Assessment reports or between Providers who prepared the report and those who would like to use such prior reports.

1.1.2.6 Contractual and legal obligations between a Provider and a User, and other parties, if any.

1.1.3 It is the responsibility of the User of this guide to establish appropriate life safety and damage prevention practices and determine the applicability of current regulatory limitations prior to use.

1.2 The objectives of this guide are:

1.2.1 To synthesize and document guidelines for seismic risk assessment of buildings from earthquakes;

1.2.2 To encourage standardized seismic risk assessment;

1.2.3 To establish guidelines for field observations of the site and physical conditions, and the document review and research considered appropriate, practical, sufficient, and reasonable for seismic risk assessment;

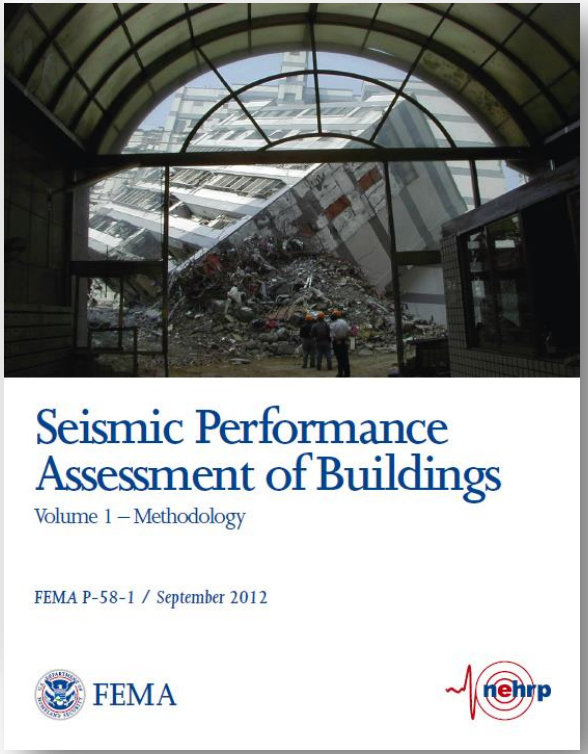
1.2.4 To establish guidelines on what reasonably can be expected of and delivered by a Provider in conducting the seismic risk assessment of buildings;

1.2.5 To establish guidelines on appropriate field observations and analysis for conducting a seismic risk assessment; and

1.2.6 To establish guidelines by which a Provider can communicate to the User observations, opinions, and conclusions in a manner that is meaningful and not misleading either by content or by omission.

[1] This guide is under the jurisdiction of ASTM Committee E06 on Performance of Buildings and is the direct responsibility of Subcommittee E06.25 on Whole Buildings and Facilities.

Current edition approved May 1, 2007. Published May 2007. Originally approved in 1999. Last previous edition approved in 1999 as E2026 – 99. DOI: 10.1520/E2026-07.



Strategy 2: mitigate

Strategy 2: mitigate

Strategy 2: mitigate

Seismic retrofit can be cost effective

395 public-sector seismic retrofits in 1993-2003:

Cost $950 M

Saved $1,390 M

BCR 1.5:1

NATURAL HAZARD MITIGATION SAVES: An Independent Study to Assess the Future Savings from Mitigation Activities

Volume 2 – Study Documentation

Seismic retrofit can be cost-effective

Nonstructural retrofit 3 data centers

- Cost ~$3 M
- Saves $100 M
- BCR ≈ 33:1

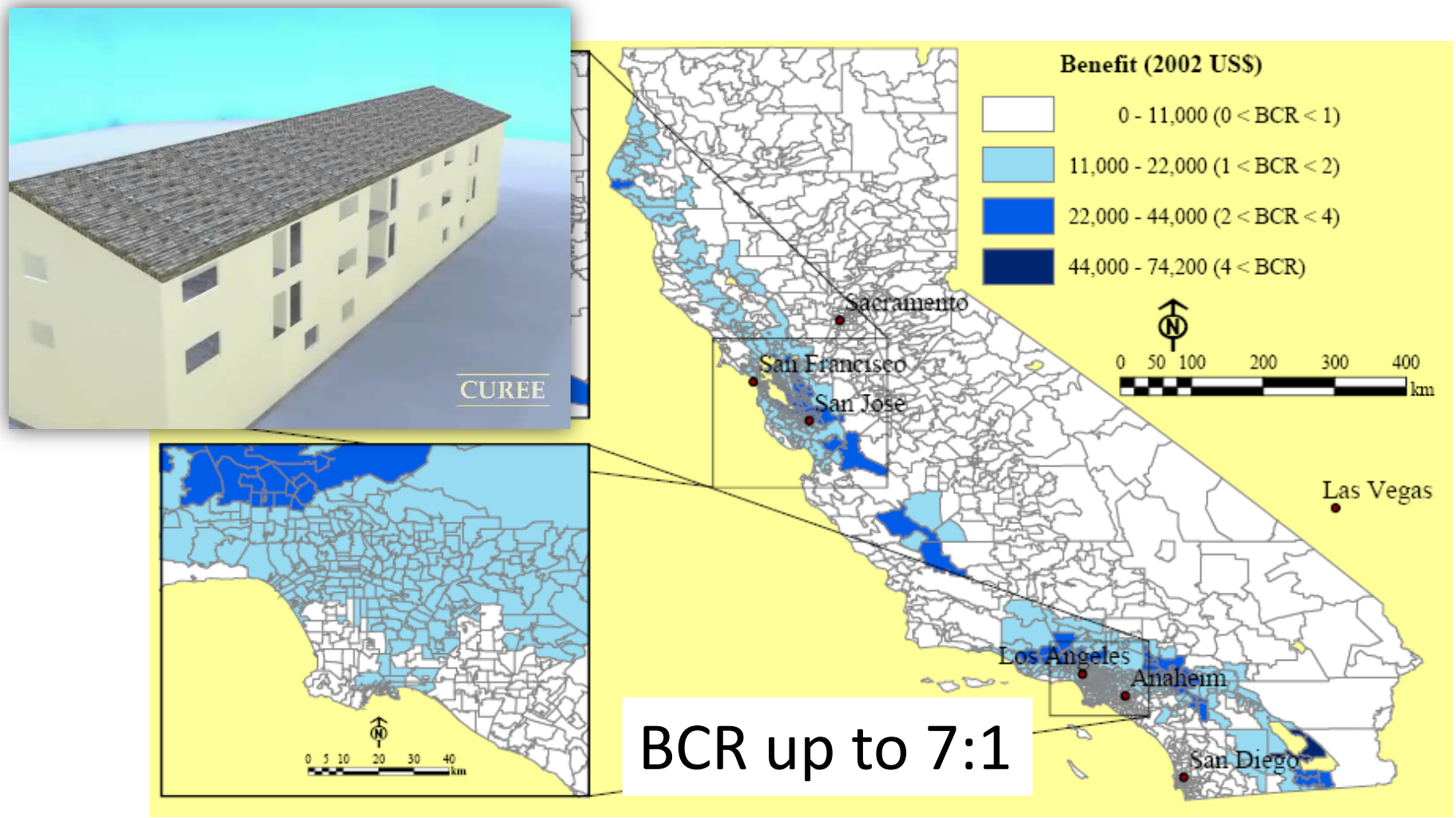
Nonstructural retrofit 2 office bldgs

- Costs $5.5 M
- Saves $75M worth of casualties
- BCR ≈ 14:1

Anheuser-Busch Brewery retrofit

- Cost $11 M
- Saved $350 M in losses in 1994
- BCR ≈ 30:1

Seismic retrofit can be cost effective

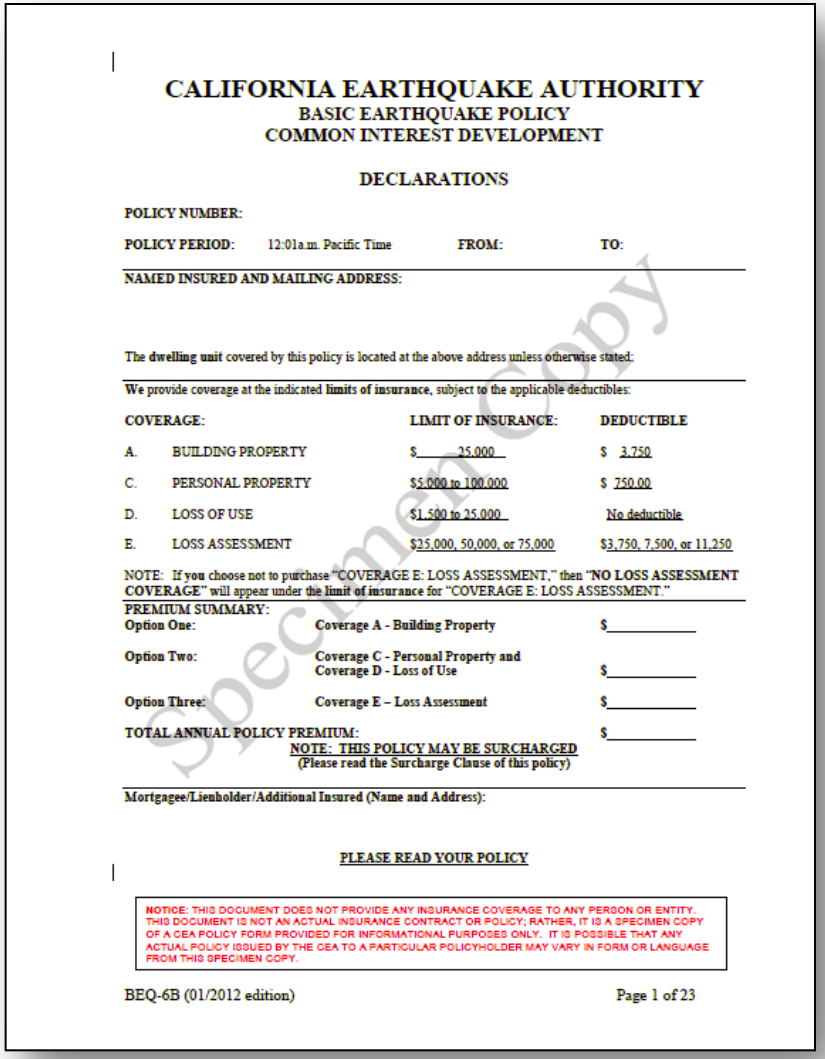


Strategy 3: insure

Costs $1.00/$1000 +

Benefit < cost

But mitigates risk of ruin



CALIFORNIA EARTHQUAKE AUTHORITY
BASIC EARTHQUAKE POLICY
COMMON INTEREST DEVELOPMENT

DECLARATIONS

POLICY NUMBER:

POLICY PERIOD: 12:01a.m. Pacific Time **FROM:** **TO:**

NAMED INSURED AND MAILING ADDRESS:

The **dwelling unit** covered by this policy is located at the above address unless otherwise stated:

We provide coverage at the indicated **limits of insurance**, subject to the applicable deductibles:

COVERAGE:		**LIMIT OF INSURANCE:**	**DEDUCTIBLE**
A.	BUILDING PROPERTY	$ 25,000	$ 3,750
C.	PERSONAL PROPERTY	$5,000 to 100,000	$ 750.00
D.	LOSS OF USE	$1,500 to 25,000	No deductible
E.	LOSS ASSESSMENT	$25,000, 50,000, or 75,000	$3,750, 7,500, or 11,250

NOTE: If you choose not to purchase "COVERAGE E: LOSS ASSESSMENT," then "**NO LOSS ASSESSMENT COVERAGE**" will appear under the **limit of insurance** for "COVERAGE E: LOSS ASSESSMENT."

PREMIUM SUMMARY:

Option One:	**Coverage A - Building Property**	$_____
Option Two:	**Coverage C - Personal Property and Coverage D - Loss of Use**	$_____
Option Three:	**Coverage E – Loss Assessment**	$_____
TOTAL ANNUAL POLICY PREMIUM:		$_____

NOTE: THIS POLICY MAY BE SURCHARGED
(Please read the Surcharge Clause of this policy)

Mortgagee/Lienholder/Additional Insured (Name and Address):

PLEASE READ YOUR POLICY

NOTICE: THIS DOCUMENT DOES NOT PROVIDE ANY INSURANCE COVERAGE TO ANY PERSON OR ENTITY. THIS DOCUMENT IS NOT AN ACTUAL INSURANCE CONTRACT OR POLICY; RATHER, IT IS A SPECIMEN COPY OF A CEA POLICY FORM PROVIDED FOR INFORMATIONAL PURPOSES ONLY. IT IS POSSIBLE THAT ANY ACTUAL POLICY ISSUED BY THE CEA TO A PARTICULAR POLICYHOLDER MAY VARY IN FORM OR LANGUAGE FROM THIS SPECIMEN COPY.

BEQ-6B (01/2012 edition) Page 1 of 23

Strategy 4: plan (emergency management & biz continuity)

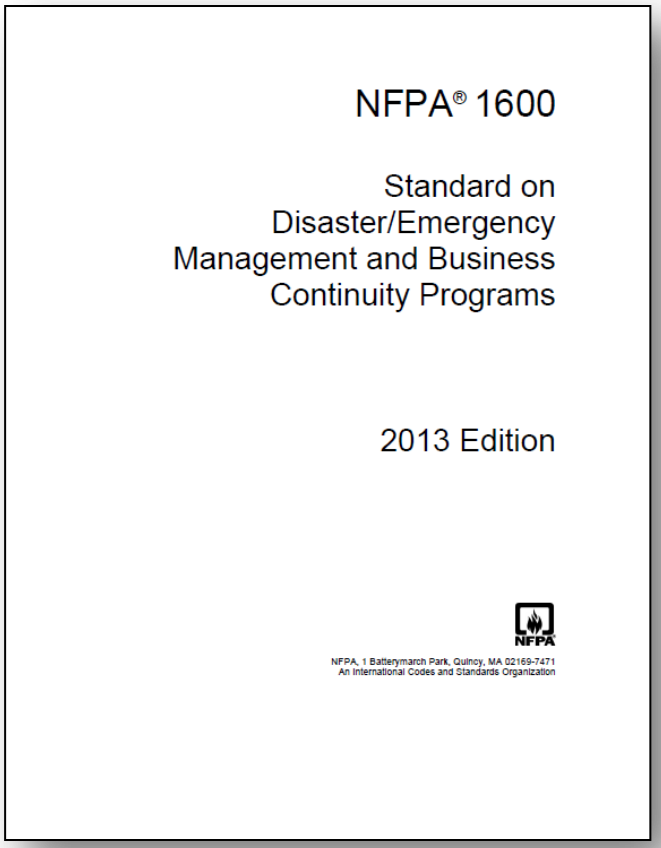
Prevention strategies

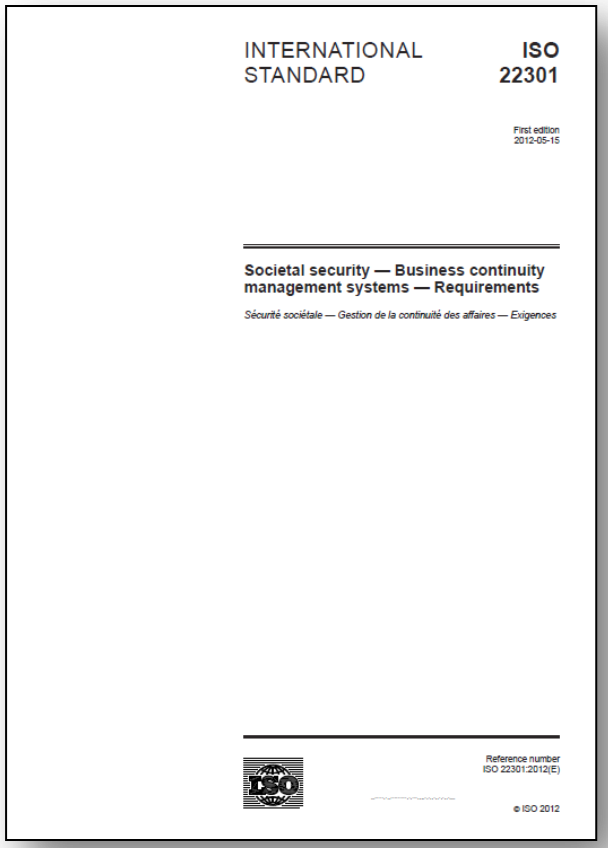
Mitigation strategies, e.g., alternate workplace

Incident command system

...

Strategy 4: plan





Emergency management & business continuity planning relatively inexpensive, probably very high BCR

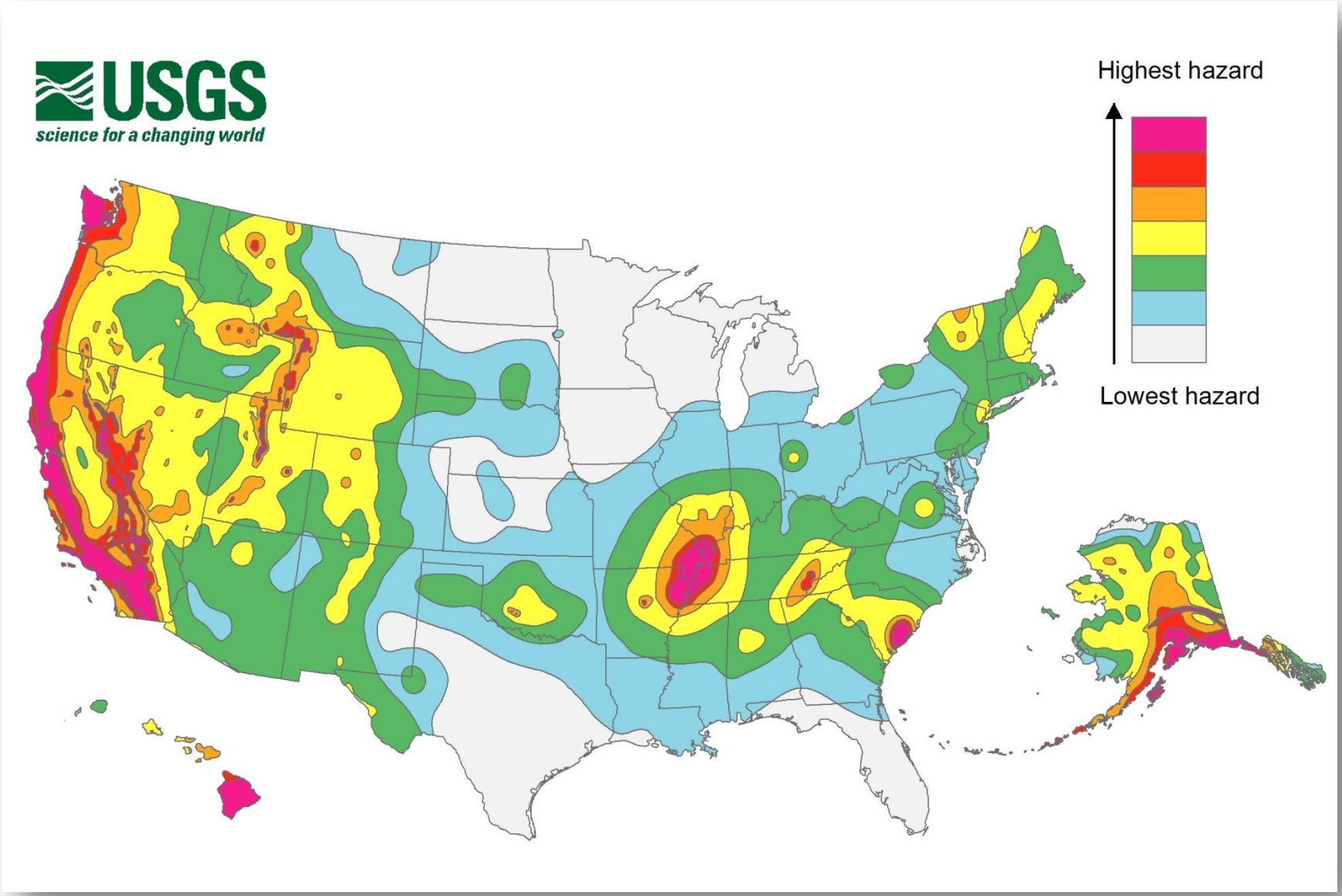
Evaluating risk

Some basic principles

What the evaluator will look for

- Hazard
- Structure type
- Era of construction
- Important features
- Concealed details

Hazard


USGS
science for a changing world
Highest hazard
Lowest hazard

Structure type
Worst

Unreinforced masonry bearing wall

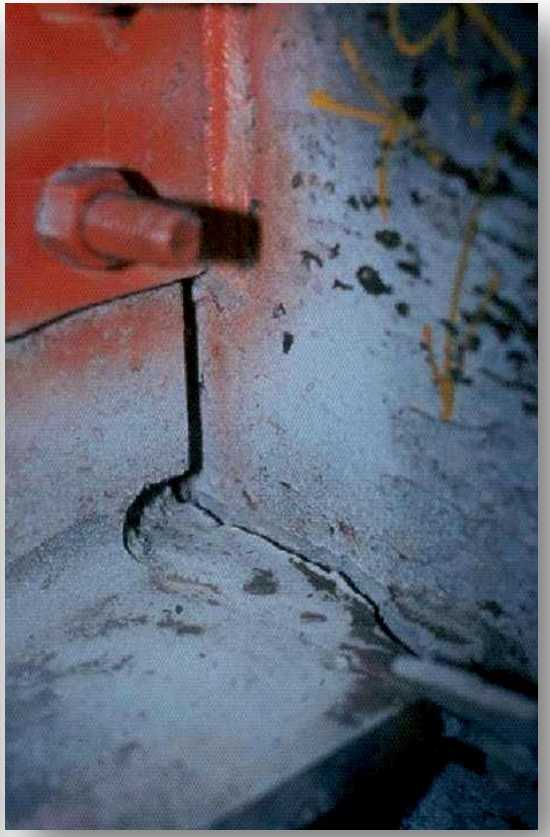
Pre-1976 reinforced concrete frame

Structure type
From worst to best

Pre-1976 tiltup concrete

Steel frame with unreinforced masonry infill cladding

Structure type
From worst to best



Pre-1994 steel frame

Structure type
From worst to best

Steel braced frame

Woodframe

Structure type
From worst to best

Concrete shearwall

Reinforced masonry

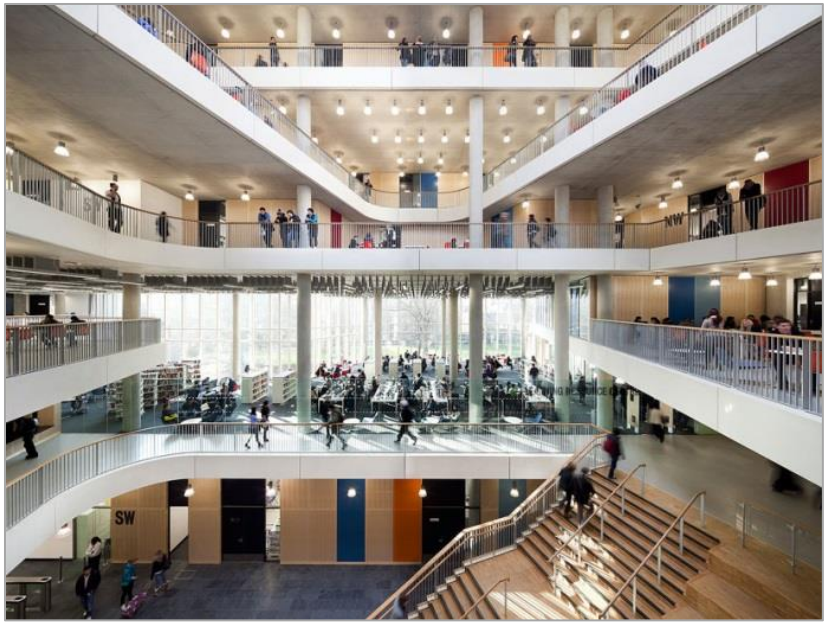
Important features

Soft story

Close to adjacent building

Important features

Sloping site

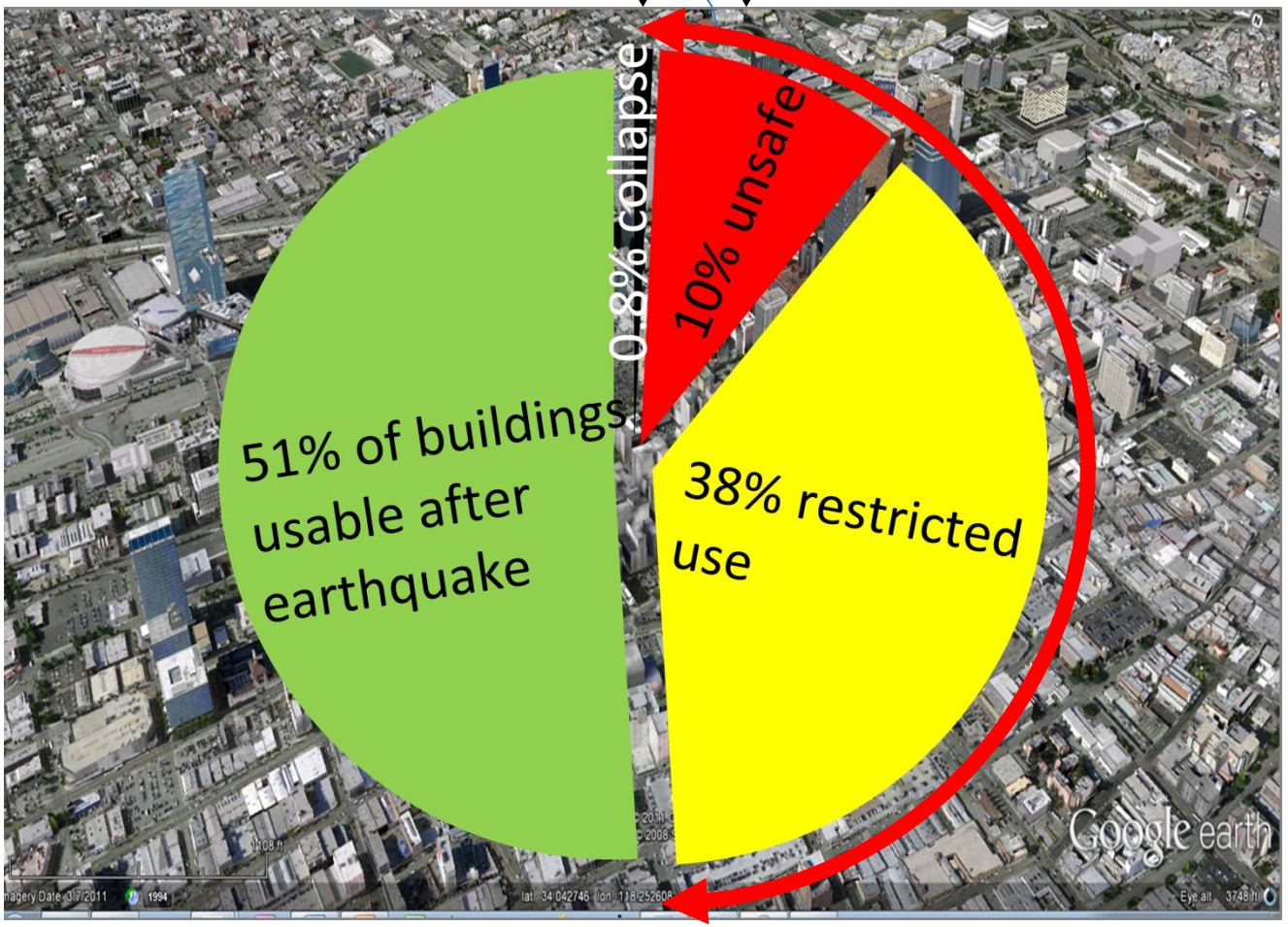


Atria & irregular plans

Newer is better, but code goal is *life safety*

Code limits collapse

Accepts impairment



¾ design level, ~100-year shaking

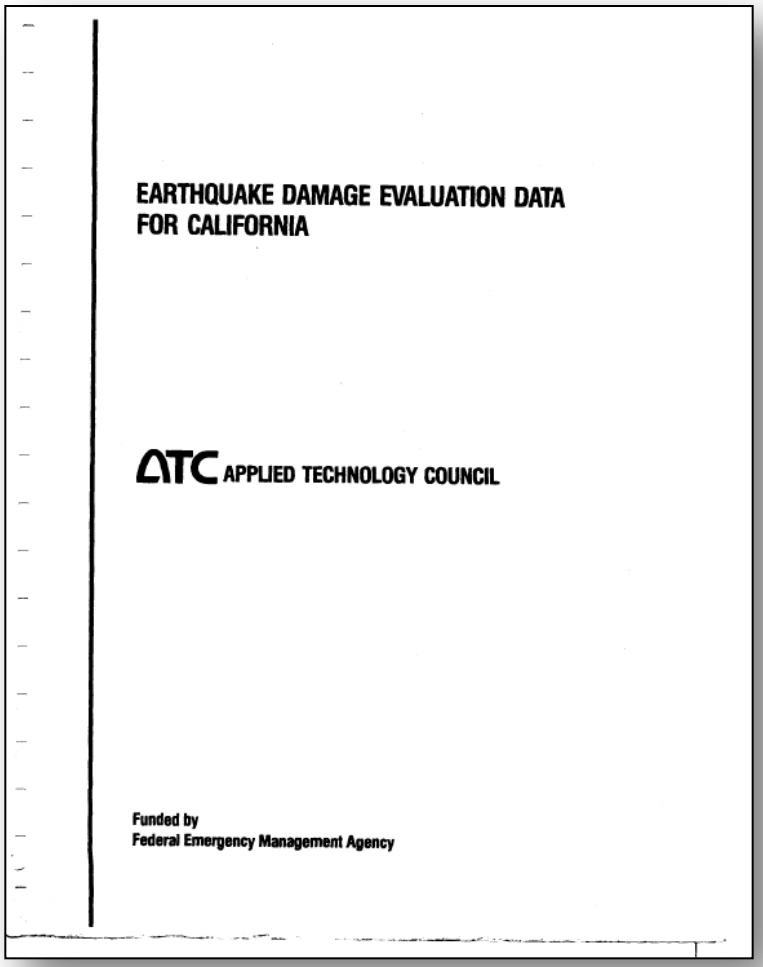
Evaluation procedures

Choices for PML-type studies

Steinbrugge's PML (1970s-1999)

upper-bound loss (90 %ile)
in rare earthquake (0.2% chance per year)
as a fraction of construction cost
considering location,
structure type,
and important features

PML estimation procedures



- ATC-13 (1985)
- Expert judgment + limited experience
- Foundation for seismic risk estimates around the world even to today
- Evaluators were professional engineers

1989, 1994 scared insurers & lenders

Lenders began to require PML < 20% or insurance

20th Century Insurance Out of Quake Action

June 10, 1994 | THOMAS S. MULLIGAN | TIMES STAFF WRITER

In a move certain to shake up the Southern California insurance market, earthquake-battered 20th Century Insurance Co. said Thursday that it will stop selling earthquake policies immediately and phase out all homeowner coverage over the next two years.

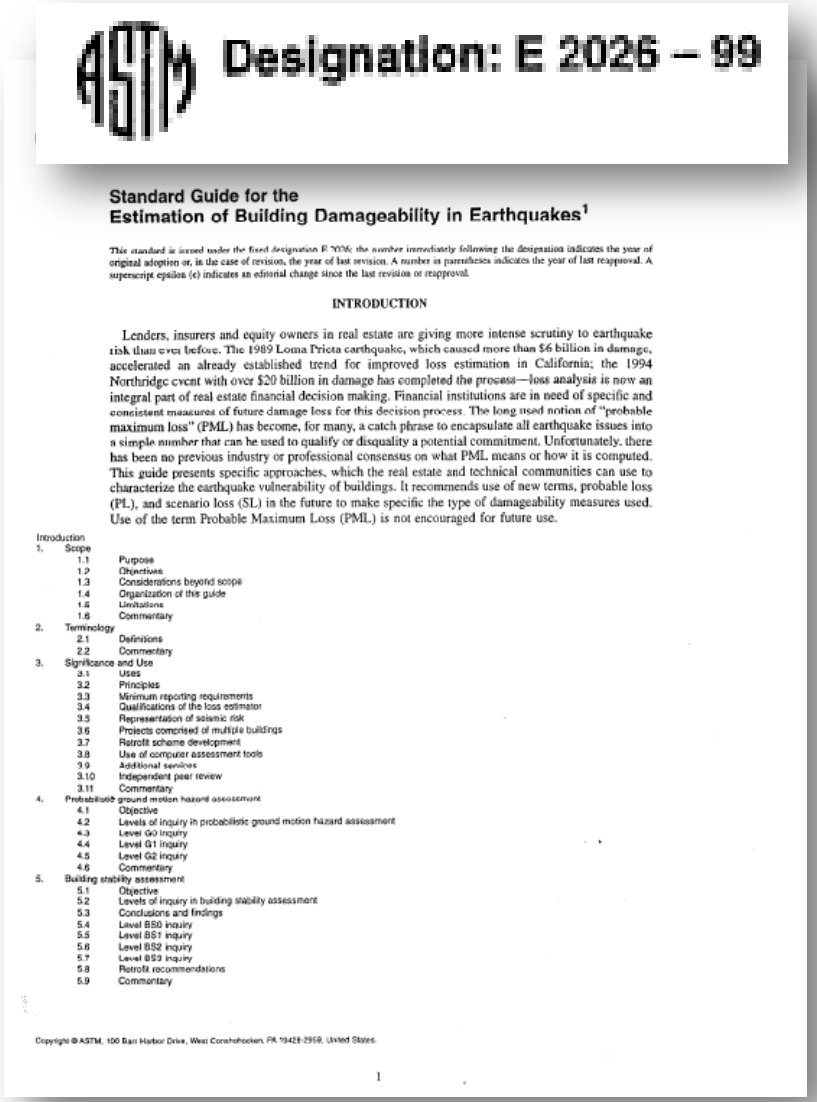
The big insurer's exit increases fears that consumers--especially in the Los Angeles Basin--will have trouble finding earthquake insurance.

In Orange County, 34,894 homeowner policy holders who have insurance with 20th Century will have to look elsewhere. They represent 14.7% of the company's business statewide.

The action also prompted renewed calls for a national catastrophe insurance program such as the Natural Disaster Protection Act now before Congress.

Woodland Hills-based 20th Century said it will take no new customers in either homeowner or earthquake insurance, but will concentrate on the cut-rate auto policies that form the bulk of its business and have fueled its 30 years of fast growth and high profits.

1990s: new terms muddy the waters



Designation: E 2026 – 99

Standard Guide for the Estimation of Building Damageability in Earthquakes[1]

This standard is issued under the fixed designation E 2026; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

INTRODUCTION

Lenders, insurers and equity owners in real estate are giving more intense scrutiny to earthquake risk than ever before. The 1989 Loma Prieta earthquake, which caused more than $6 billion in damage, accelerated an already established trend for improved loss estimation in California; the 1994 Northridge event with over $20 billion in damage has completed the process—loss analysis is now an integral part of real estate financial decision making. Financial institutions are in need of specific and consistent measures of future damage loss for this decision process. The long used notion of "probable maximum loss" (PML) has become, for many, a catch phrase to encapsulate all earthquake issues into a simple number that can be used to qualify or disqualify a potential commitment. Unfortunately, there has been no previous industry or professional consensus on what PML means or how it is computed. This guide presents specific approaches, which the real estate and technical communities can use to characterize the earthquake vulnerability of buildings. It recommends use of new terms, probable loss (PL), and scenario loss (SL) in the future to make specific the type of damageability measures used. Use of the term Probable Maximum Loss (PML) is not encouraged for future use.

SEL scenario expected loss

PL probable loss

SL scenario loss

Easier to get SEL < 20%

Helps avoid buying insurance

Little incentive for rigor & QA

PML studies become a $500 box to check

2000s: new standards, same problems

Designation: E2026 – 07

Standard Guide for
Seismic Risk Assessment of Buildings[1]

This standard is issued under the fixed designation E2026; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

INTRODUCTION

Lenders, insurers, and equity owners in real estate are giving more intense scrutiny to earthquake risk than ever before. The 1989 Loma Prieta, California earthquake, which caused more than $6 billion in damage, accelerated the trend toward considering loss estimation in real estate transactions. The 1994 Northridge, California earthquake, with over $20 billion in damage, made seismic risk assessment an integral part of real estate financial decision-making for regions at risk of damaging earthquakes. Users of Seismic Risk Assessment reports need specific and consistent measures for assessing the possibility of future loss due to earthquake occurrences. This guide discusses specific approaches that the real estate and technical communities can consider a basis for characterizing the seismic risk assessment of buildings in an earthquake. It uses two concepts to characterize earthquake loss: probable loss (PL) and scenario loss (SL). Use of the term probable maximum loss (PML) is acceptable, provided it is specifically and adequately defined by the User.

1. Scope

1.1 This guide provides guidance on conducting seismic risk assessments for buildings. As such, this guide assists a User to assess a property's potential for losses from earthquake occurrences.

1.1.1 Hazards addressed in this guide include earthquake ground shaking, earthquake-caused site instability, including fault rupture, landslides and soil liquefaction, lateral spreading and settlement, and earthquake-caused off-site response impacting the property, including flooding from dam or dike failure, tsunamis and seiches.

1.1.2 This guide does not address the following:

1.1.2.1 Earthquake-caused fires and toxic materials releases.

1.1.2.2 Federal, state, or local laws and regulations of building construction or maintenance. Users are cautioned that current federal, state, and local laws and regulations may differ from those in effect at the time of the original construction of the building(s).

1.1.2.3 Preservation of life safety.

1.1.2.4 Prevention of building damage.

1.1.2.5 Contractual and legal obligations between prior and subsequent Users of Seismic Risk Assessment reports or between Providers who prepared the report and those who would like to use such prior reports.

1.1.2.6 Contractual and legal obligations between a Provider and a User, and other parties, if any.

1.1.3 It is the responsibility of the User of this guide to establish appropriate life safety and damage prevention practices and determine the applicability of current regulatory limitations prior to use.

1.2 The objectives of this guide are:

1.2.1 To synthesize and document guidelines for seismic risk assessment of buildings from earthquakes;

1.2.2 To encourage standardized seismic risk assessment;

1.2.3 To establish guidelines for field observations of the site and physical conditions, and the document review and research considered appropriate, practical, sufficient, and reasonable for seismic risk assessment;

1.2.4 To establish guidelines on what reasonably can be expected of and delivered by a Provider in conducting the seismic risk assessment of buildings;

1.2.5 To establish guidelines on appropriate field observations and analysis for conducting a seismic risk assessment; and

1.2.6 To establish guidelines by which a Provider can communicate to the User observations, opinions, and conclusions in a manner that is meaningful and not misleading either by content or by omission.

[1] This guide is under the jurisdiction of ASTM Committee E06 on Performance of Buildings and is the direct responsibility of Subcommittee E06.25 on Whole Buildings and Facilities.

Current edition approved May 1, 2007. Published May 2007. Originally approved in 1999. Last previous edition approved in 1999 as E2026 – 99. DOI: 10.1520/E2026-07.

Toolbox

Designation: E2557 – 07

Standard Practice for
Probable Maximum Loss (PML) Evaluations for Earthquake
Due-Diligence Assessments[1,2]

This standard is issued under the fixed designation E2557; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice establishes standard-of-care for evaluation and classification of the financial risks from earthquake damage to real estate improvements for use in financial transactions. As such, this practice permits a user to satisfy, in part, their real estate transaction due-diligence requirements with respect to assessing and characterizing a property's potential losses from earthquakes. This practice is intended to address only physical damage to the property from site and building response.

1.1.1 Hazards addressed in this practice include earthquake ground shaking, earthquake-caused site instability, including faulting, subsidence, settlement landslides and soil liquefaction, earthquake-caused tsunamis and seiches, and earthquake-caused flooding from dam or dike failures.

1.1.2 Earthquake-caused fires and toxic materials releases are not hazards considered in this practice.

1.1.3 This practice does not purport to provide for the preservation of life safety, or prevention of building damage associated with its use, or both.

1.1.3.1 This practice does not address requirements of any federal, state, or local laws and regulations of building construction or maintenance. Users are cautioned that current federal, state, and local laws and regulations may differ from those in effect at the times of construction or modification of the building(s), or both.

1.1.3.2 This practice does not address the contractual and legal obligations between prior and subsequent Users of PML reports or between providers who prepared the report and those who would like to use such prior reports.

1.1.3.3 This practice does not address the contractual and legal obligations between a provider and a user, and other parties, if any.

1.1.4 It is the responsibility of the owner of the building(s) to establish appropriate life-safety and damage prevention practices and determine the applicability of current regulatory limitations prior to use.

1.2 Considerations not included in the scope: the impacts of damage to building contents, loss of income(s), rents, or other economic benefits of use of the property, or from legal judgments, fire sprinkler water-induced damage or fire.

1.3 *The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]
E2026 Guide for Seismic Risk Assessment of Buildings

2.2 *Other Standards:*[4]
UBC-97 Unifrom Building Code, 1997 Edition
International Building Code 2006 Edition

2.3 *ASCE Standards:*[5]
ASCE 7 Minimum Design Loads for Buildings and Other Structures
ASCE 31 Seismic Evaluation of Existing Buildings
ASCE 41 Seismic Rehabilitation of Existing Buildings

3. Terminology

3.1 See also definitions in Guide E2026.

3.2 *DBE, n*—Design Basis Earthquake, as defined in Guide E2026.

3.3 *lateral load-resisting system, n*—Lateral Load Resisting System, as defined in Guide E2026.

3.4 *MCE, n*—Maximum Capable Earthquake as defined in Guide E2026.

3.5 *PML, n*—Term historically used to characterize building damageability in earthquakes.

[1] This practice is under the jurisdiction of ASTM Committee E06 on Performance of Buildings and is the direct responsibility of Subcommittee E06.25 on Whole Buildings and Facilities.

Current edition approved May 1, 2007. Published May 2007. DOI: 10.1520/E2557-07.

[2] Portions of this publication reproduce content from the 1997 Uniform Building Code, International Code Council, Inc. Falls Church, Virginia. Reproduced with permission. All rights reserved.

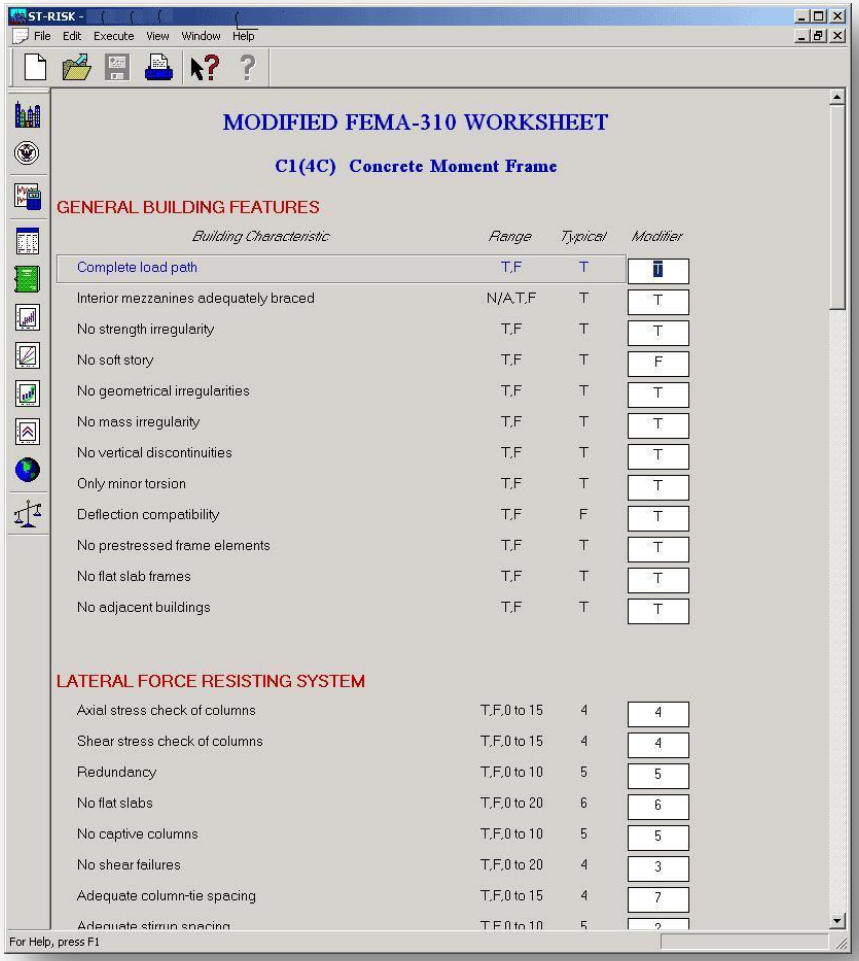
[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[4] Available from International Organization for Standardization (ISO), 1 rue de Varembé, Case postale 56, CH-1211, Geneva 20, Switzerland, http://www.iso.ch.

[5] Available from American Society of Civil Engineers (ASCE), 1801 Alexander Bell Dr., Reston, VA 20191, http://www.asce.org.

Standard practice

ST-Risk



ATC-13 + engineering refinements + Hazus-MH + insurance loss data

Proprietary code

Enter the USRC

Goals

- Meaningful ratings
- Measuring 3Ds
- Experienced, accredited professional engineers
- Technical review
- Consistent
- Affordable

USRC Ratings

Safety

5★	Injuries and blocking of exit paths unlikely
4★	Serious injuries unlikely
3★	Loss of life unlikely
2★	Loss of life possible in isolated locations
1★	Loss of life likely in the building

Damage

5★	Minimal damage (< 5%)
4★	Moderate damage (< 10%)
3★	Significant damage (< 20%)
2★	Substantial damage (< 40%)
1★	Severe damage (40%+)
NE	Not Evaluated

Recovery

5★	Immediately to days
4★	Within days to weeks
3★	Within weeks to months
2★	Within months to a year
1★	More than one year
NE	Not evaluated

USRC's 2 levels of effort

Transaction Rating	Verified Rating
1-3 stars, 3 dimensions	1-5 stars, 3 dimensions
Financial due diligence; no display	Display and marketing
Trained certified professional engineer	Trained certified professional engineer
3rd party review (1 in 7, afterwards)	3rd party review (all, prior to issue)
Transparent use of national standards	Transparent use of national standards
Designed to prevent manipulation	Designed to prevent manipulation
$700-900	$1,000+

Adapted from Ron Mayes

USRC adapted ASCE/SEI 31 checklists

Building System

C NC N/A LOAD PATH: The structure shall contain a minimum of one complete load path for Life Safety and Immediate Occupancy for seismic force effects from any horizontal direction that serves to transfer the inertial forces from the mass to the foundation. (Tier 2: Sec. 4.3.1.1)

Building Contents and Furnishing

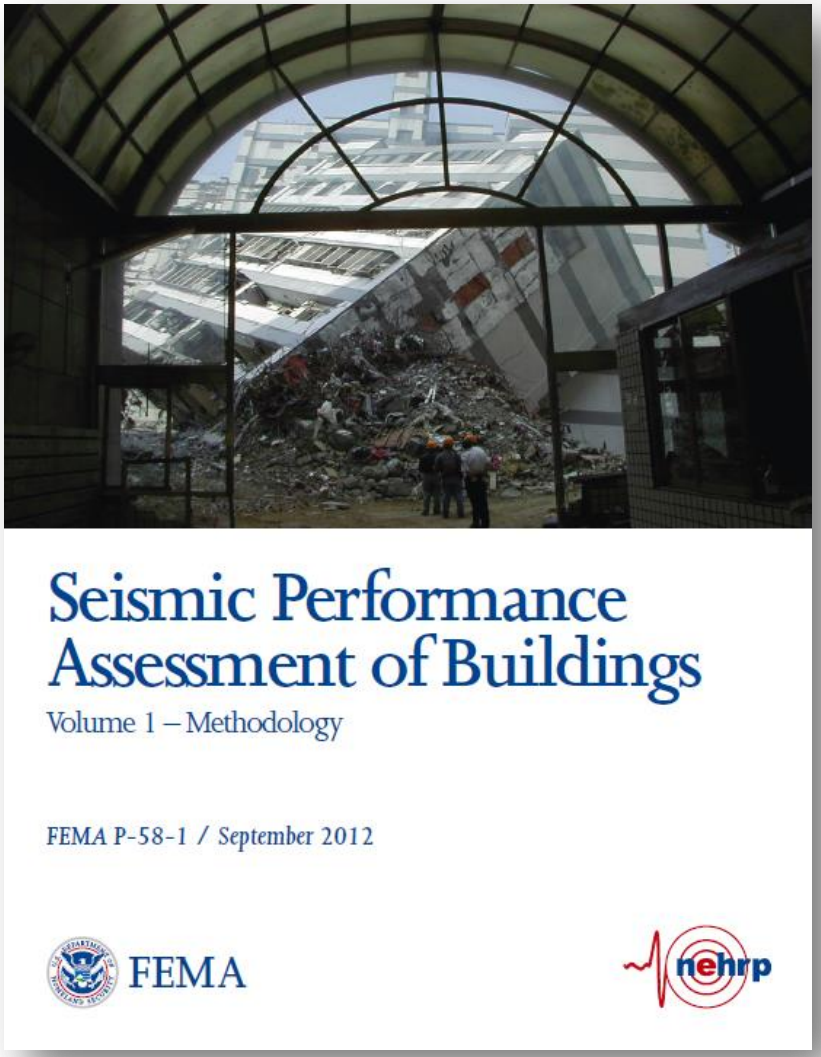
C NC N/A TALL NARROW CONTENTS: Contents over 4 feet in height with a height-to-depth or height-to-width ratio greater than 3-to-1 shall be anchored to the floor slab or adjacent structural walls. A height-to-depth or height-to-width ratio of up to 4-to-1 is permitted where only the Basic Nonstructural Component Checklist is required by Table 3-2. (Tier 2: Sec. 4.8.11.1)

Light Fixtures

C NC N/A INDEPENDENT SUPPORT: Light fixtures in suspended grid ceilings shall be supported independently of the ceiling suspension system by a minimum of two wires at diagonally opposite corners of the fixtures. (Tier 2: Sec. 4.8.3.2)

Highly reputable backers

FEMA P-58 for the very high end



How likely are various

- Repair costs
- Duration of repair time
- Casualties

With and without retrofit

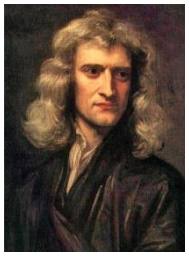
Weigh costs and benefits in $ terms

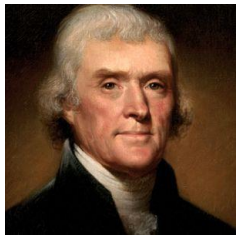
Little reliance on judgment

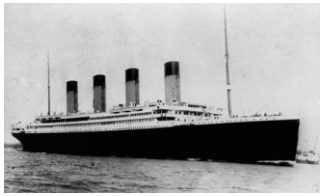
Expensive--$10,000s

High-end structural engineering skills

Reconciles hazard & business timescales







1700

1800

1900

2000

2100

2200

2015-2020

Can reflect risk on a balance sheet

Expected repair cost & downtime in coming 5 years

Example Company
Balance Sheet
December 31, 2014

ASSETS		LIABILITIES & OWNER'S EQUITY	
Current assets		Current Liabilities	
Investments		Long-term liabilities	
Property, plant, and equipment		Total liabilities	
Intangible assets			
Other assets		Owner's equity	
Total assets		Total liabilities & owner's equity	

Conclusions

- PML studies have been a $500 checkbox
- USRC seems able to provide solid benchmarks
- FEMA P-58 is costly, expresses risk in meaningful terms
- Acceptability criteria are still unclear
- Still no affordable balance-sheet risk assessment
- Many decisions don’t need costly risk estimates—you don’t need FEMA P-58 to justify DCHO, etc.

Thanks

Keith Porter

keith.porter@colorado.edu

626-233-9758