NORTHRIDGE 30

1994 – 2024

The Northridge Earthquake - 30 Years Later

A Catalyst for Engineering Resilient Communities

2024 Webinar Series

EarthquakeCountry.org/northridge/events

ASCE | INFRASTRUCTURE RESILIENCE · ASCE LOS ANGELES SECTION · EERI SOUTHERN CALIFORNIA · SEAOSC STRUCTURAL ENGINEERS ASSOCIATION OF SOUTHERN CALIFORNIA · Earthquake Country Alliance

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Series Partners:

- American Society of Civil Engineers (ASCE) Infrastructure Resilience Division
- ASCE Los Angeles Section
- Earthquake Engineering Research Institute (EERI) Southern California Chapter
- Structural Engineers Association of Southern California (SEOASC)
- Earthquake Country Alliance (ECA), led by the Statewide California Earthquake Center

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The Northridge Earthquake - 30 Years Later

A Catalyst for Engineering Resilient Communities

Episode 1: The January 17, 1994 Northridge Earthquake – Science & Engineering Aspects
K. Hudnut, J. Stewart, C. Davis, D. Cocke
EarthquakeCountry.org/northridge30-webinar1

Episode 2: Insurance Issues and Impacts Following the Northridge Earthquake
C. Scawthorn, J. Maffei
EarthquakeCountry.org/northridge30-webinar2

Episode 3: 30 Years of Progress in Quantification of Seismic Hazards
Y. Bozorgnia
EarthquakeCountry.org/northridge30-webinar3

The Northridge Earthquake - 30 Years Later

A Catalyst for Engineering Resilient Communities

2024 Webinar Series

Episode 4: An Unexpected Milestone in Real-Time Loss Estimation

Ron Eguchi, CEO and Co-Founder (ImageCat, Inc.)

David Wald, Research Geophysicist (USGS)

Episode 4 of the Northridge 30th Anniversary Webinar Series:
The Northridge Earthquake – 30 Years Later – A Catalyst for Engineering Resilient Communities

The Northridge Earthquake: An Unexpected Milestone in Real-Time Loss Estimation

Presenters:

Ronald T. Eguchi
ImageCat, Inc.

David Wald, Ph.D.
USGS

ImageCat

July 24, 2024

NORTHRIDGE 30
1994 2024

What unexpected milestones were achieved …

The vision that real-time earthquake monitoring was possible & has a role in post-earthquake response and recovery

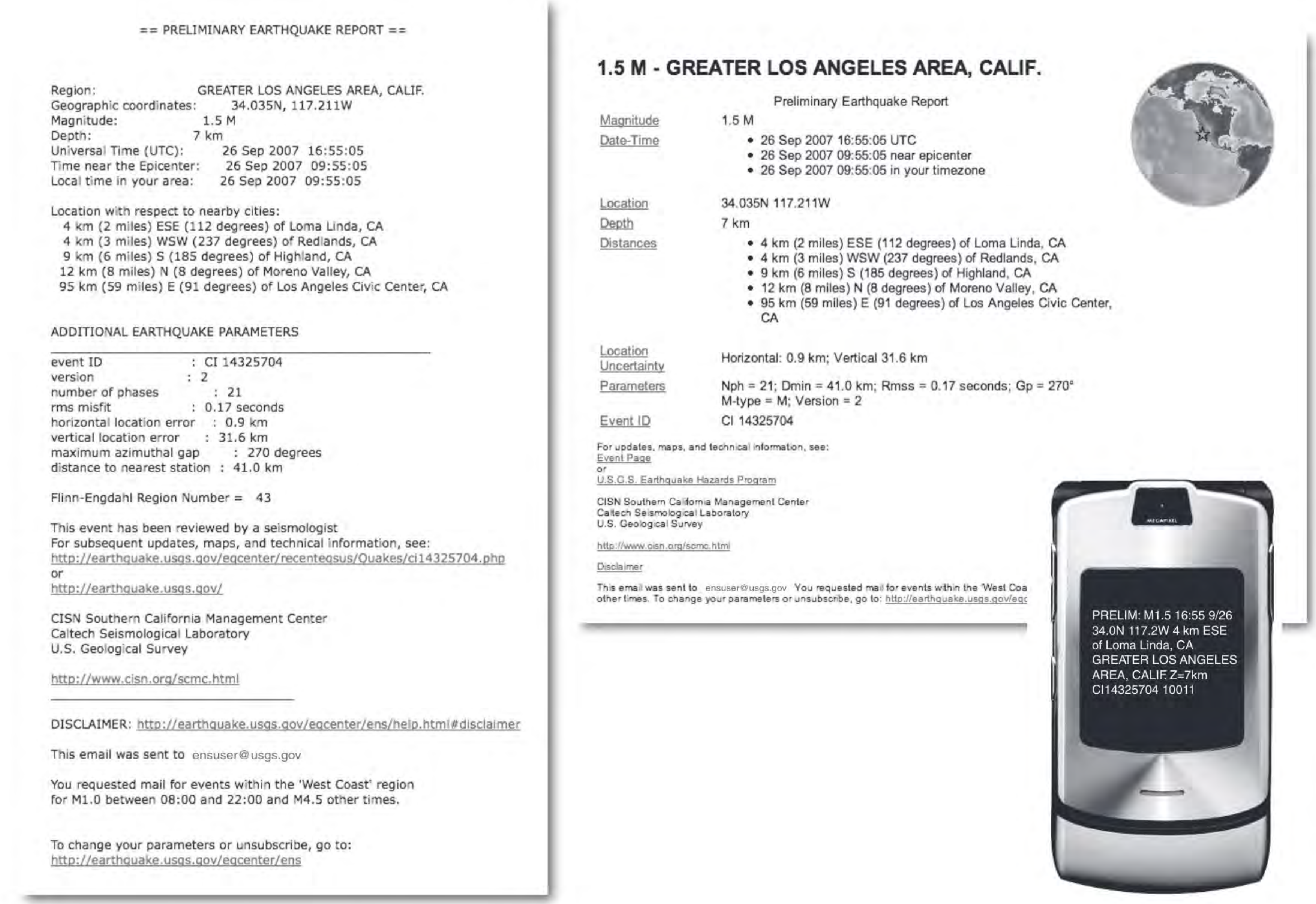
Loss estimation model results helped to guide the initial response activities after the Northridge Earthquake

Geographic Information Systems (GIS) were critical in tracking and measuring the recovery process

Caltech - USGS Broadcast of Earthquakes (CUBE)

Rolled out in 1990 to provide near real-time information for emergency response following significant earthquakes in southern California.

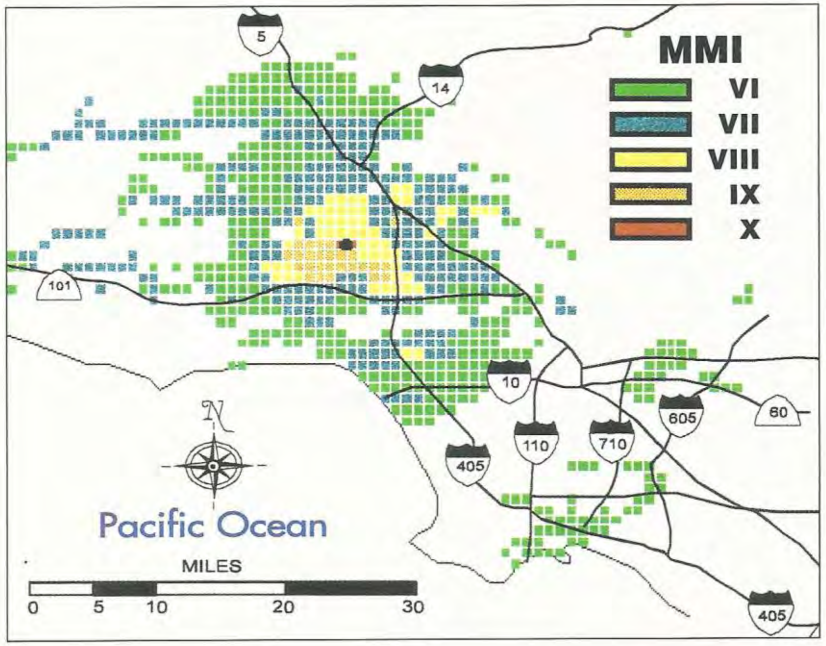
USGS



▲ **Figure 2.** Example notifications in three formats: plain text e-mail, HTML-formatted e-mail, or cell/pager format. The content contains basic information about the earthquake, and the e-mail messages also include hyperlinks to the event-specific Web page for additional details and images.

EPEDAT - Early Post-Earthquake Damage Assessment Tool

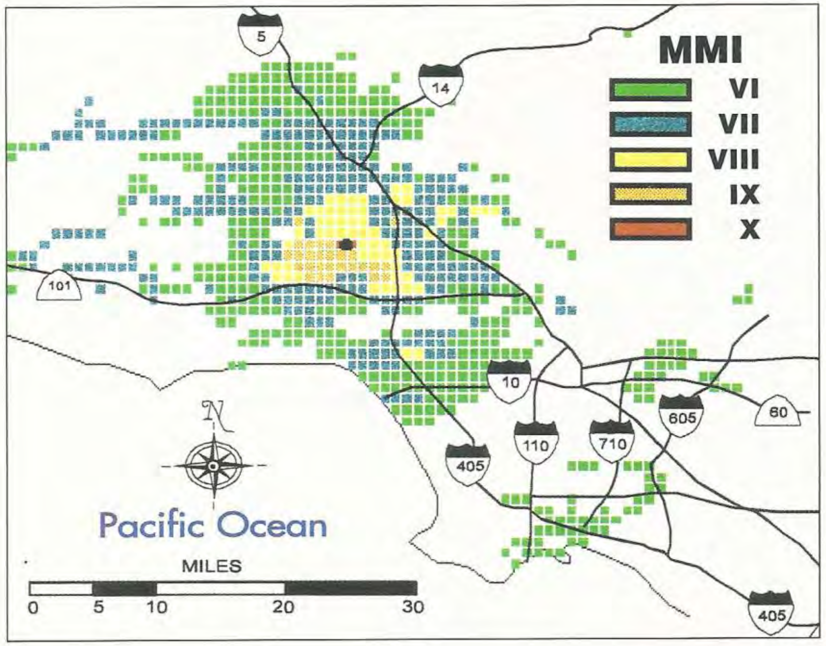
- At the time of the earthquake, only the data and models that would eventually form the basis of EPEDAT existed
- EQEHAZARD (Scawthorn) was used to generate a Modified Mercalli Intensity (MMI) map approximately 10 hours after the earthquake
- Human impacts estimated, 4 days after the earthquake):
  - No. of deaths estimated: 40-430 (Actual – 57)
  - No. of injuries estimated: 1,590-54,340 (Actual – 11,846)
  - No. of displaced persons estimated: 6,490-19,400 (Actual – 24,000)



13) Preliminary estimates of Modified Mercalli Intensity for the Northridge, California earthquake of January 17, 1994. From Eguchi et al., p. 827.

EPEDAT - Early Post-Earthquake Damage Assessment Tool

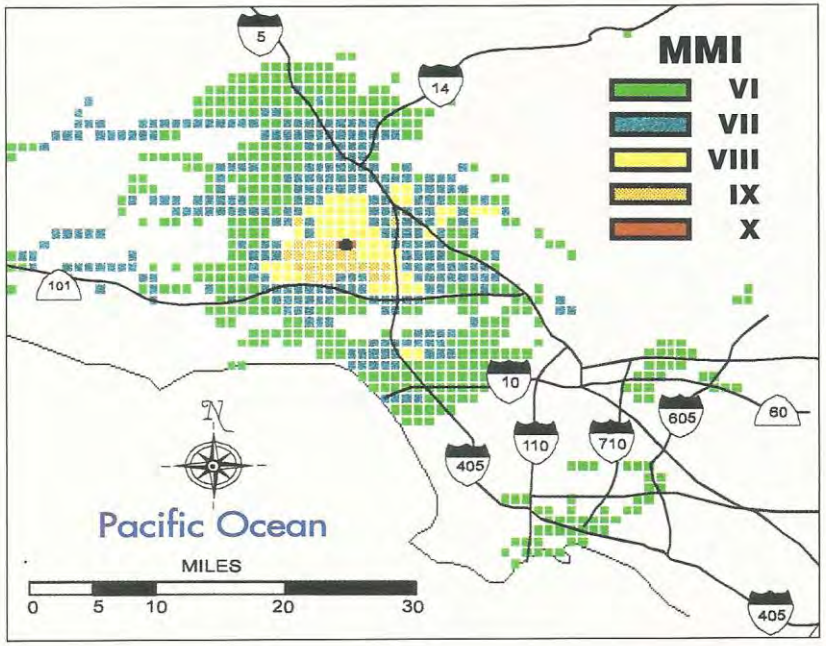
- Used by CA OES to define regional scope of the disaster during the critical 24-48 hours after the event
- Instrumental in approximating the locations of heaviest damage
- Used in briefing state agency executives, including the Governor
- Used in making decisions regarding shelter needs
- “Fast-tracking” the federal Disaster Housing Assistance Program



13) Preliminary estimates of Modified Mercalli Intensity for the Northridge, California earthquake of January 17, 1994. From Eguchi et al., p. 827.

EPEDAT - Early Post-Earthquake Damage Assessment Tool

- A total dollar loss estimate of $15B to $17B, generated within 24 hours of the earthquake, served as the basis for negotiation of a supplemental appropriation from Congress
- This total was further refined based on field reconnaissance to $15B to $30B
- A more comprehensive assessment of direct economic losses compiled three years after the event suggested that losses could be as high as $40B (Eguchi, et al., 1998, Spectra)



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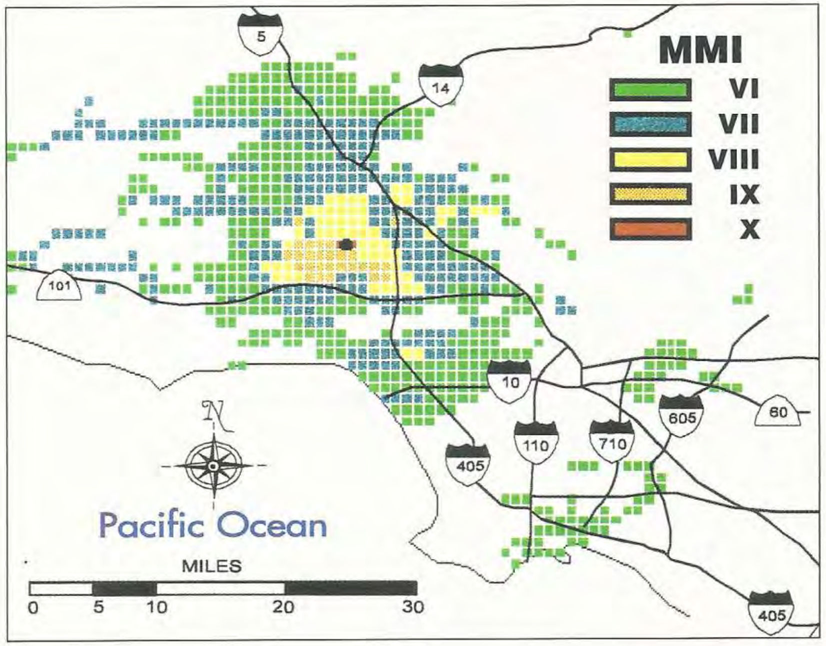
EPEDAT - Early Post-Earthquake Damage Assessment Tool

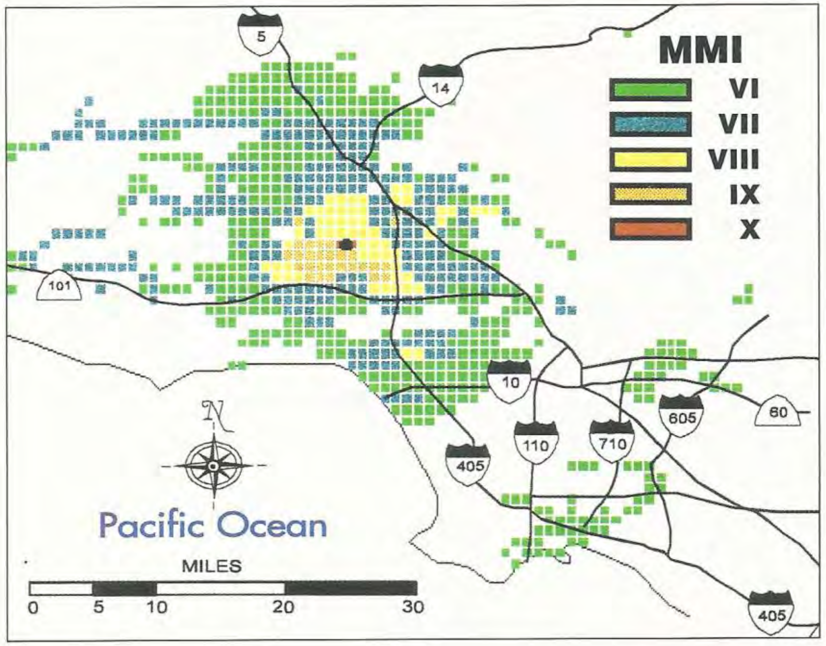
- EPEDAT and its use during the Northridge Earthquake paved the way to a series of important developments, including:
  - A recognition that network/sensor (e.g., CUBE) driven loss estimates can provide timely and accurate information for response and recovery
  - Investments in a National Standardized Loss Estimation Methodology, namely HAZUS
  - Tools that allow a regional assessment of mitigation priorities, OES/RAMP
  - A future role for loss estimation models to explore different rebuilding strategies after large disasters, following the PEPPER model (Pre-Earthquake Planning for Post-Earthquake Rebuilding, Spangle, 1986)



13) Preliminary estimates of Modified Mercalli Intensity for the Northridge, California earthquake of January 17, 1994. From Eguchi et al., p. 827.

EPEDAT - Early Post-Earthquake Damage Assessment Tool

- Key Players in the development of EPEDAT
  - Hope Seligson
  - Jim Goltz
  - Charlie Huyck
  - Neil Blais
  - Tom Heaton
  - Paul Flores
  - Ed Bortugno
  - Ken Campbell
  - Charlie Scawthorn
  - Dick Andrews
  - Ron Eguchi



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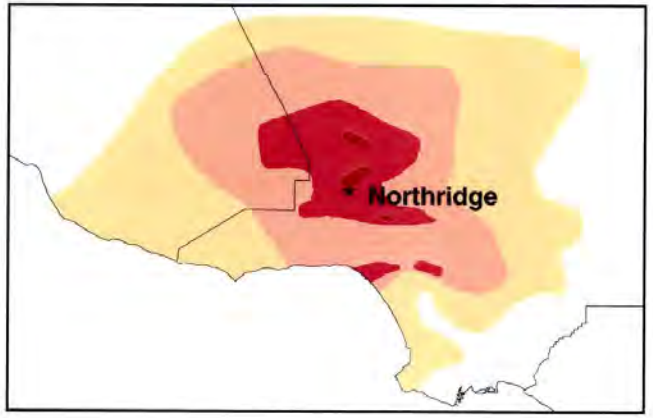
The Northridge Earthquake of January 17, 1994:
Report of Data Collection and Analysis

Part A: Damage and Inventory Data



Prepared by:

EQE International, Inc.
and
The Geographic Information Systems Group
of the Governor's Office of Emergency Services

for

The Governor's Office of Emergency Services
of the State of California

May 1995

The Northridge Earthquake of January 17, 1994:
Report of Data Collection and Analysis

Part B: Analysis and Trends

Prepared by:

EQE International, Inc.
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The Geographic Information Systems Group
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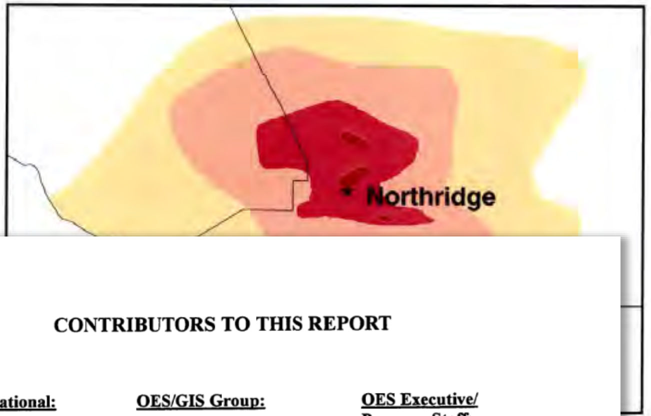
April 1997

The Northridge Earthquake of January 17, 1994: Report of Data Collection and Analysis

Part A: Damage and Inventory Data



CONTRIBUTORS TO THIS REPORT

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Ronald T. Eguchi	Pam Lane	
James D. Goltz	Kevin Miller	
Keith A. Porter	Andre Petrow	
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	Ken Wallace	
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The Northridge Earthquake of January 17, 1994: Report of Data Collection and Analysis

Part B: Analysis and Trends

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Charles K. Huyck	Jeannie Taylor	
Dewey Pham	Elizabeth Wojdak	
Hope A. Seligson		
Paul Thenhaus		
Solveig Thorvald		

Figure 2-19:

USGS Observed Modified Mercalli Intensity (MMI) Contours and Observation Points

Northridge Earthquake DR-1008

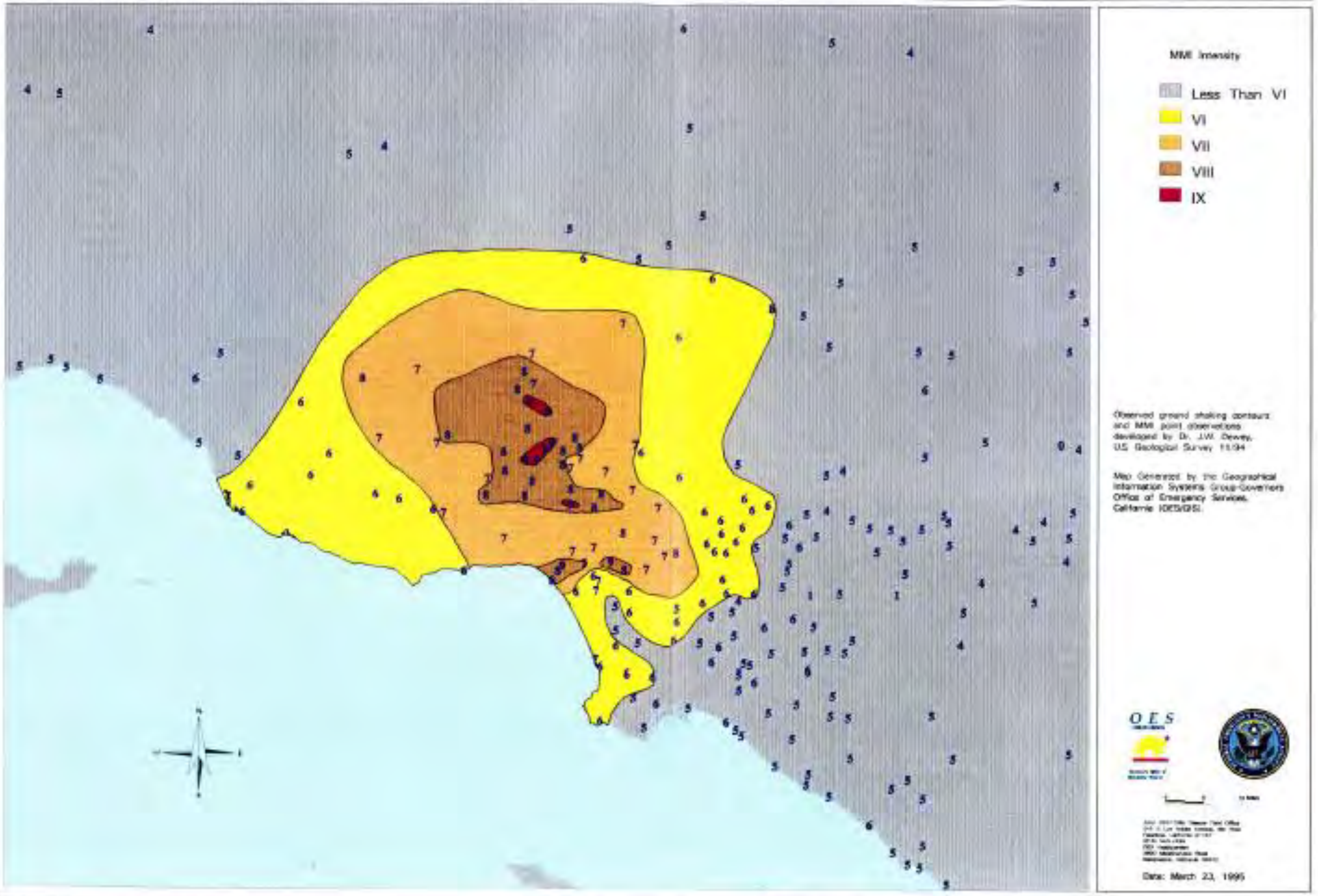


Table 3-3c
Number of Wood Frame Buildings in Los Angeles County Assessor's Database
by Intensity, Vintage, Use, and Square Feet

Soil Sites

Year Built	General Use	VI				VII				VIII				IX				<VI				Total
		<1600	1600-2500	>2500	N/A	<1600	1600-2500	>2500	N/A	<1600	1600-2500	>2500	N/A	<1600	1600-2500	>2500	N/A	<1600	1600-2500	>2500	N/A	
Pre 1941 and Null	Non Res				4,467				4,924				1,136				29				2,817	13,373
	Multi-Family	16,472	3,031	1,689		19,713	5,626	9,424		2,835	1,275	1,167		51	6	3		9,744	1,932	2,193		75,161
	Single-Family	90,732	19,419	6,355		56,686	20,519	11,031		18,359	6,587	2,305		431	144	22		34,583	5,616	1,409		274,198
1941-1950	Non Res				3,978				2,368				1,225				54				2,768	10,393
	Multi-Family	7,629	2,328	1,523		2,350	1,137	1,702		1,102	866	948		43	10	27		5,393	1,251	904		27,213
	Single-Family	83,604	19,635	3,369		27,160	7,767	2,426		25,532	6,693	1,374		808	198	50		71,329	9,891	994		260,830
1951-1960	Non Res				3,965				1,856				1,366				145				3,621	11,173
	Multi-Family	6,713	2,061	4,437		1,776	720	4,272		723	426	2,673		44	23	150		5,028	1,643	2,535		33,224
	Single-Family	62,002	24,271	4,429		19,387	7,886	2,545		43,313	19,995	2,458		3,685	2,534	371		138,721	32,663	2,446		366,706
1961-1976	Non Res				2,744				1,643				1,027				72				3,300	8,786
	Multi-Family	2,492	1,543	7,319		828	493	5,516		265	156	4,571		10	4	245		2,244	1,458	6,127		33,271
	Single-Family	13,364	18,491	4,597		8,056	7,342	1,776		8,063	16,517	5,068		300	1,243	623		37,862	31,370	4,404		159,076
Post 1976	Non Res				2,325				1,370				670				59				2,356	6,980
	Multi-Family	1,012	1,242	6,645		878	717	5,664		191	248	3,814		8	4	256		1,098	1,167	6,402		29,346
	Single-Family	11,851	11,266	6,880		5,154	6,022	2,790		3,579	7,092	5,817		50	242	340		21,893	24,895	6,607		114,478
Total		295,871	103,287	47,243	17,499	141,988	58,229	47,146	12,161	103,962	59,855	30,195	5,624	5,430	4,408	2,087	359	327,895	111,886	34,021	15,062	1,424,208

Single-Family Includes Modular Dwellings. SFD Does Not Include Condominiums, Condominium Conversions, or Mobile Homes.
Multi-Family Includes Condominiums (Use Code 01*C), and Condominium Conversions (Use Code 01*E).

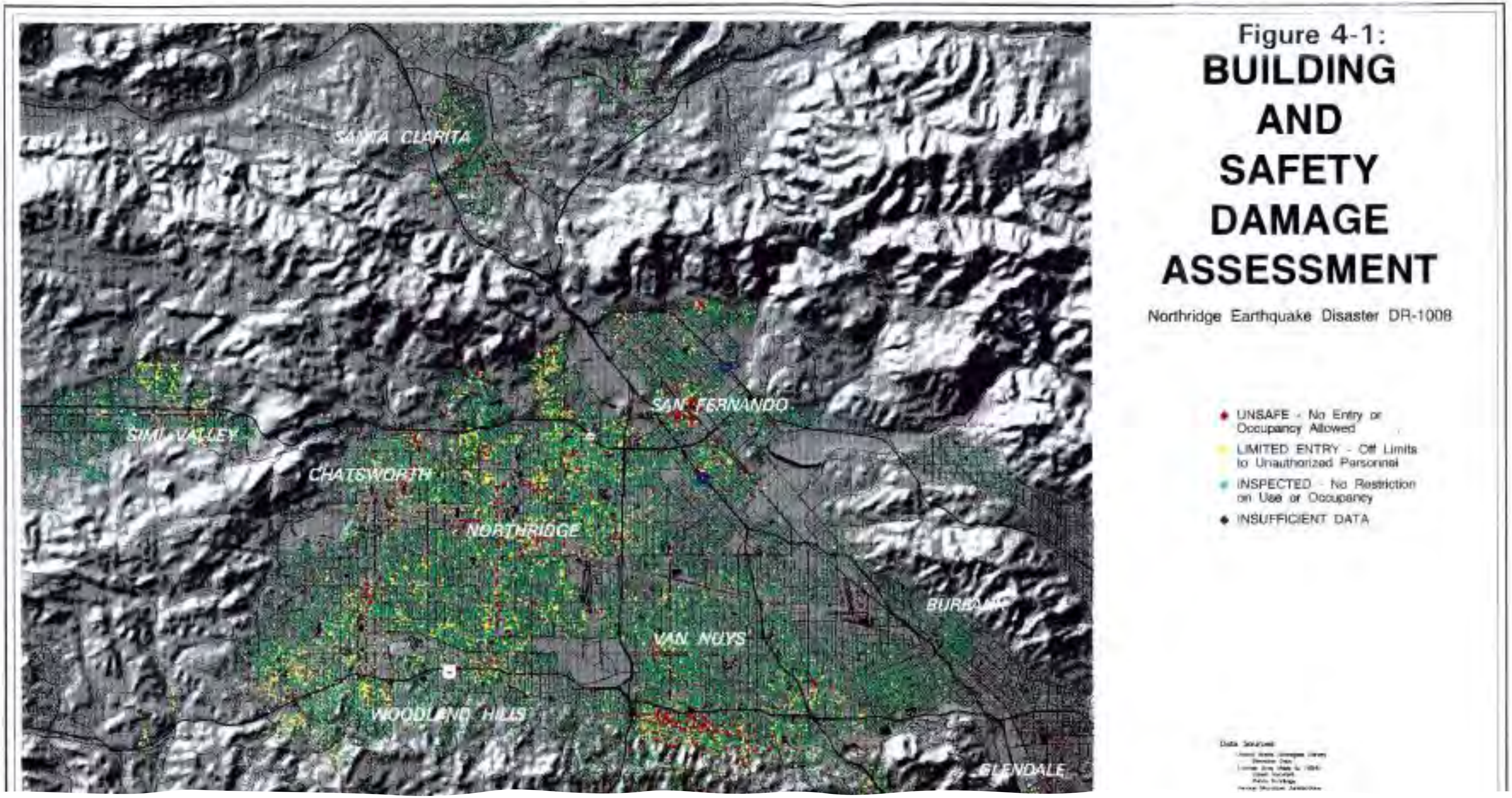


Figure 4-1:
BUILDING AND SAFETY DAMAGE ASSESSMENT

Northridge Earthquake Disaster DR-1008

Table 4-2: Building and Safety Damage Data by Jurisdiction

Los Angeles County													
Jurisdiction	Total Buildings Inspected	Residential				Commercial / Industrial				Other Building Usage			
		Red	Yellow	Green	Unknown	Red	Yellow	Green	Unknown	Red	Yellow	Green	Unknown
Agoura Hills	194	0	1	100	20	0	0	3	0	0	0	5	65
Alhambra	340	3	4	67	148	0	1	14	5	2	3	9	84
Arcadia	40	0	0	0	29	0	0	0	6	0	0	0	5
Azusa	1	-	-	-	-	-	-	-	-	0	0	0	1
Bellflower	13	-	-	-	-	-	-	-	-	3	0	0	10
Beverly Hills	1,239	21	53	583	345	9	7	78	21	3	26	52	41
Burbank	2,145	3	7	74	102	0	0	5	0	33	90	986	845
Calabasas	1,017	-	-	-	-	-	-	-	-	4	315	686	12
Commerce	7	-	-	-	-	-	-	-	-	1	0	0	6
Compton	17	0	0	0	11	0	0	0	1	0	0	0	5
Culver City	704	15	12	1	581	12	3	1	66	0	0	0	13
Downey	3	-	-	-	-	0	0	2	0	0	0	1	0
Glendale	2,341	17	9	346	699	14	2	54	53	6	2	720	419
Hermosa Beach	15	0	0	8	1	0	0	5	0	0	0	1	0
Hidden Hills	94	1	47	38	6	-	-	-	-	0	2	0	0
Huntington Park	6	-	-	-	-	-	-	-	-	-	-	-	6
Inglewood	56	-	-	-	-	-	-	-	-	-	-	-	56
La Canada/Flintridge	39	-	-	-	-	-	-	-	-	-	-	-	39
LA County	948	28	85	689	0	18	16	98	0	3	2	9	0
La Habra Heights	4	0	0	4	0	-	-	-	-	-	-	-	-
La Mirada	25	0	0	0	15	0	0	0	7	0	0	0	3
Lakewood	25	0	0	12	13	-	-	-	-	-	-	-	-
Los Angeles	85,997	1,604	7,715	70,035	272	445	1,105	4,738	8	9	21	41	4
Manhattan Beach	300	-	-	-	-	-	-	-	-	5	254	26	15
Maywood	4	-	-	-	-	-	-	-	-	0	0	0	4
Montebello	9	-	-	-	-	-	-	-	-	0	0	0	9
Norwalk	7	-	-	-	-	-	-	-	-	0	0	0	7
Paramount	6	0	0	0	3	-	-	-	-	0	0	0	3
Pasadena	260	5	13	72	88	5	3	15	46	1	1	9	2
San Fernando	1,603	27	117	1,184	0	12	28	101	0	108	1	25	0
San Marino	9	0	0	5	3	0	1	0	0	-	-	-	-
Santa Clarita	4,939	83	184	4,134	137	38	37	272	7	3	5	37	2
Santa Monica	2,101	67	239	1,452	4	29	57	110	2	11	20	98	12
South Gate	51	0	0	16	1	1	1	21	2	1	0	6	2
South Pasadena	4	-	-	-	-	-	-	-	-	0	0	0	4
Torrance	7	0	0	2	0	0	0	2	0	0	0	2	1
Vernon	11	-	-	-	-	2	1	7	0	0	0	1	0
West Hollywood	253	4	8	16	203	0	1	0	21	-	-	-	-
Whittier	185	0	1	145	6	1	4	19	1	0	1	7	0
Total LA County	**105,019**	**1,878**	**8,495**	**78,983**	**2,687**	**586**	**1,267**	**5,545**	**246**	**193**	**743**	**2,721**	**1,675**
		Total Residential			**92,043**	**Total Commercial/Industrial**			**7,644**	**Total Other**			**5,332**

Table 4-7c
Number of Wood Frame Buildings in Damage Database by Intensity, Vintage, Use, and Square Feet

Soil Sites

Year Built	General Use	VI				VII				VIII				IX				<VI				Total
		<1600	1600-2500	>2500	N/A	<1600	1600-2500	>2500	N/A	<1600	1600-2500	>2500	N/A	<1600	1600-2500	>2500	N/A	<1600	1600-2500	>2500	N/A	
Pre 1941 and Null	Non Res	12	11	34		41	26	152		56	38	138	1	4	2	9				2		526
	Multi-Family	217	86	169		1,008	459	1,759	27	632	339	466	9	32	4	1		4		9		5,221
	Single-Family	1,441	295	45	2	3,630	1,912	923	4	3,494	987	308	4	135	44	3		19	2	3		13,251
1941-1950	Non Res	6	4	26		22	9	52		64	37	117		5	3	15		1		1		362
	Multi-Family	41	11	42		103	53	181		212	110	251		25	4	19		2		1		1,055
	Single-Family	265	77	5		936	353	92		3,493	1,009	210		188	51	21		10	2			6,712
1951-1960	Non Res	5	4	20		18	14	50		39	28	197		5	10	32		1	1			424
	Multi-Family	23	15	248	3	59	50	762	5	117	82	1,103	2	14	3	132				5		2,623
	Single-Family	123	95	21		844	410	61		7,443	4,201	469	1	1,281	1,058	158		13	1			16,179
1961-1976	Non Res	2		14		7	9	58		13	18	203	1		3	24			2	2		354
	Multi-Family	64	16	238	1	203	54	1,265	4	603	160	2,336	4	70	15	203			1	9		5,246
	Single-Family	19	27	3		325	693	127		1,025	5,057	1,693	1	105	553	267			1			9,896
Post 1976	Non Res		3	9		7	2	49		8	10	210		2	1	24				1		326
	Multi-Family	57	34	64		507	196	686	6	1,000	450	1,059	1	97	39	114		6	2	8		4,326
	Single-Family	11	20	65		93	209	122		340	1,816	1,710	1	25	126	194			1			4,733
Total		2,286	698	1,003	6	7,803	4,449	6,337	46	18,539	14,342	10,470	25	1,988	1,916	1,216	0	56	13	41	0	71,234

Single-Family Includes Modular Dwellings. SFD Does Not Include Condominiums, Condominium Conversions, or Mobile Homes.
Multi-Family Includes Condominiums (Use Code 01*C), and Condominium Conversions (Use Code 01*E).

Table 4-15c
Number of Buildings in Damage Ranges -- Single-Family Wood Frame Dwellings by Intensity, Vintage, and Square Foot Range

Soil Sites

		VI			VII			VIII			IX			<VI			
			1600-			1600-			1600-			1600-			1600-		
Year Built	**Damage Range**	<1600	2500	>2500	<1600	2500	>2500	<1600	2500	>2500	<1600	2500	>2500	<1600	2500	>2500	Total
Pre 1941 and Null	.05-.3	39	7	3	64	37	48	55	27	11	2	1		1			295
	.3-1.25	143	58	7	418	326	224	312	149	62	6	3		2		1	1,711
	1.25-3.5	231	53	13	599	487	241	556	216	65	15	10	1				2,487
	3.5-7.5	259	42	6	611	379	144	489	193	71	27	10	1	2			2,234
	7.5-20	287	37	2	1,056	262	27	892	176	40	46	11		3	1		2,840
	20-65	43	3		213	29	9	271	28	10	26	4	1				637
	65-100	9			50	8	4	104	20	10	4	3					212
	N/A	432	95	14	623	384	226	819	178	39	9	2		11	1	2	2,835
	Total	**1,443**	**295**	**45**	**3,634**	**1,912**	**923**	**3,498**	**987**	**308**	**135**	**44**	**3**	**19**	**2**	**3**	**13,251**
1941-1950	.05-.3	7	4	1	36	16	5	73	29	12	2						185
	.3-1.25	44	11		151	86	31	425	143	31	24	8	2	1			957
	1.25-3.5	44	11	1	192	69	14	671	229	35	38	6	4				1,314
	3.5-7.5	32	10		109	49	9	630	207	47	40	17	6				1,156
	7.5-20	18	1		124	28	2	739	191	38	47	10	5				1,203
	20-65	1			25	5	1	156	34	17	14	3	2	1			259
	65-100	1			3			21	6	3		2	2				38
	N/A	118	40	3	296	100	30	778	170	27	23	5		8	2		1,600
	Total	**265**	**77**	**5**	**936**	**363**	**92**	**3,493**	**1,009**	**210**	**188**	**51**	**21**	**10**	**2**		**6,712**
1951-1960	.05-.3	5	6	3	42	25	5	195	109	28	20	15					453
	.3-1.25	19	16	5	137	91	10	1,004	649	79	185	145	16	2			2,358
	1.25-3.5	15	18	4	152	77	13	1,431	939	104	245	252	29	1			3,280
	3.5-7.5	10	9	2	110	50	2	1,362	928	95	275	234	44				3,121
	7.5-20	7	3		108	28		1,777	802	92	343	270	36	1			3,467
	20-65	2			7	1		302	152	24	86	45	16				635
	65-100				5	3		42	23	9	11	10	4				107
	N/A	65	43	7	283	135	31	1,331	599	38	116	87	13	9	1		2,758
	Total	**123**	**95**	**21**	**844**	**410**	**61**	**7,444**	**4,201**	**469**	**1,281**	**1,058**	**158**	**13**	**1**		**16,179**

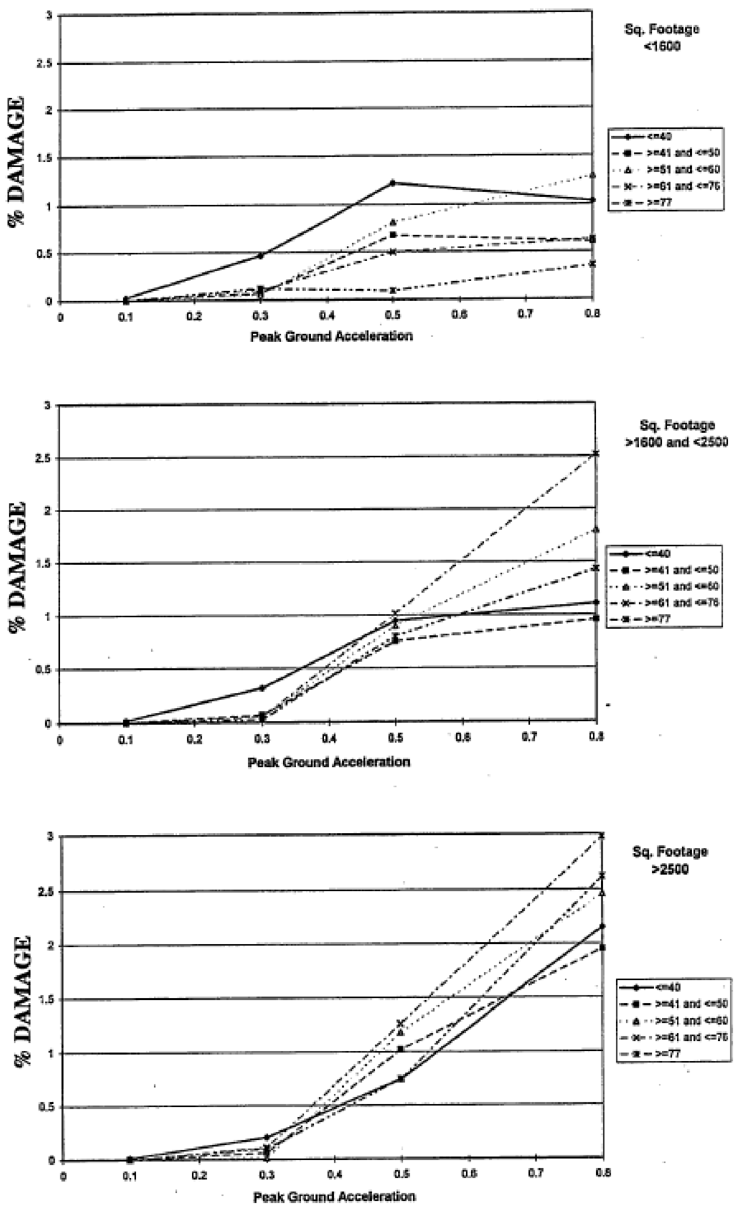
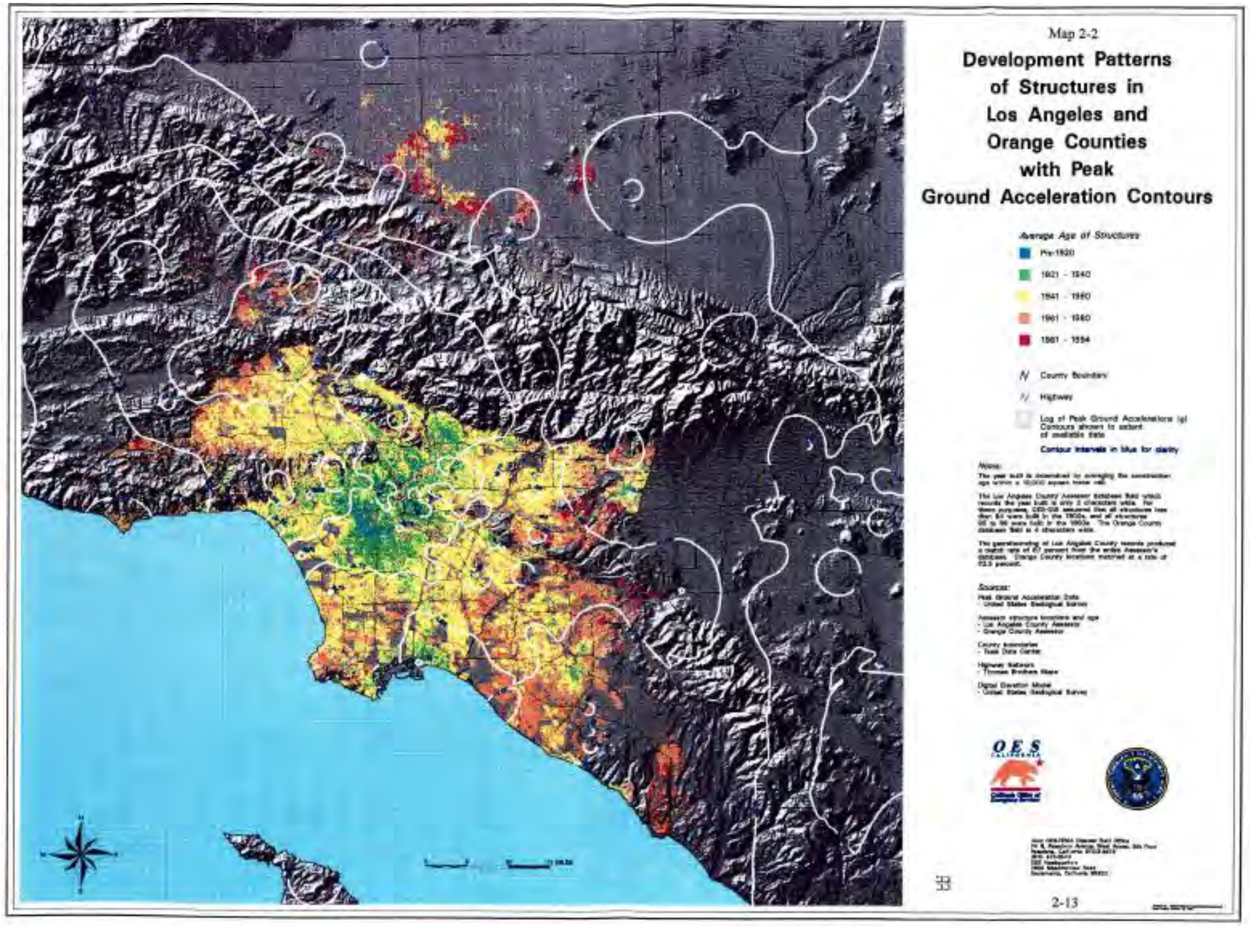
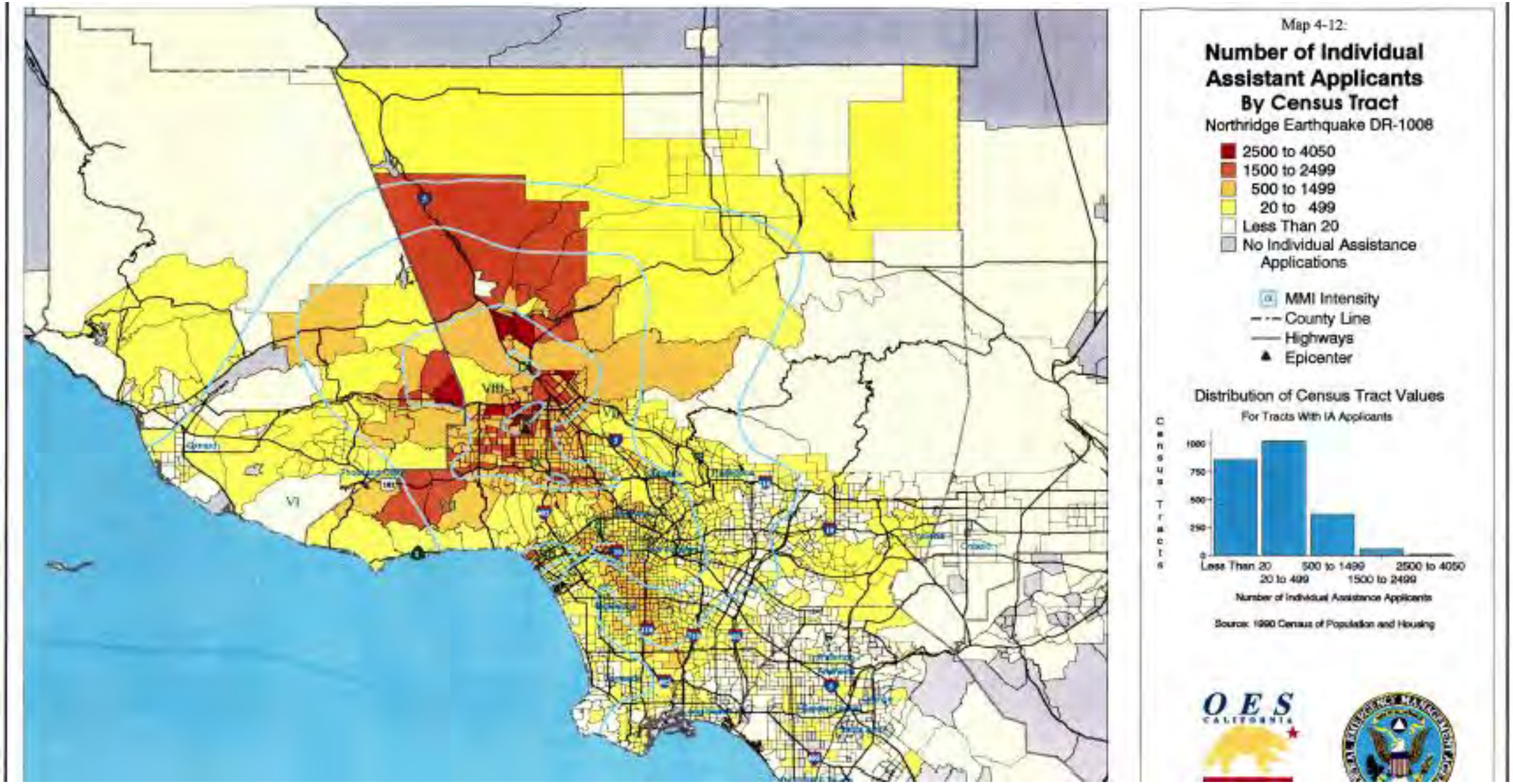
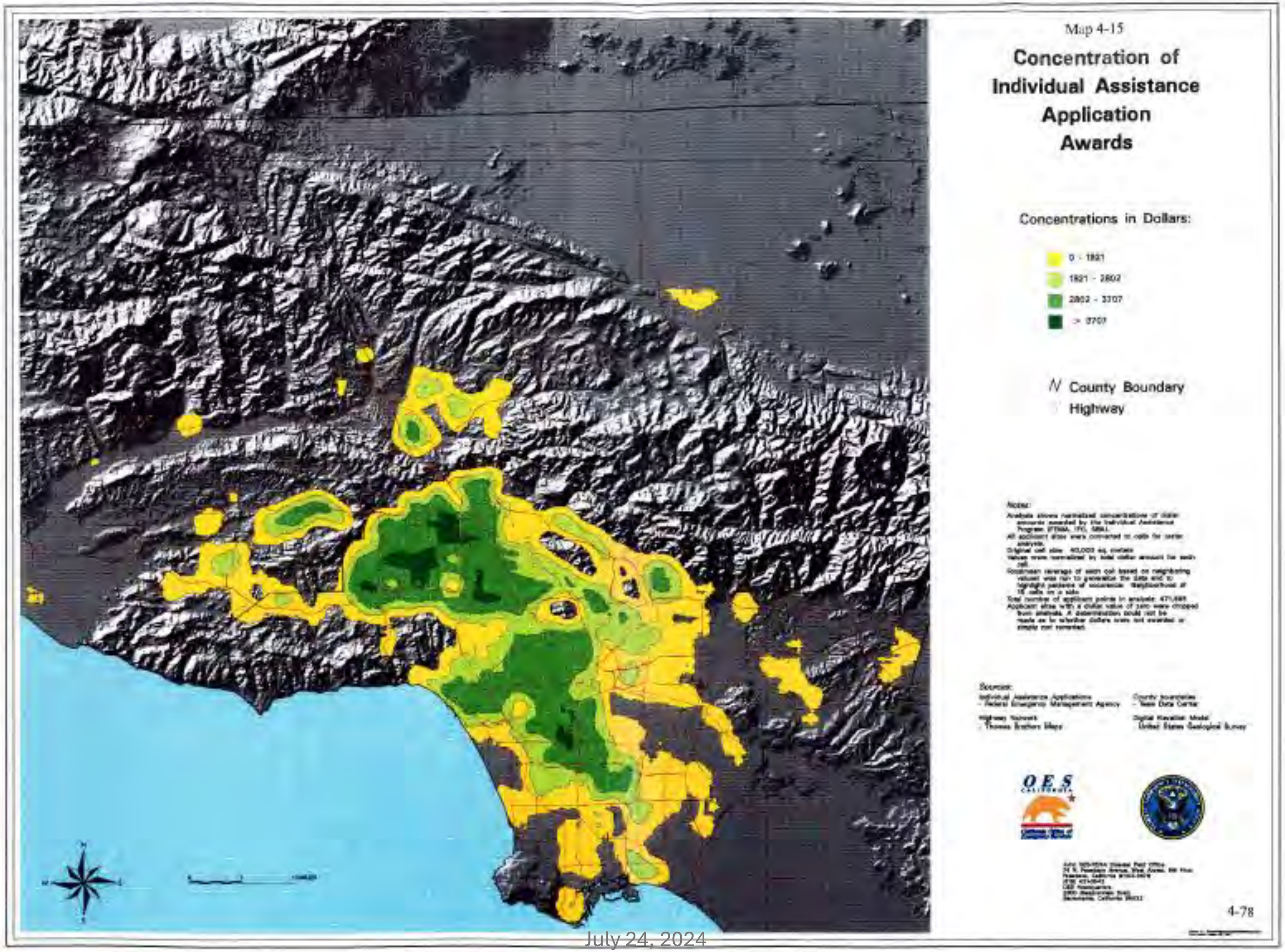


Figure 6-7: Plot of Damage Factors In Terms of Percent Replacement Cost as a Function of Peak Ground Acceleration, Square Footage and Year of Construction




Map 4-12:
Number of Individual Assistant Applicants By Census Tract
Northridge Earthquake DR-1008
2500 to 4050
1500 to 2499
500 to 1499
20 to 499
Less Than 20
No Individual Assistance Applications
MMI Intensity
County Line
Highways
Epicenter
Distribution of Census Tract Values
For Tracts With IA Applicants
Census Tracts
Less Than 20
20 to 499
500 to 1499
1500 to 2499
2500 to 4050
Number of Individual Assistance Applicants
Source: 1990 Census of Population and Housing
OES CALIFORNIA


Map 4-15
Concentration of Individual Assistance Application Awards
Concentrations in Dollars:
0 - 1921
1921 - 2802
2802 - 3707
> 3707
County Boundary
Highway
Notes:
Sources:
4-78

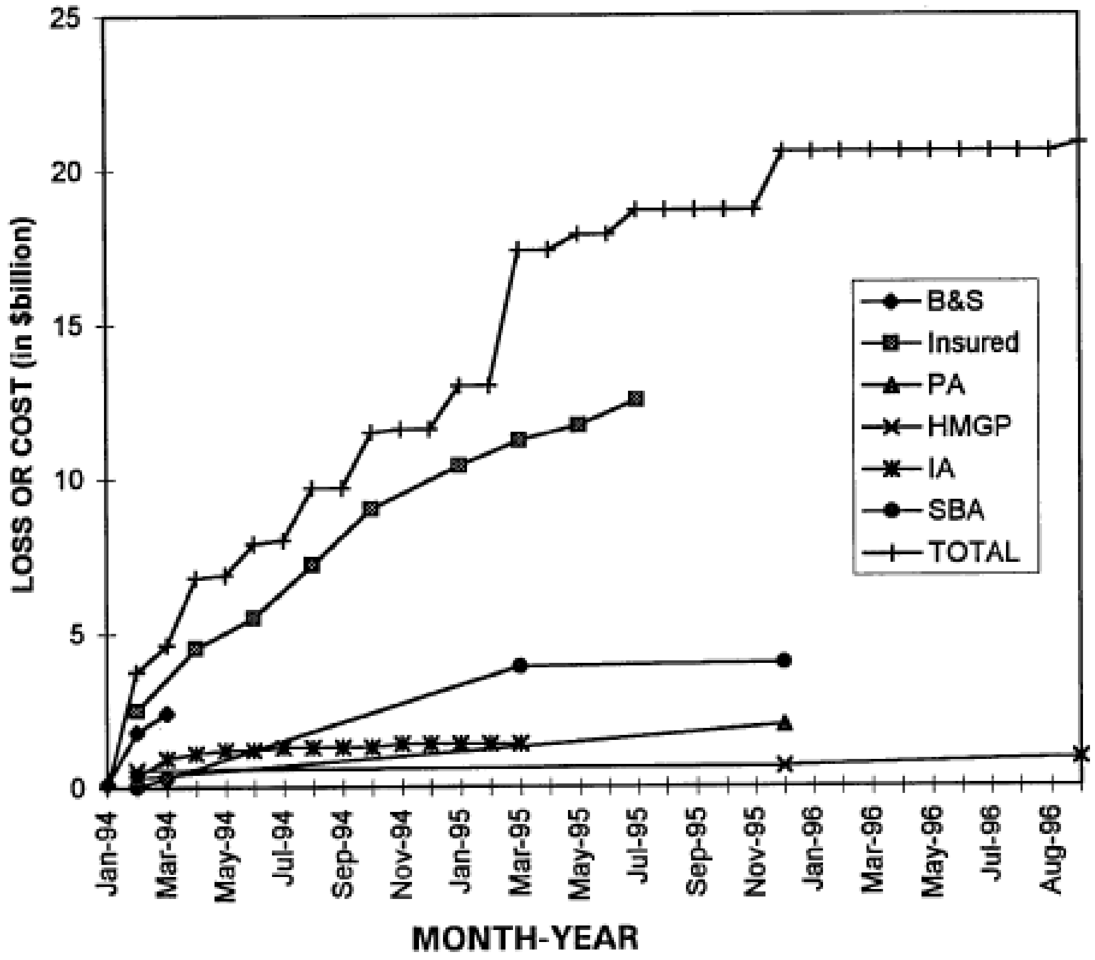


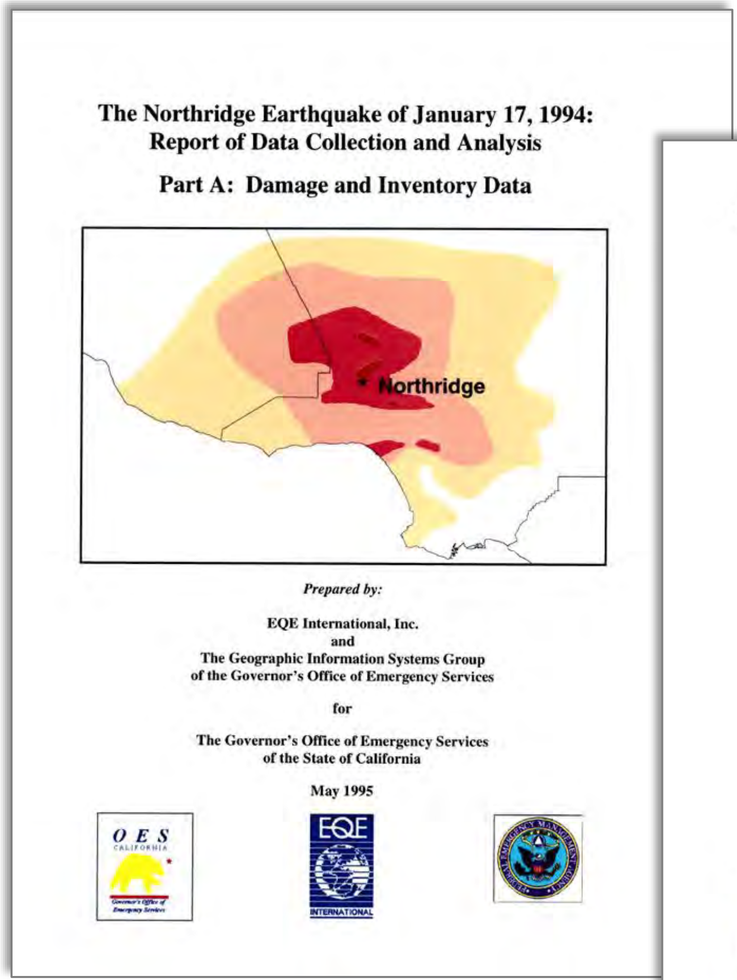
Figure 3-1: Loss or Cost Totals with Time

rte@imagecatinc.com

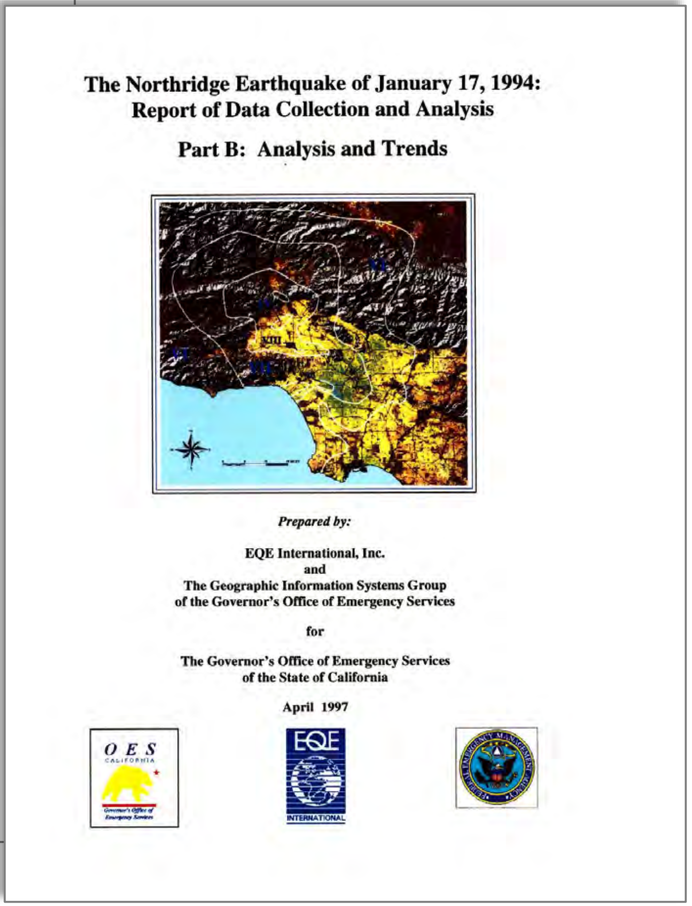
GIS Applications …

- EQE & OES/GIS groups contributed to the following response activities after the Northridge Earthquake:
  - Summarizing seismotectonic and ground motion data
  - Collection of building inventory data
  - Collection of building damage data
  - Generating building damage trend curves
  - Estimating direct capital losses
  - Analyzing Individual Assistance data
  - Analyzing shelter data
  - Producing GIS maps for public and executive use

https://www.imagecatinc.com/reference/NR_EQ_Report_Part_A.pdf
https://www.imagecatinc.com/reference/NR_EQ_Report_Part_B.pdf


The Northridge Earthquake of January 17, 1994:
Report of Data Collection and Analysis
Part A: Damage and Inventory Data

Prepared by:
EQE International, Inc.
and
The Geographic Information Systems Group
of the Governor's Office of Emergency Services
for
The Governor's Office of Emergency Services
of the State of California
May 1995


The Northridge Earthquake of January 17, 1994:
Report of Data Collection and Analysis
Part B: Analysis and Trends

Prepared by:
EQE International, Inc.
and
The Geographic Information Systems Group
of the Governor's Office of Emergency Services
for
The Governor's Office of Emergency Services
of the State of California
April 1997

Episode 4 of the Northridge 30th Anniversary Webinar Series:
The Northridge Earthquake – 30 Years Later – A Catalyst for Engineering Resilient Communities

The Northridge Earthquake: An Unexpected Milestone in Real-Time Loss Estimation

David Wald, Ph.D.

Coordinator
Real-time Earthquake Information Products
Golden, Colorado
wald@usgs.gov

For K. Allstadt, M. Hearne, K. Jaiswal, K. Lin,
K. Marano, E. Thompson, B. Worden, & others!

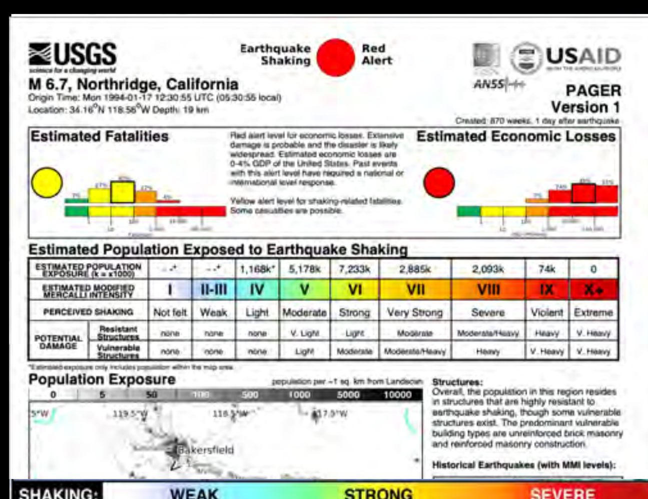
July 24, 2024

USGS

NORTHRIDGE 30
1994 – 2024

Episode 4 of the Northridge 30th Anniversary Webinar Series:
The Northridge Earthquake – 30 Years Later – A Catalyst for Engineering Resilient Communities

The Northridge Earthquake: An Unexpected Milestone in Real-Time Loss Estimation



ESTIMATED POPULATION EXPOSURE (k = x1000)		--*	--*	1,168k*	5,178k	7,233k	2,885k	2,093k	74k	0
ESTIMATED MODIFIED MERCALLI INTENSITY		I	II-III	IV	V	VI	VII	VIII	IX	X+
PERCEIVED SHAKING		Not felt	Weak	Light	Moderate	Strong	Very Strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	Resistant Structures	none	none	none	V. Light	Light	Moderate	Moderate/Heavy	Heavy	V. Heavy
	Vulnerable Structures	none	none	none	Light	Moderate	Moderate/Heavy	Heavy	V. Heavy	V. Heavy

USGS

NORTHRIDGE 30
1994 – 2024

The Southern California Network Bulletin: 1990-1993 Summary

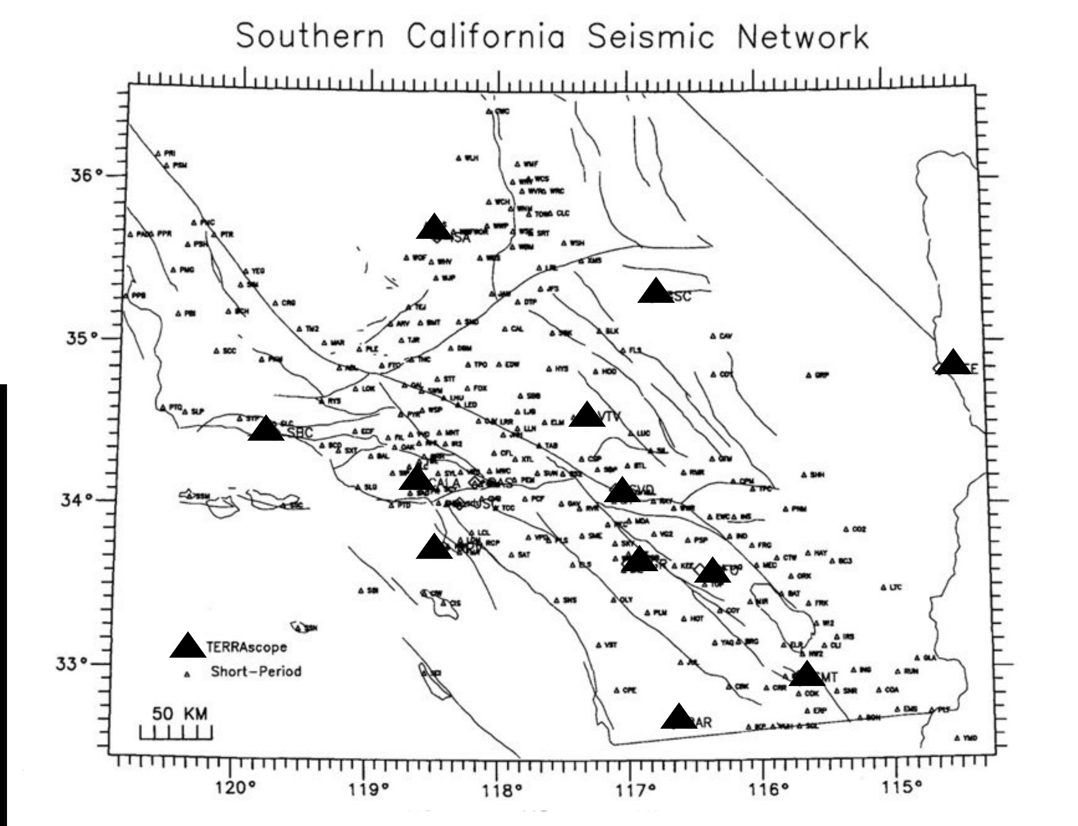
Lisa A. Wald
U.S. Geological Survey

L. Katherine Hutton
U.S. Geological Survey

Douglas D. Given
California Institute of Technology

1993

USGS



Southern California Seismic Network: Caltech/USGS Element of TriNet 1997–2001

Egill Hauksson, Patrick Small, Katrin Hafner, Robert Busby, Robert Clayton, James Goltz, Tom Heaton, Kate Hutton, Hiroo Kanamori, Jascha Polet
Seismological Laboratory, California Institute of Technology

2002

Doug Given, Lucile M. Jones, and David Wald
U.S. Geological Survey, Pasadena, California

INTRODUCTION

The California Institute of Technology (Caltech), the United States Geological Survey (USGS), and the California Department of Conservation, Division of Mines and Geology (CDMG) are completing the implementation of TriNet, a modern seismic information system for southern California. TriNet consists of two elements, the Caltech-USGS element and the CDMG element (Mori *et al.*, 1998). The Caltech-USGS element (Caltech-USGS TriNet) concentrates on rapid notification and archiving of data for seismological applications, while the CDMG element is focused on the needs of engineering users (Hauksson *et al.*, 2002). All three TriNet agencies are working toward facilitating emergency response and long-term mitigation of earthquake hazards in cooperation with other agencies. The technical development of Caltech-USGS TriNet is sufficiently different from the CDMG element of TriNet to warrant a separate description.

This paper provides a technical overview of the design

data. Real-time communication is a requirement to facilitate rapid processing and notification about seismicity for emergency management. The data acquisition systems are designed to ensure redundancy and automated processing of data. To accomplish automation, high-speed computers and advanced software form the inner workings of the Caltech-USGS TriNet system. Adopting the commercial database *Oracle* is an important foundation of our data management system. The automated flow of data into an accessible data center and the automatic population of the database is part of our new seismic network design and is an essential feature of Caltech-USGS TriNet. The TriNet real-time systems and database have been operating online for more than two years, processing real-time data currently from more than 375 stations, or more than 1,200 high sample-rate data channels. Many of these capabilities were tested in the 1999 M_w 7.1 Hector Mine earthquake. New postprocessing and catalog-generation approaches have also been implemented in 2001.

Caltech-USGS TriNet is one of the first U.S. regional

TERRAscope

Caltech's TERRAscope project began in **1988** and initially had six very broadband seismic stations (PAS, GSC, PFO, SBC, ISA, and SVD) in southern California. TERRAscope's goals were to provide high-quality broadband data needed for significant advances in both regional & global seismology & to replace the old Caltech seismographic network, which dated back to the 1920s. Data were available within 30 minutes after a regional event and several hours after a global earthquakes.

TriNET

The Caltech-USGS element concentrated on rapid notification & archiving of data for seismological applications with short-period & broadband seismic stations, while the CDMG focused on engineering uses with strong-motion instruments. The goal was to record small & large earthquakes on scale.

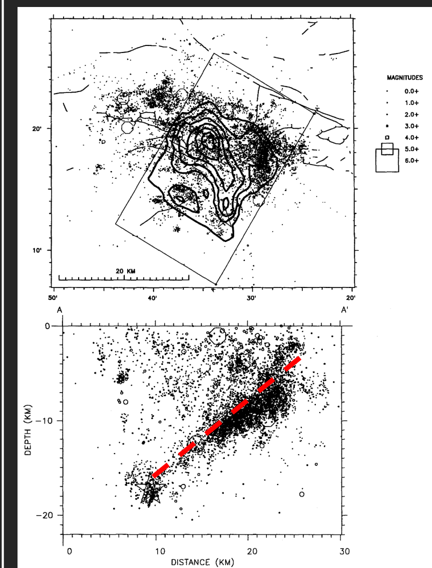
Caltech USGS CDMG

USGS

1995

The Slip History of the 1994 Northridge, California, Earthquake Determined from Strong-Motion, Teleseismic, GPS, and Leveling Data

by David J. Wald, Thomas H. Heaton,* and K. W. Hudnut



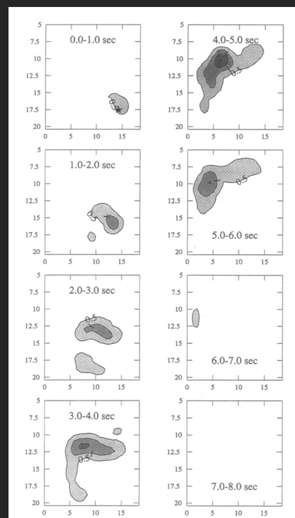
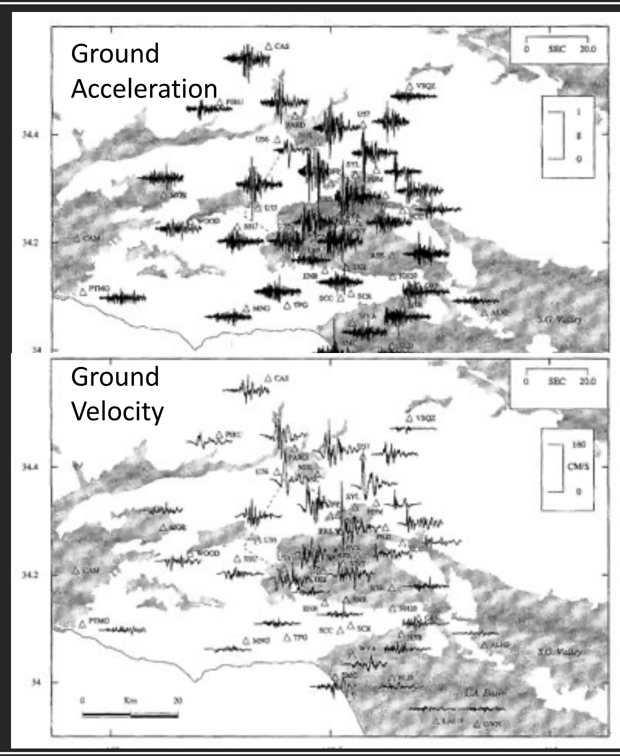


Figure 16. Time progression of the combined rupture model given at intervals of 1 sec as labeled. The contour interval is 0.5 m.



1995

The Slip History of the 1994 Northridge, California, Earthquake Determined from Strong-Motion, Teleseismic, GPS, and Leveling Data

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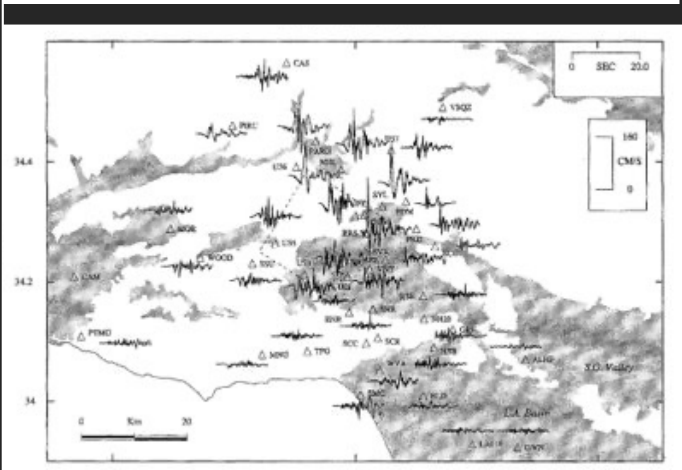
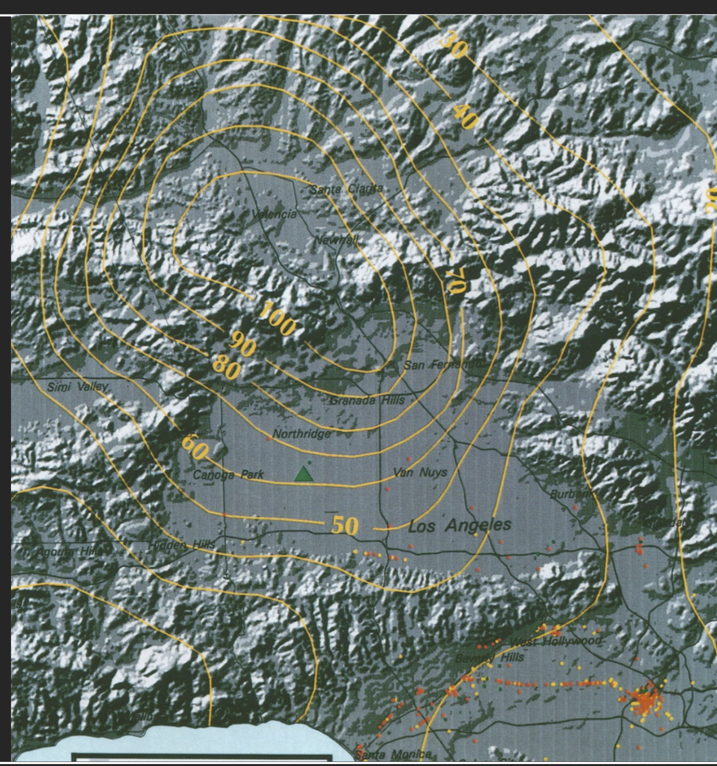
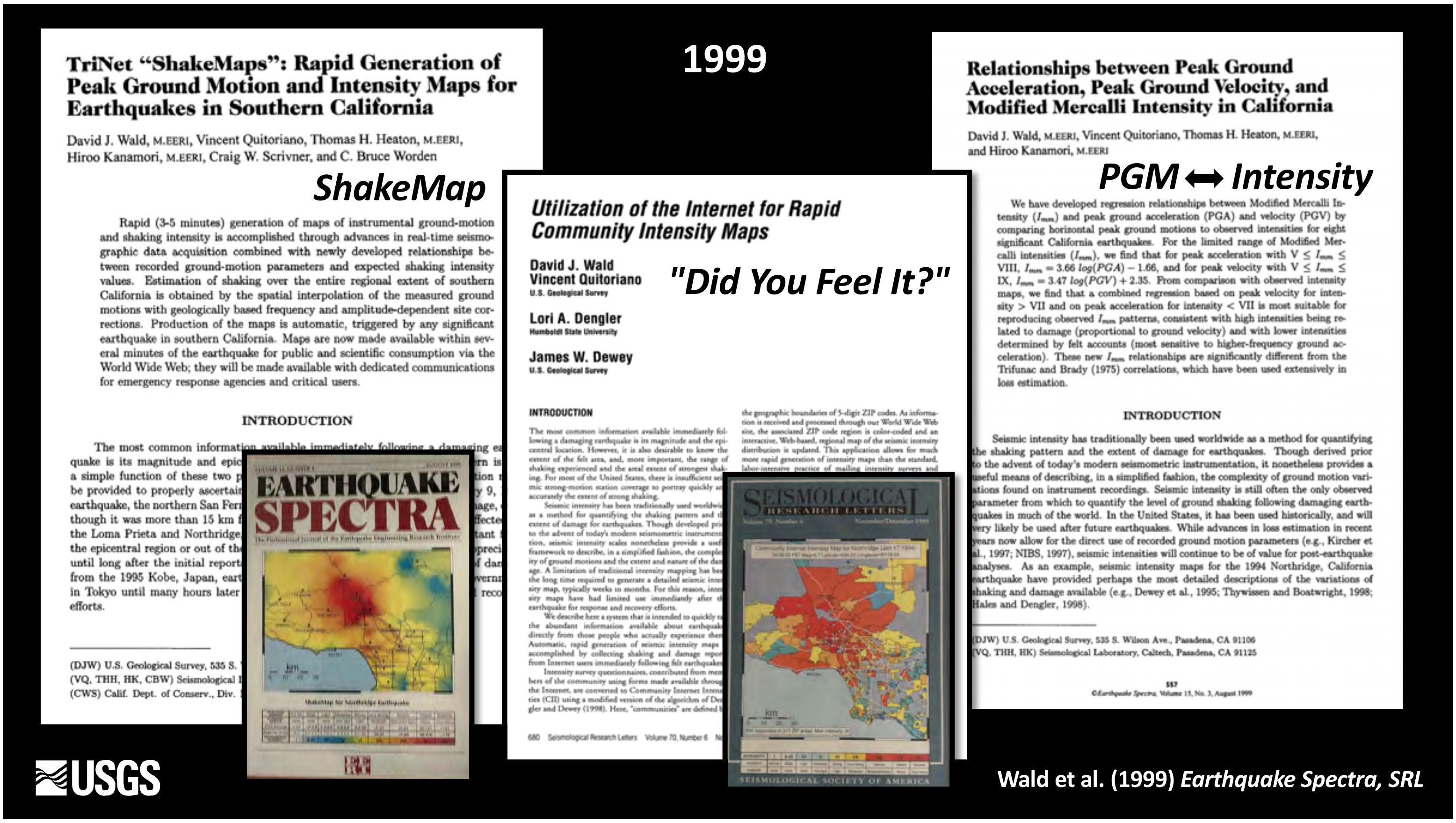
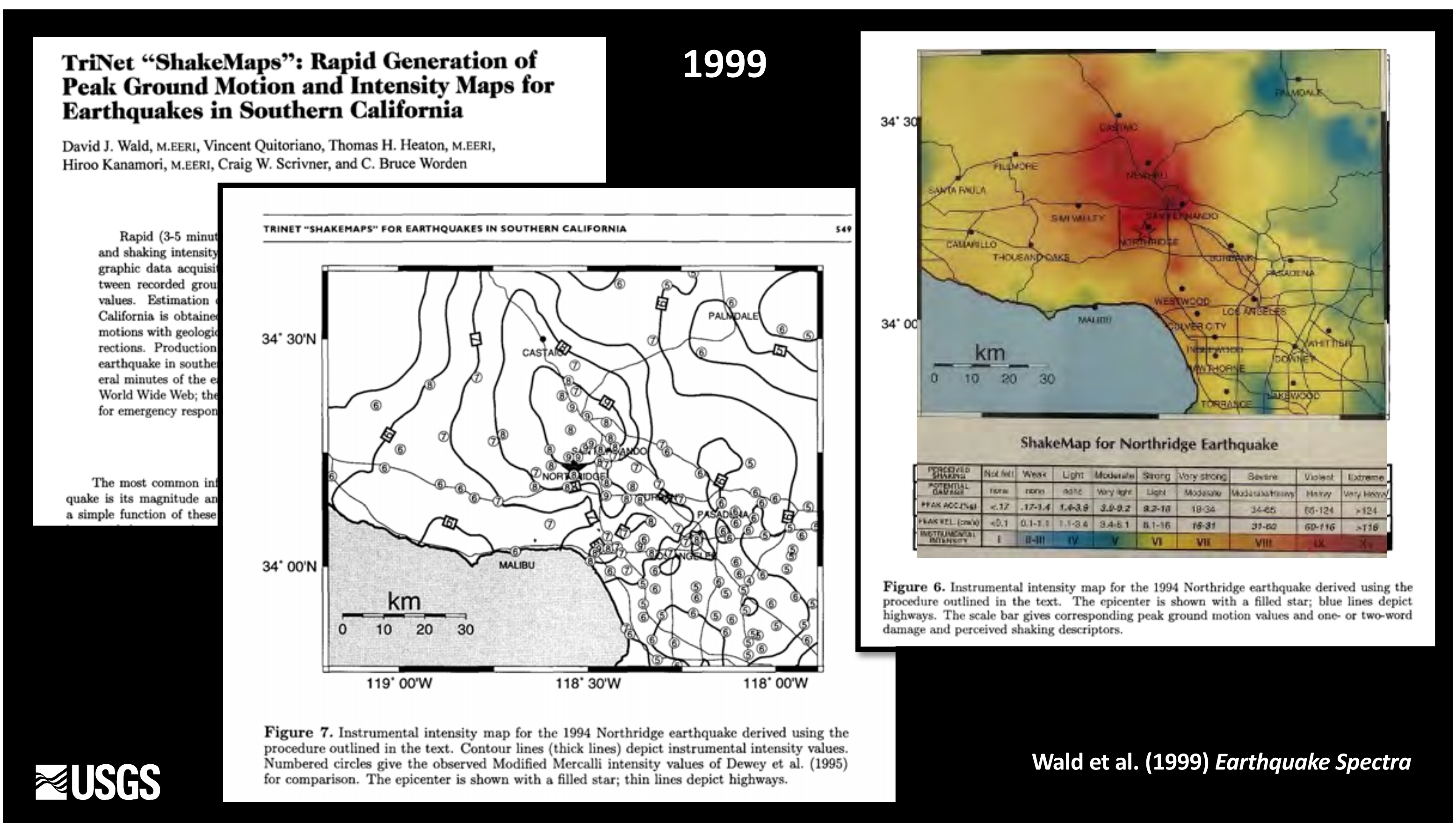


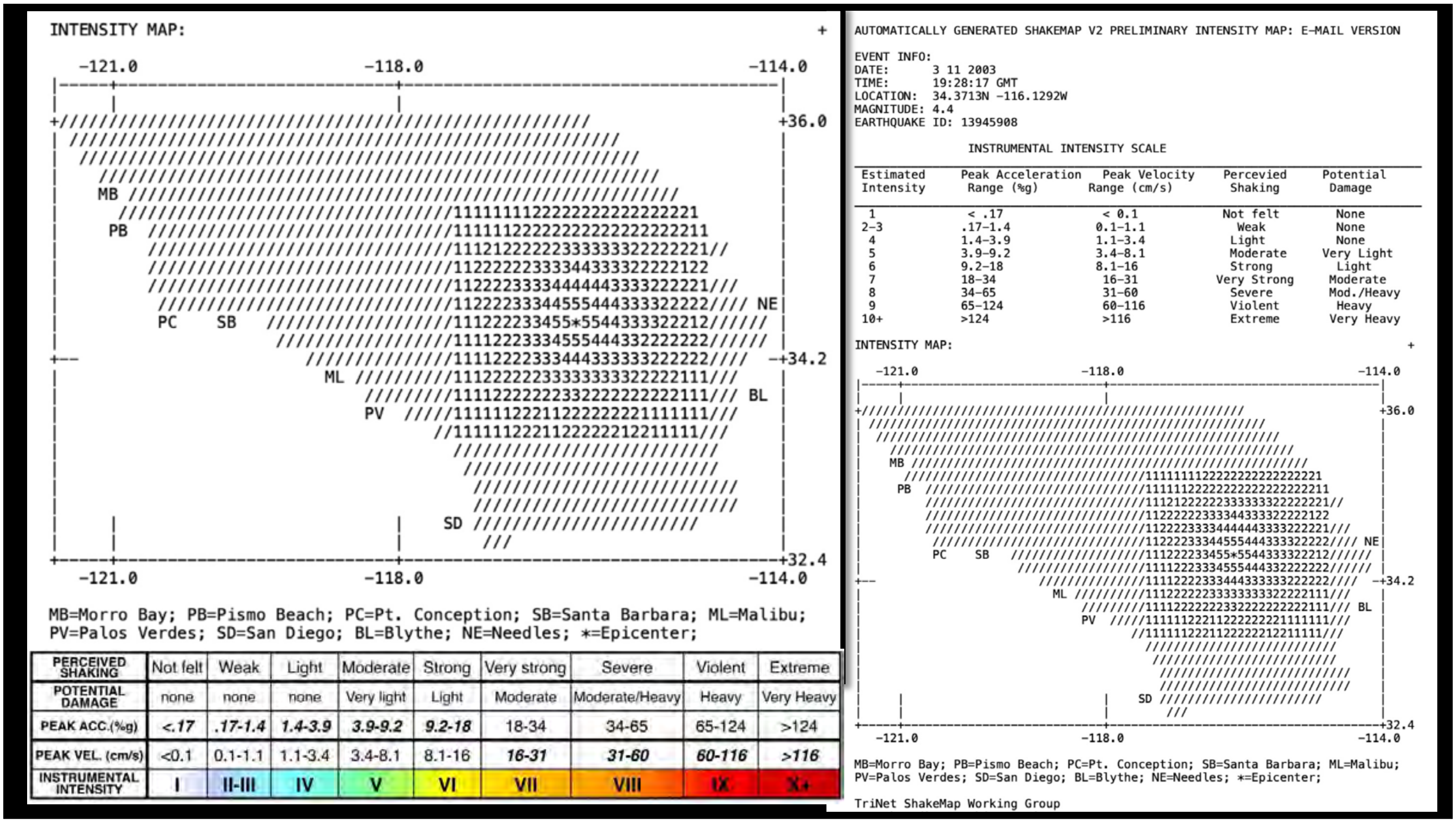



1999
TriNet "ShakeMaps": Rapid Generation of Peak Ground Motion and Intensity Maps for Earthquakes in Southern California
David J. Wald, M.EERI, Vincent Quitoriano, Thomas H. Heaton, M.EERI, Hiroo Kanamori, M.EERI, Craig W. Scrivner, and C. Bruce Worden
ShakeMap
Rapid (3-5 minutes) generation of maps of instrumental ground-motion and shaking intensity is accomplished through advances in real-time seismographic data acquisition combined with newly developed relationships between recorded ground-motion parameters and expected shaking intensity values. Estimation of shaking over the entire regional extent of southern California is obtained by the spatial interpolation of the measured ground motions with geologically based frequency and amplitude-dependent site corrections. Production of the maps is automatic, triggered by any significant earthquake in southern California. Maps are now made available within several minutes of the earthquake for public and scientific consumption via the World Wide Web; they will be made available with dedicated communications for emergency response agencies and critical users.
INTRODUCTION
EARTHQUAKE SPECTRA
Utilization of the Internet for Rapid Community Intensity Maps
David J. Wald
Vincent Quitoriano
U.S. Geological Survey
Lori A. Dengler
Humboldt State University
James W. Dewey
U.S. Geological Survey
"Did You Feel It?"
INTRODUCTION
SEISMOLOGICAL RESEARCH LETTERS
Relationships between Peak Ground Acceleration, Peak Ground Velocity, and Modified Mercalli Intensity in California
David J. Wald, M.EERI, Vincent Quitoriano, Thomas H. Heaton, M.EERI, and Hiroo Kanamori, M.EERI
PGM ⟷ Intensity
We have developed regression relationships between Modified Mercalli Intensity (I_{mm}) and peak ground acceleration (PGA) and velocity (PGV) by comparing horizontal peak ground motions to observed intensities for eight significant California earthquakes. For the limited range of Modified Mercalli intensities (I_{mm}), we find that for peak acceleration with V ≤ I_{mm} ≤ VIII, $I_{mm} = 3.66 \log(PGA) - 1.66$, and for peak velocity with V ≤ I_{mm} ≤ IX, $I_{mm} = 3.47 \log(PGV) + 2.35$. From comparison with observed intensity maps, we find that a combined regression based on peak velocity for intensity > VII and on peak acceleration for intensity < VII is most suitable for reproducing observed I_{mm} patterns, consistent with high intensities being related to damage (proportional to ground velocity) and with lower intensities determined by felt accounts (most sensitive to higher-frequency ground acceleration). These new I_{mm} relationships are significantly different from the Trifunac and Brady (1975) correlations, which have been used extensively in loss estimation.
INTRODUCTION
(DJW) U.S. Geological Survey, 535 S. Wilson Ave., Pasadena, CA 91106
(VQ, THH, HK) Seismological Laboratory, Caltech, Pasadena, CA 91125
USGS
Wald et al. (1999) *Earthquake Spectra, SRL*

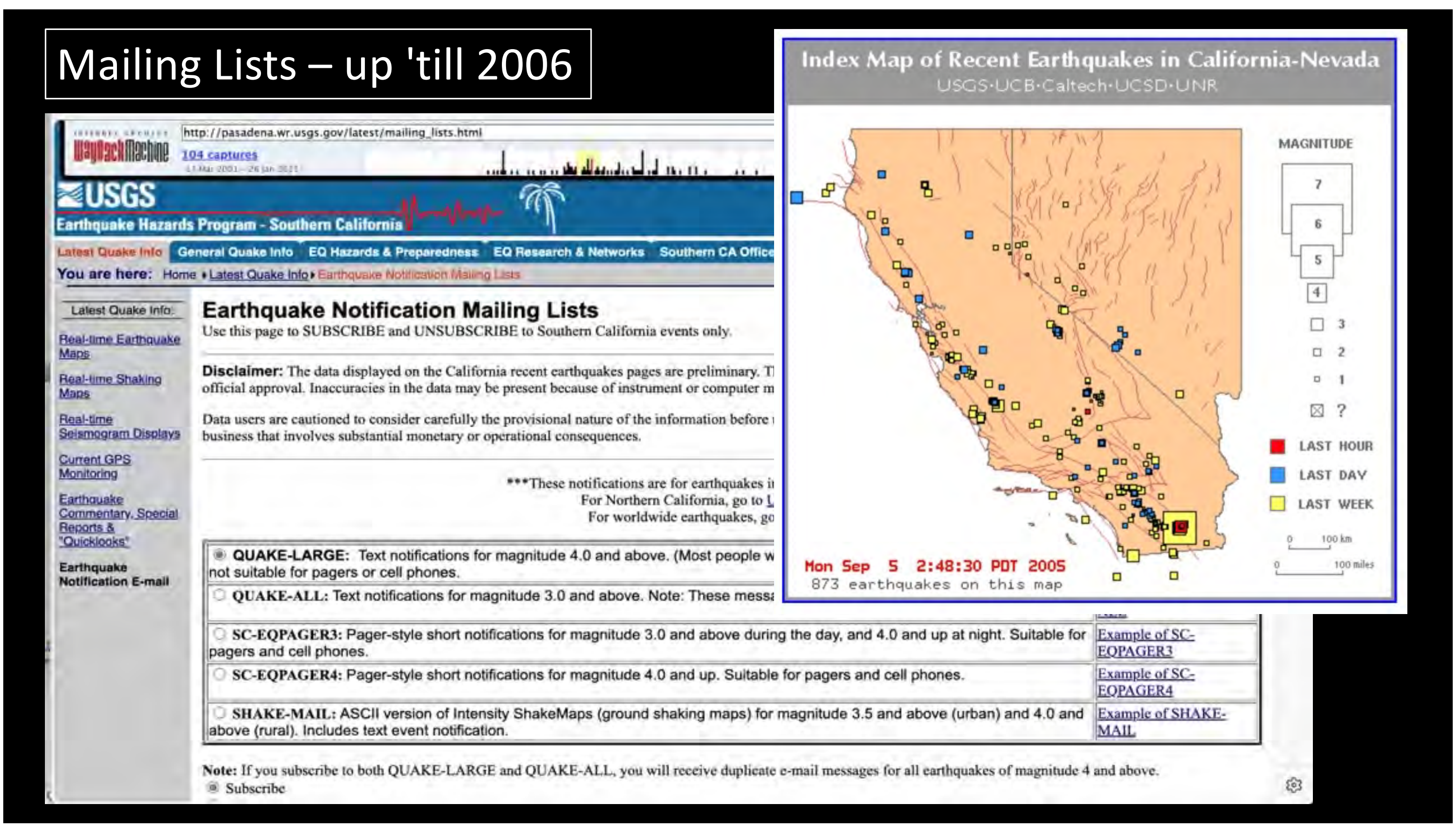
12


1999
TriNet "ShakeMaps": Rapid Generation of Peak Ground Motion and Intensity Maps for Earthquakes in Southern California
David J. Wald, M.EERI, Vincent Quitoriano, Thomas H. Heaton, M.EERI, Hiroo Kanamori, M.EERI, Craig W. Scrivner, and C. Bruce Worden
TRINET "SHAKEMAPS" FOR EARTHQUAKES IN SOUTHERN CALIFORNIA 549
34° 30'N
34° 00'N
119° 00'W
118° 30'W
118° 00'W
PALMDALE
MALIBU
PASADENA
km
0 10 20 30
Figure 7. Instrumental intensity map for the 1994 Northridge earthquake derived using the procedure outlined in the text. Contour lines (thick lines) depict instrumental intensity values. Numbered circles give the observed Modified Mercalli intensity values of Dewey et al. (1995) for comparison. The epicenter is shown with a filled star; thin lines depict highways.
ShakeMap for Northridge Earthquake
Figure 6. Instrumental intensity map for the 1994 Northridge earthquake derived using the procedure outlined in the text. The epicenter is shown with a filled star; blue lines depict highways. The scale bar gives corresponding peak ground motion values and one- or two-word damage and perceived shaking descriptors.
USGS
Wald et al. (1999) *Earthquake Spectra*

13

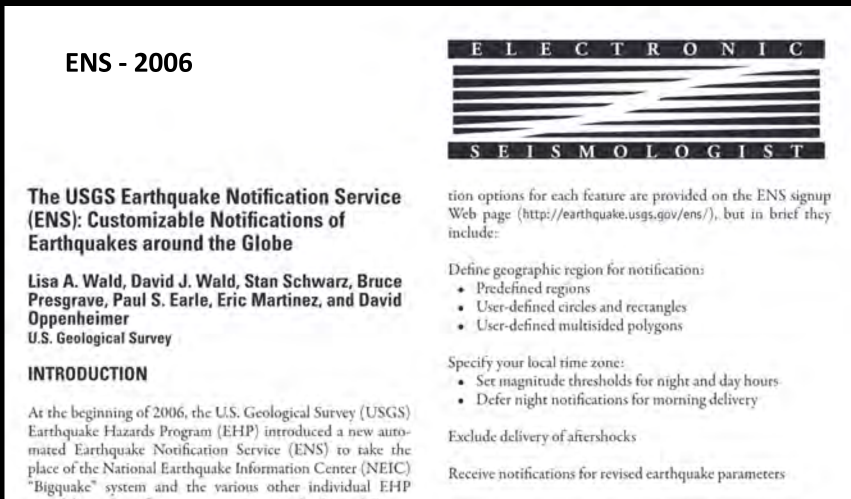

INTENSITY MAP:
-121.0 -118.0 -114.0
+36.0
+34.2
+32.4
MB PB PC SB ML PV SD NE BL
MB=Morro Bay; PB=Pismo Beach; PC=Pt. Conception; SB=Santa Barbara; ML=Malibu;
PV=Palos Verdes; SD=San Diego; BL=Blythe; NE=Needles; *=Epicenter;
PERCEIVED SHAKING | Not felt | Weak | Light | Moderate | Strong | Very strong | Severe | Violent | Extreme
POTENTIAL DAMAGE | none | none | none | Very light | Light | Moderate | Moderate/Heavy | Heavy | Very Heavy
PEAK ACC.(%g) | <.17 | .17-1.4 | 1.4-3.9 | 3.9-9.2 | 9.2-18 | 18-34 | 34-65 | 65-124 | >124
PEAK VEL. (cm/s) | <0.1 | 0.1-1.1 | 1.1-3.4 | 3.4-8.1 | 8.1-16 | 16-31 | 31-60 | 60-116 | >116
INSTRUMENTAL INTENSITY | I | II-III | IV | V | VI | VII | VIII | IX | X+
AUTOMATICALLY GENERATED SHAKEMAP V2 PRELIMINARY INTENSITY MAP: E-MAIL VERSION
EVENT INFO:
DATE: 3 11 2003
TIME: 19:28:17 GMT
LOCATION: 34.3713N -116.1292W
MAGNITUDE: 4.4
EARTHQUAKE ID: 13945908
INSTRUMENTAL INTENSITY SCALE
Estimated Intensity | Peak Acceleration Range (%g) | Peak Velocity Range (cm/s) | Percevied Shaking | Potential Damage
1 | < .17 | < 0.1 | Not felt | None
2-3 | .17-1.4 | 0.1-1.1 | Weak | None
4 | 1.4-3.9 | 1.1-3.4 | Light | None
5 | 3.9-9.2 | 3.4-8.1 | Moderate | Very Light
6 | 9.2-18 | 8.1-16 | Strong | Light
7 | 18-34 | 16-31 | Very Strong | Moderate
8 | 34-65 | 31-60 | Severe | Mod./Heavy
9 | 65-124 | 60-116 | Violent | Heavy
10+ | >124 | >116 | Extreme | Very Heavy
INTENSITY MAP:
MB=Morro Bay; PB=Pismo Beach; PC=Pt. Conception; SB=Santa Barbara; ML=Malibu;
PV=Palos Verdes; SD=San Diego; BL=Blythe; NE=Needles; *=Epicenter;
TriNet ShakeMap Working Group

14


Mailing Lists – up 'till 2006
http://pasadena.wr.usgs.gov/latest/mailing_lists.html
104 captures
USGS
Earthquake Hazards Program - Southern California
Latest Quake Info | General Quake Info | EQ Hazards & Preparedness | EQ Research & Networks | Southern CA Office
You are here: Home › Latest Quake Info › Earthquake Notification Mailing Lists
Latest Quake Info:
Real-time Earthquake Maps
Real-time Shaking Maps
Real-time Seismogram Displays
Current GPS Monitoring
Earthquake Commentary, Special Reports & "Quicklooks"
Earthquake Notification E-mail
Earthquake Notification Mailing Lists
Use this page to SUBSCRIBE and UNSUBSCRIBE to Southern California events only.
Disclaimer: The data displayed on the California recent earthquakes pages are preliminary. T
official approval. Inaccuracies in the data may be present because of instrument or computer m
Data users are cautioned to consider carefully the provisional nature of the information before
business that involves substantial monetary or operational consequences.
***These notifications are for earthquakes i
For Northern California, go to
For worldwide earthquakes, go
QUAKE-LARGE: Text notifications for magnitude 4.0 and above. (Most people w
not suitable for pagers or cell phones.
QUAKE-ALL: Text notifications for magnitude 3.0 and above. Note: These messa
SC-EQPAGER3: Pager-style short notifications for magnitude 3.0 and above during the day, and 4.0 and up at night. Suitable for pagers and cell phones.
Example of SC-EQPAGER3
SC-EQPAGER4: Pager-style short notifications for magnitude 4.0 and up. Suitable for pagers and cell phones.
Example of SC-EQPAGER4
SHAKE-MAIL: ASCII version of Intensity ShakeMaps (ground shaking maps) for magnitude 3.5 and above (urban) and 4.0 and above (rural). Includes text event notification.
Example of SHAKE-MAIL
Note: If you subscribe to both QUAKE-LARGE and QUAKE-ALL, you will receive duplicate e-mail messages for all earthquakes of magnitude 4 and above.
Subscribe
Index Map of Recent Earthquakes in California-Nevada
USGS·UCB·Caltech·UCSD·UNR
MAGNITUDE
7
6
5
4
3
2
1
?
LAST HOUR
LAST DAY
LAST WEEK
Mon Sep 5 2:48:30 PDT 2005
873 earthquakes on this map

15

Earthquake Notification Service (ENS)



ENS - 2006

ELECTRONIC SEISMOLOGIST

The USGS Earthquake Notification Service (ENS): Customizable Notifications of Earthquakes around the Globe

Lisa A. Wald, David J. Wald, Stan Schwarz, Bruce Presgrave, Paul S. Earle, Eric Martinez, and David Oppenheimer
U.S. Geological Survey

INTRODUCTION

At the beginning of 2006, the U.S. Geological Survey (USGS) Earthquake Hazards Program (EHP) introduced a new automated Earthquake Notification Service (ENS) to take the place of the National Earthquake Information Center (NEIC) "Bigquake" system and the various other individual EHP

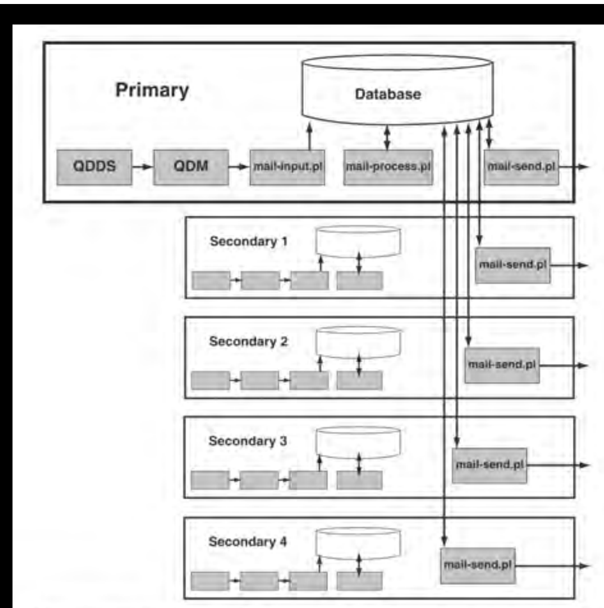
tion options for each feature are provided on the ENS signup Web page (http://earthquake.usgs.gov/ens/), but in brief they include:

Define geographic region for notification:
- Predefined regions
- User-defined circles and rectangles
- User-defined multisided polygons

Specify your local time zone:
- Set magnitude thresholds for night and day hours
- Defer night notifications for morning delivery

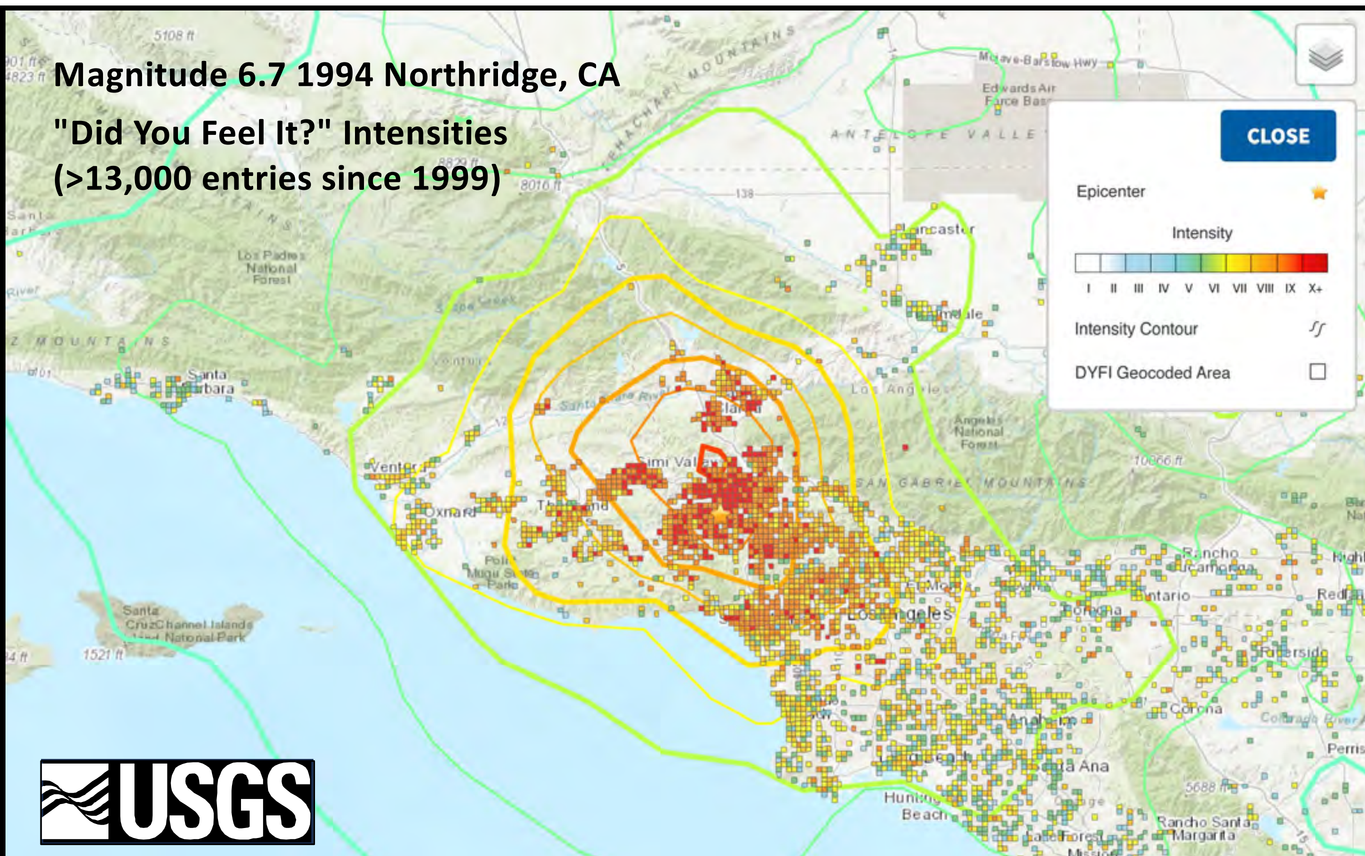
Exclude delivery of aftershocks

Receive notifications for revised earthquake parameters



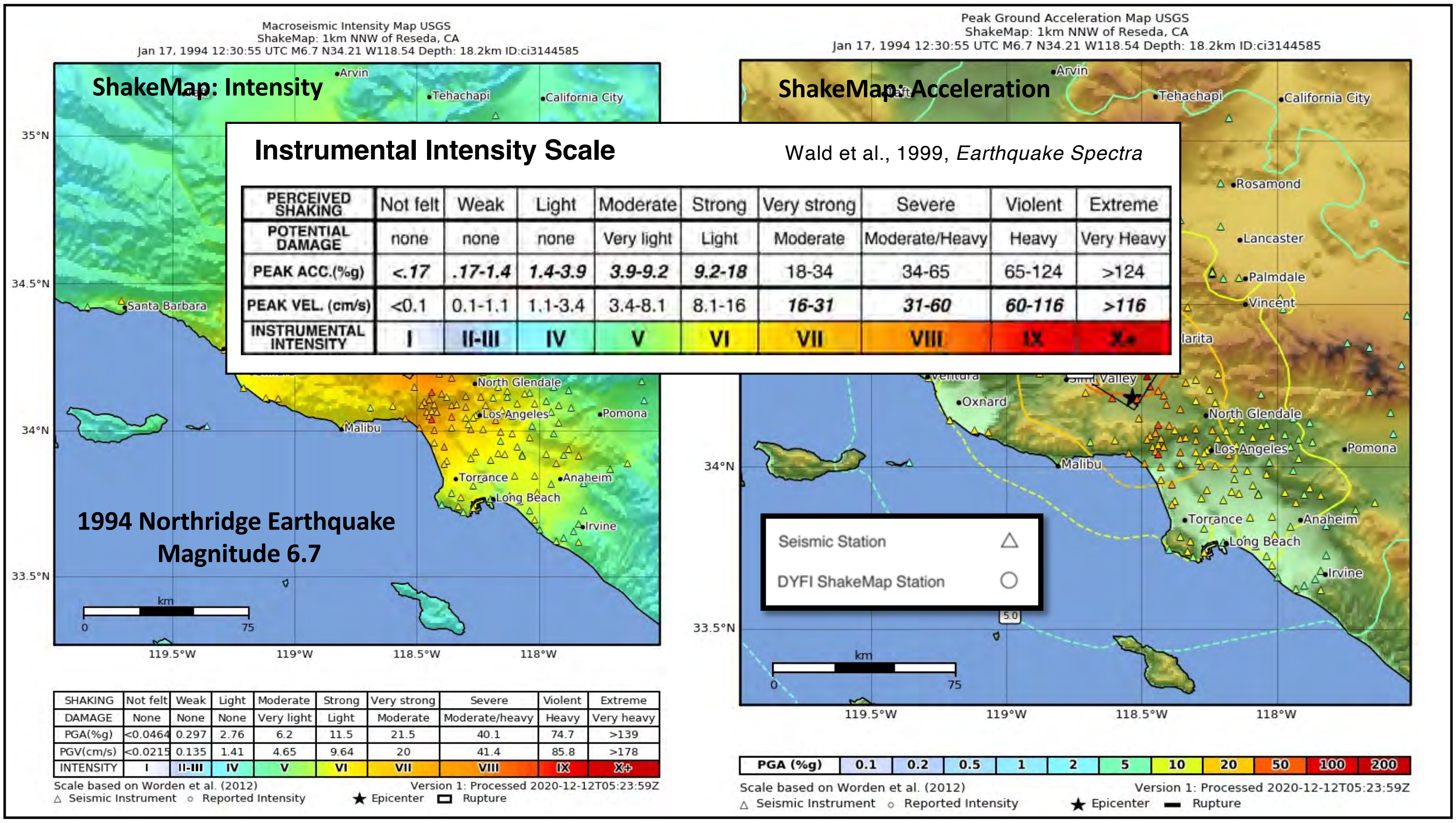
USGS

16



USGS

17

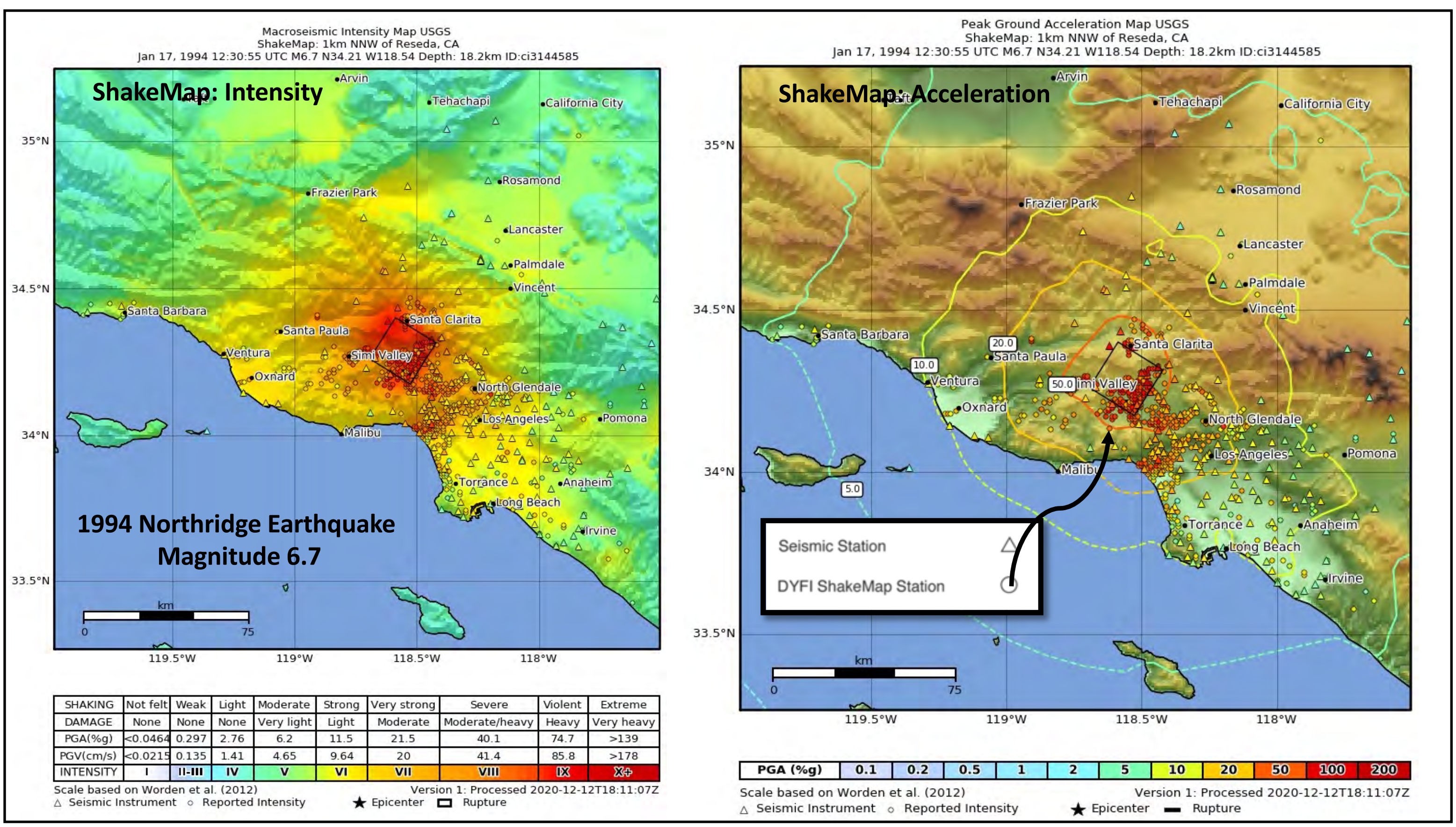


PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
PEAK VEL. (cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
INSTRUMENTAL 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
PGA(%g)	<0.0464	0.297	2.76	6.2	11.5	21.5	40.1	74.7	>139
PGV(cm/s)	<0.0215	0.135	1.41	4.65	9.64	20	41.4	85.8	>178
INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

PGA (%g)	0.1	0.2	0.5	1	2	5	10	20	50	100	200

18



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
PGA(%g)	<0.0464	0.297	2.76	6.2	11.5	21.5	40.1	74.7	>139
PGV(cm/s)	<0.0215	0.135	1.41	4.65	9.64	20	41.4	85.8	>178
INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

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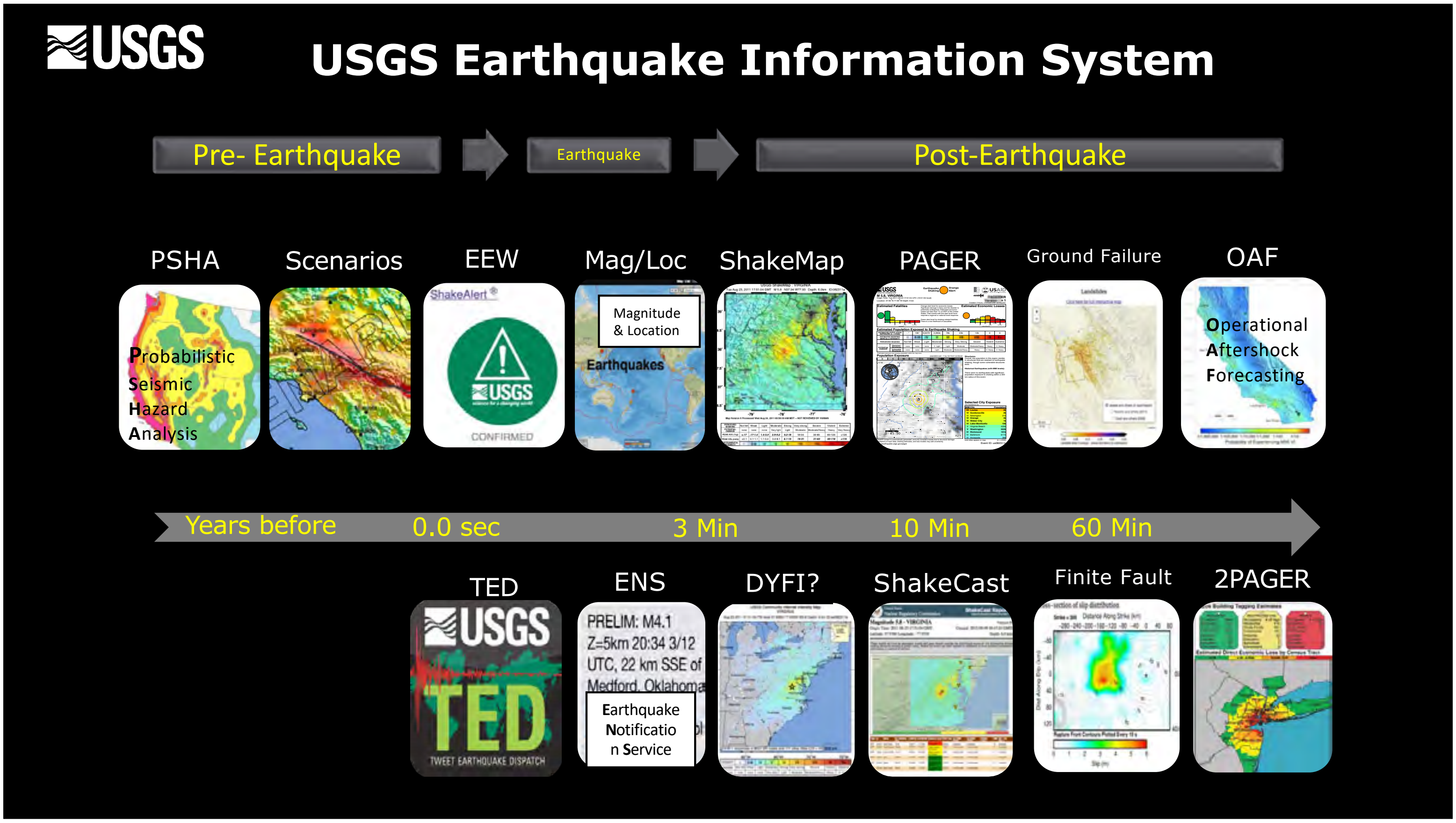
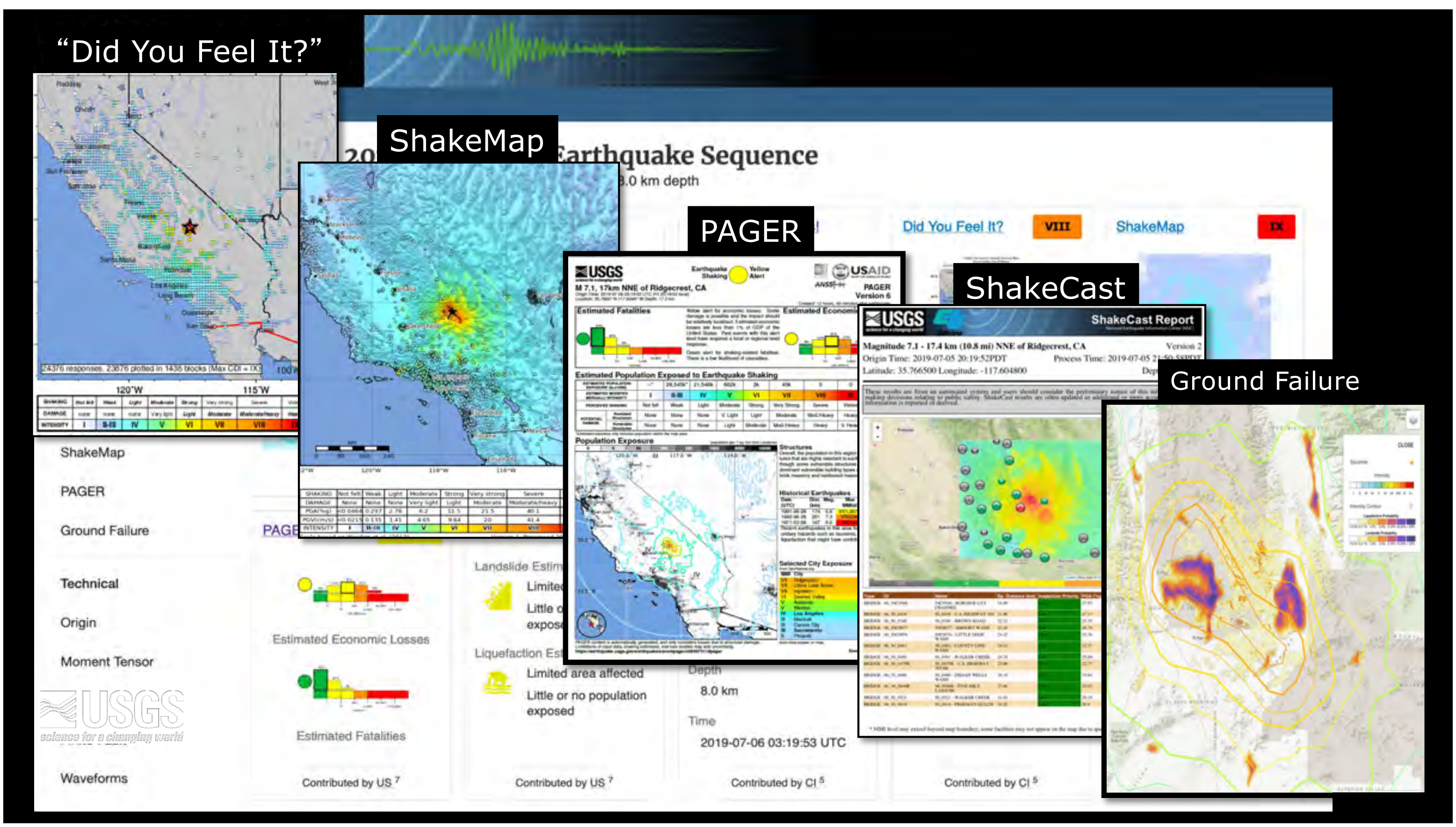
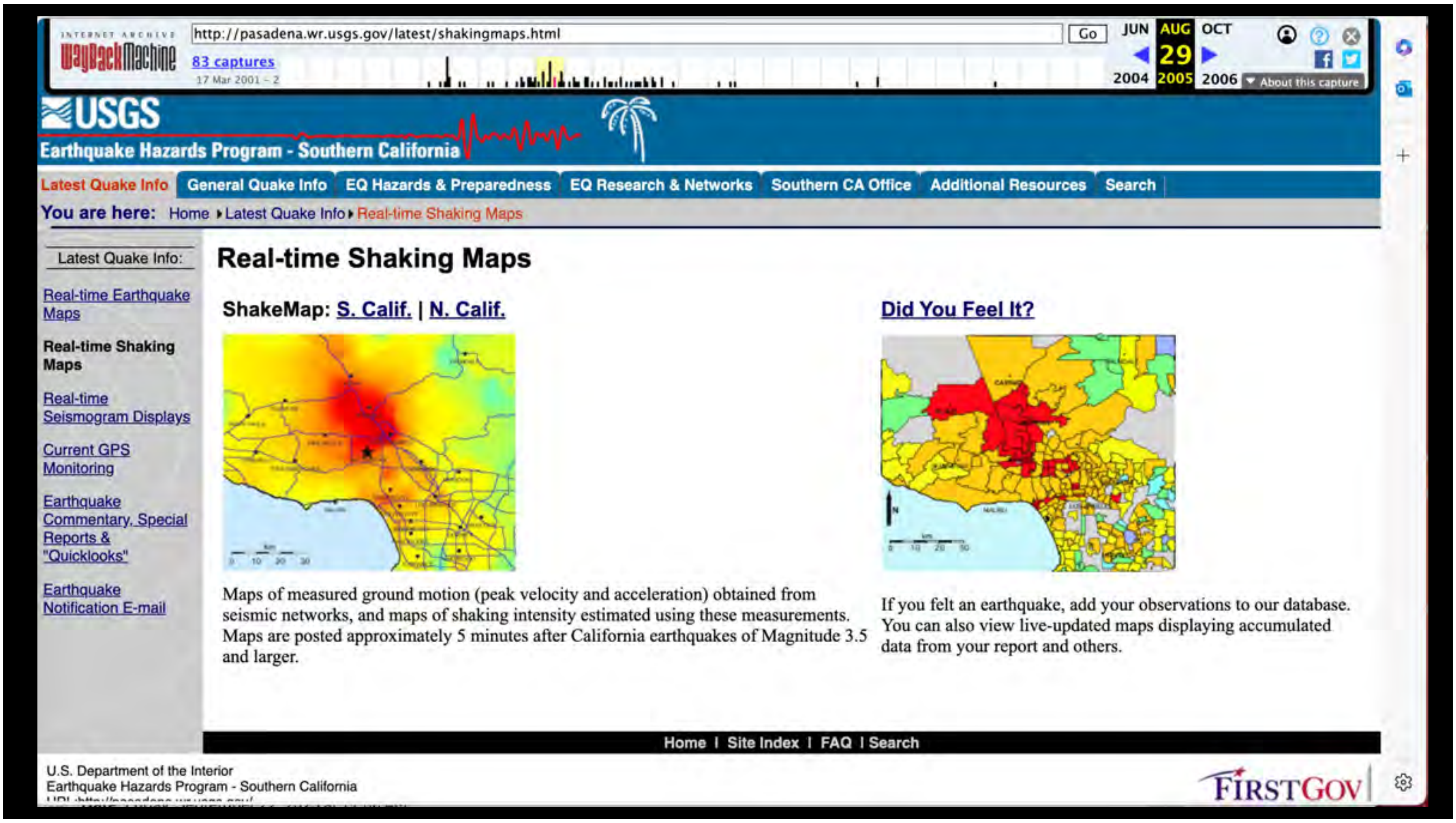

USGS
USGS Earthquake Information System
Pre- Earthquake
Earthquake
Post-Earthquake
PSHA
Scenarios
EEW
Mag/Loc
ShakeMap
PAGER
Ground Failure
OAF
Probabilistic Seismic Hazard Analysis
ShakeAlert
CONFIRMED
Magnitude & Location
Earthquakes
Operational Aftershock Forecasting
Years before
0.0 sec
3 Min
10 Min
60 Min
TED
ENS
DYFI?
ShakeCast
Finite Fault
2PAGER
TED
TWEET EARTHQUAKE DISPATCH
PRELIM: M4.1 Z=5km 20:34 3/12 UTC, 22 km SSE of Medford, Oklahoma
Earthquake Notificatio n Service

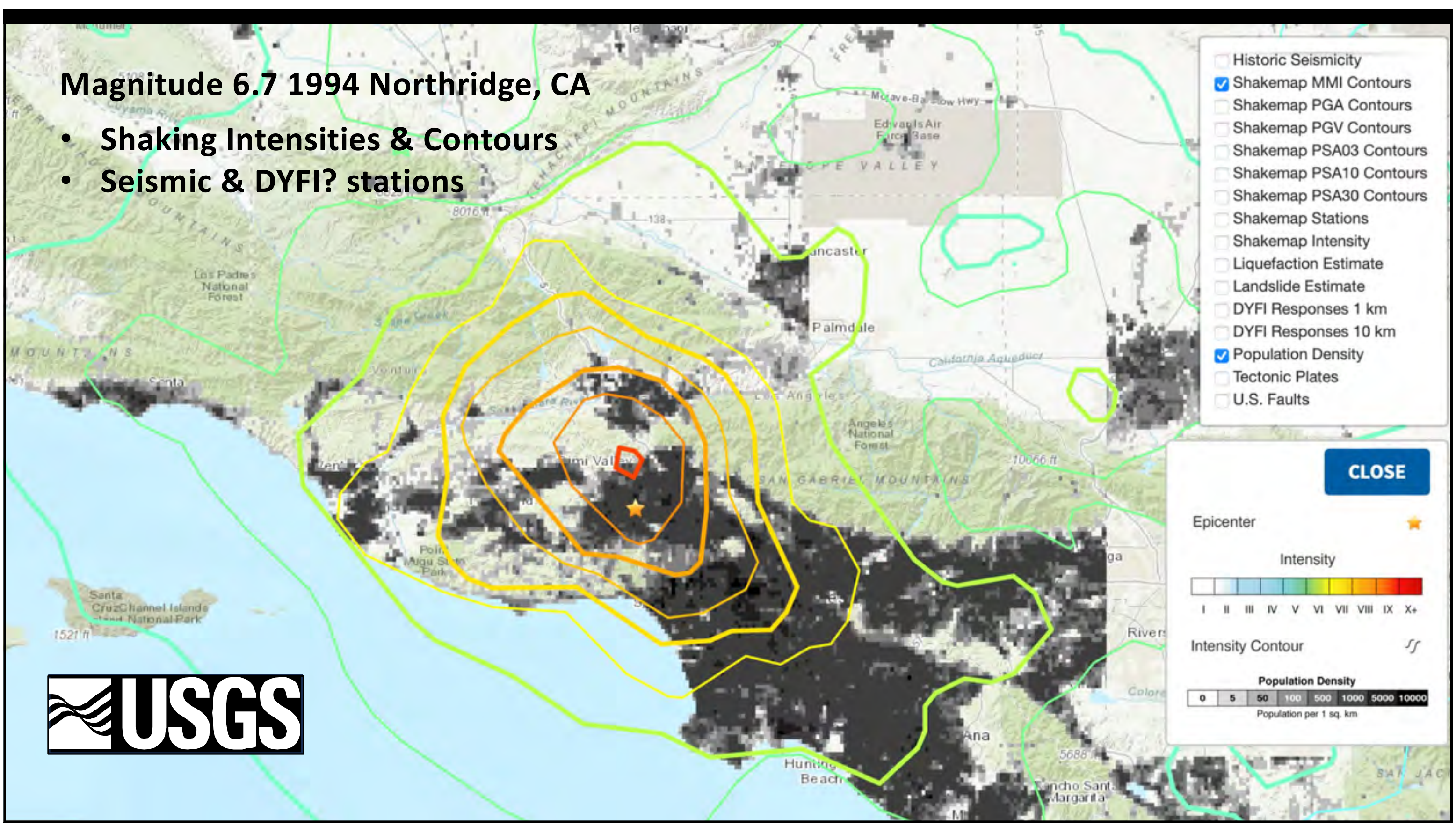
20


"Did You Feel It?"
ShakeMap
Earthquake Sequence
PAGER
Did You Feel It?
VIII
ShakeMap
IX
ShakeCast
ShakeCast Report
Ground Failure
ShakeMap
PAGER
Ground Failure
Technical
Origin
Moment Tensor
Waveforms
Estimated Economic Losses
Estimated Fatalities
Landslide Estim
Liquefaction Es
Limited area affected
Little or no population exposed
Depth
8.0 km
Time
2019-07-06 03:19:53 UTC
Contributed by US
Contributed by CI
M 7.1, 17km NNE of Ridgecrest, CA
Magnitude 7.1 - 17.4 km (10.8 mi) NNE of Ridgecrest, CA

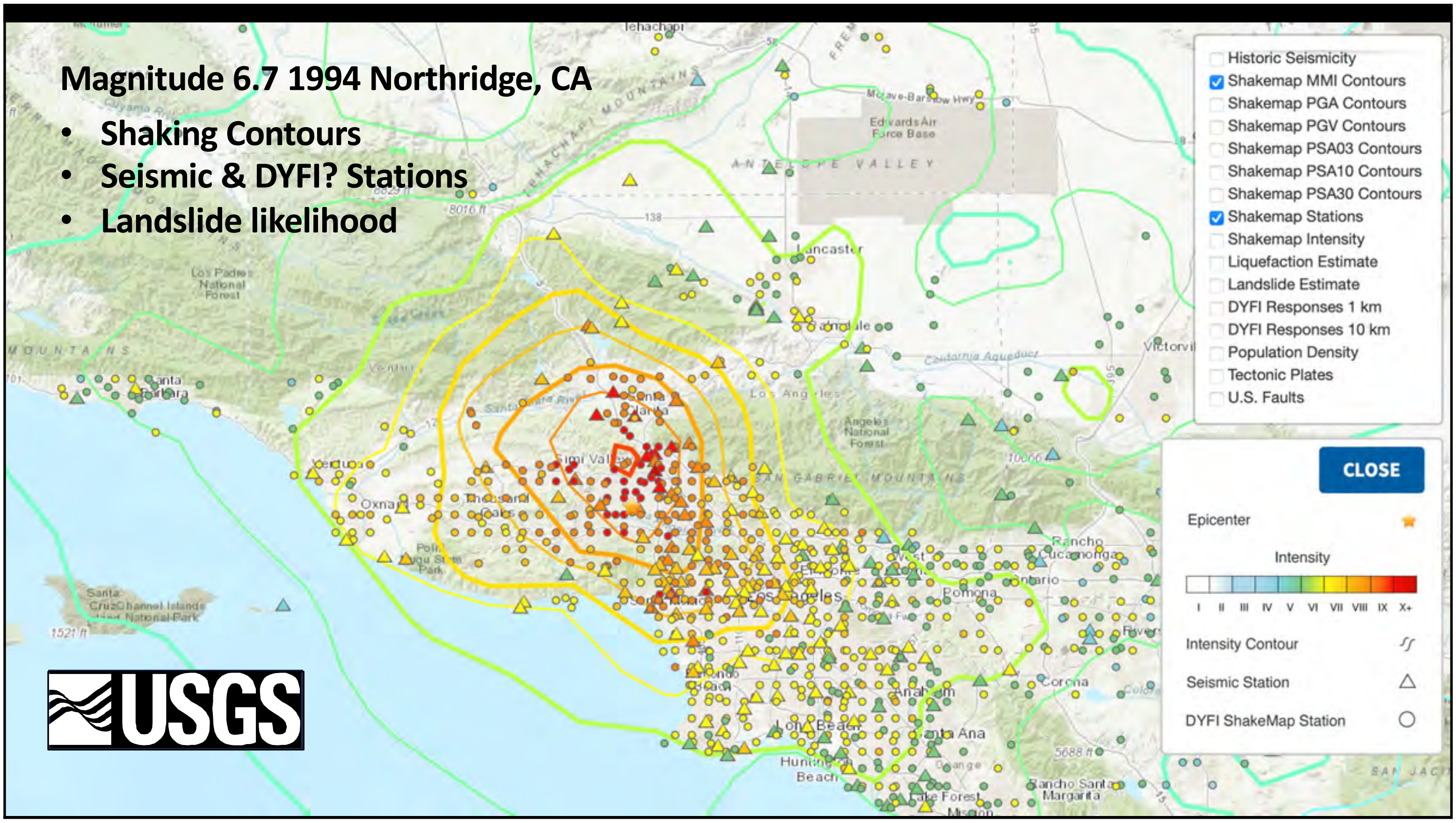
21


INTERNET ARCHIVE WaybackMachine
http://pasadena.wr.usgs.gov/latest/shakingmaps.html
Go
83 captures
17 Mar 2001 – 2
JUN AUG OCT
29
2004 2005 2006
About this capture
USGS
Earthquake Hazards Program - Southern California
Latest Quake Info
General Quake Info
EQ Hazards & Preparedness
EQ Research & Networks
Southern CA Office
Additional Resources
Search
You are here: Home Latest Quake Info Real-time Shaking Maps
Latest Quake Info:
Real-time Earthquake Maps
Real-time Shaking Maps
Real-time Seismogram Displays
Current GPS Monitoring
Earthquake Commentary, Special Reports & "Quicklooks"
Earthquake Notification E-mail
Real-time Shaking Maps
ShakeMap: S. Calif. | N. Calif.
Did You Feel It?
Maps of measured ground motion (peak velocity and acceleration) obtained from seismic networks, and maps of shaking intensity estimated using these measurements. Maps are posted approximately 5 minutes after California earthquakes of Magnitude 3.5 and larger.
If you felt an earthquake, add your observations to our database. You can also view live-updated maps displaying accumulated data from your report and others.
Home | Site Index | FAQ | Search
U.S. Department of the Interior
Earthquake Hazards Program - Southern California
FIRSTGOV

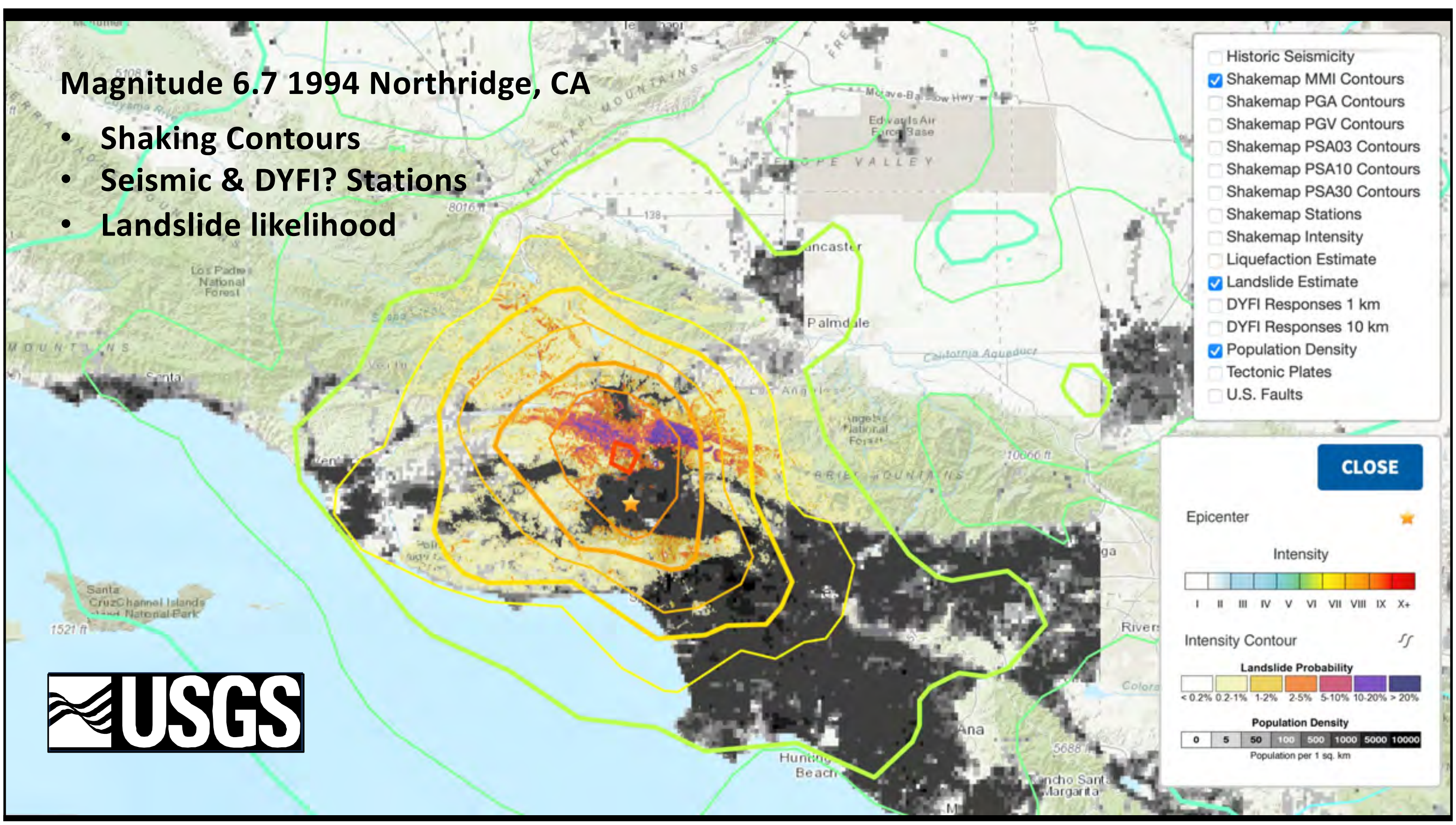
22


Magnitude 6.7 1994 Northridge, CA
• Shaking Intensities & Contours
• Seismic & DYFI? stations
Historic Seismicity
Shakemap MMI Contours
Shakemap PGA Contours
Shakemap PGV Contours
Shakemap PSA03 Contours
Shakemap PSA10 Contours
Shakemap PSA30 Contours
Shakemap Stations
Shakemap Intensity
Liquefaction Estimate
Landslide Estimate
DYFI Responses 1 km
DYFI Responses 10 km
Population Density
Tectonic Plates
U.S. Faults
CLOSE
Epicenter
Intensity
I II III IV V VI VII VIII IX X+
Intensity Contour
Population Density
0 5 50 100 500 1000 5000 10000
Population per 1 sq. km
USGS

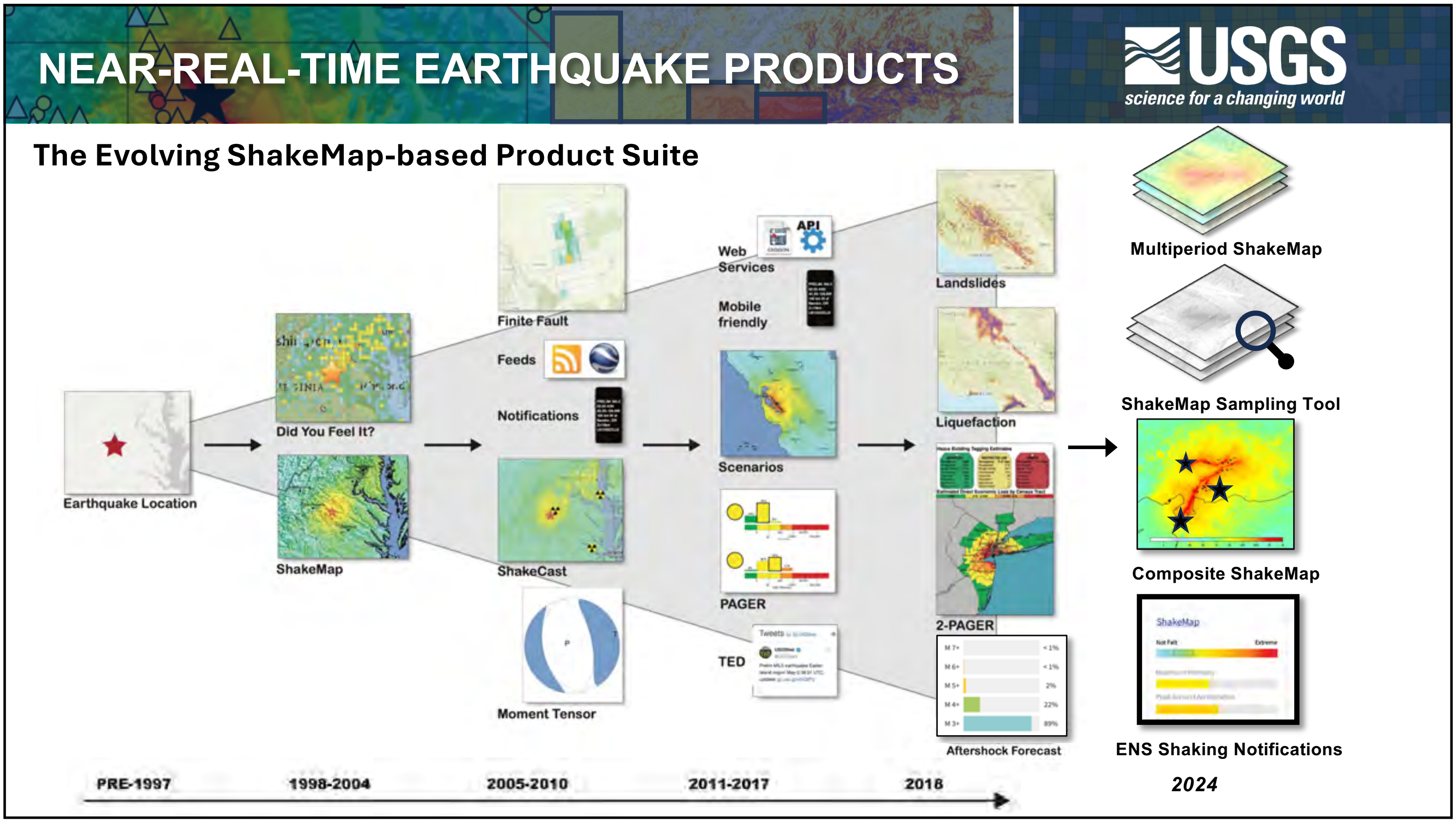
23


Magnitude 6.7 1994 Northridge, CA
• Shaking Contours
• Seismic & DYFI? Stations
• Landslide likelihood
Historic Seismicity
Shakemap MMI Contours
Shakemap PGA Contours
Shakemap PGV Contours
Shakemap PSA03 Contours
Shakemap PSA10 Contours
Shakemap PSA30 Contours
Shakemap Stations
Shakemap Intensity
Liquefaction Estimate
Landslide Estimate
DYFI Responses 1 km
DYFI Responses 10 km
Population Density
Tectonic Plates
U.S. Faults
CLOSE
Epicenter
Intensity
I II III IV V VI VII VIII IX X+
Intensity Contour
Seismic Station
DYFI ShakeMap Station
USGS

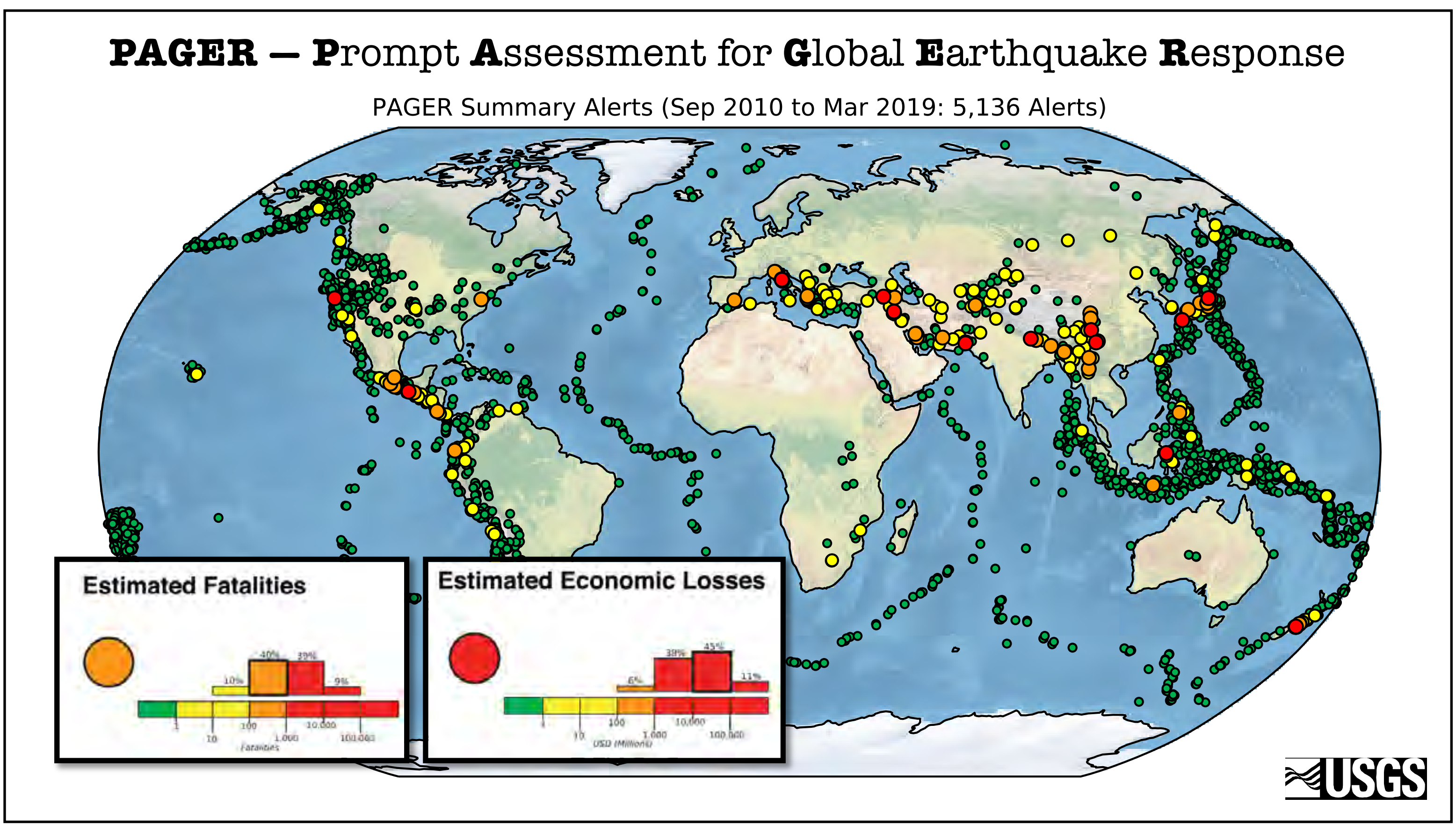
24


Magnitude 6.7 1994 Northridge, CA
• Shaking Contours
• Seismic & DYFI? Stations
• Landslide likelihood
Historic Seismicity
Shakemap MMI Contours
Shakemap PGA Contours
Shakemap PGV Contours
Shakemap PSA03 Contours
Shakemap PSA10 Contours
Shakemap PSA30 Contours
Shakemap Stations
Shakemap Intensity
Liquefaction Estimate
Landslide Estimate
DYFI Responses 1 km
DYFI Responses 10 km
Population Density
Tectonic Plates
U.S. Faults
CLOSE
Epicenter
Intensity
I II III IV V VI VII VIII IX X+
Intensity Contour
Landslide Probability
< 0.2% 0.2-1% 1-2% 2-5% 5-10% 10-20% > 20%
Population Density
0 5 50 100 500 1000 5000 10000
Population per 1 sq. km
USGS

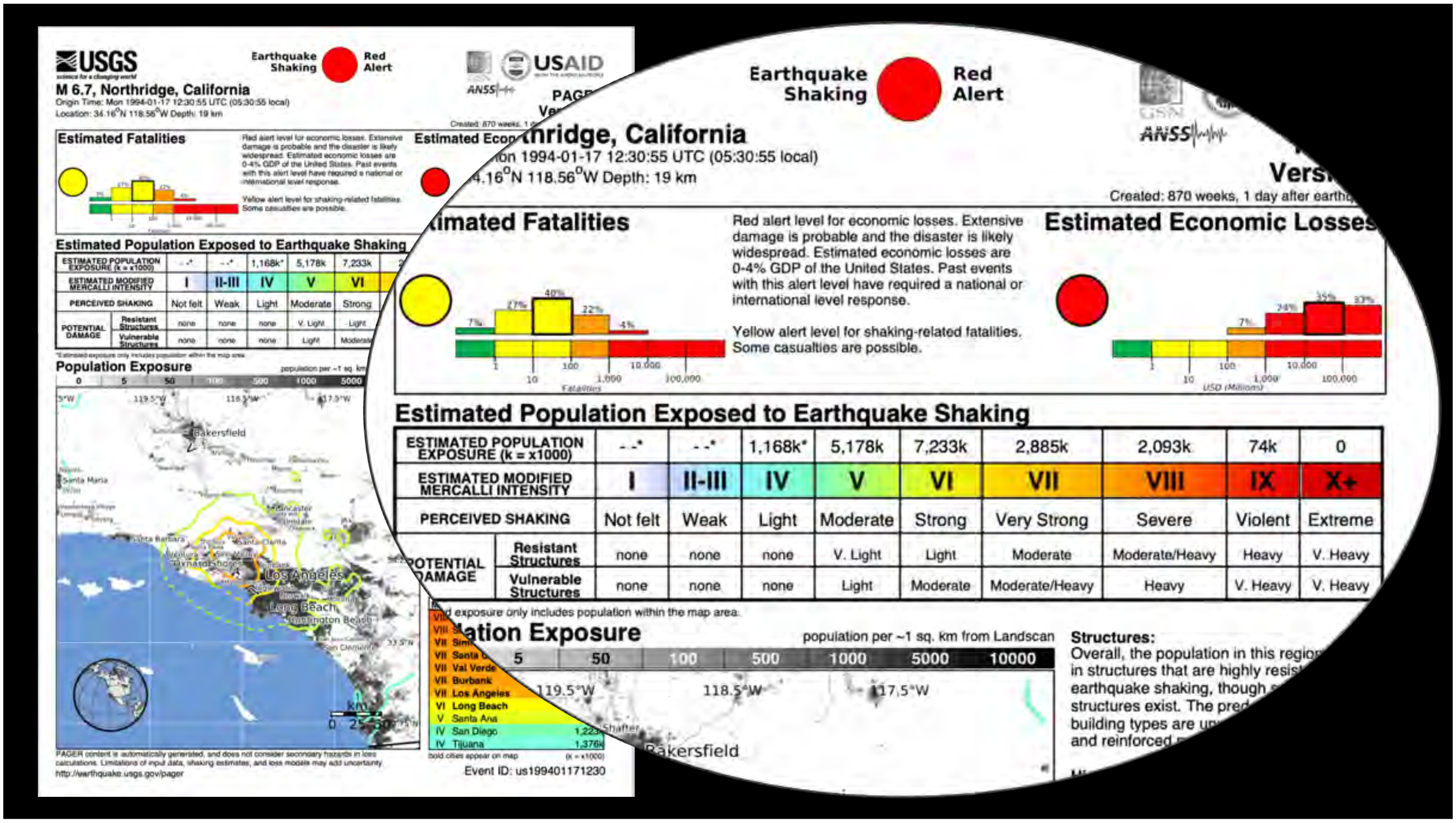
25


NEAR-REAL-TIME EARTHQUAKE PRODUCTS
USGS
science for a changing world
The Evolving ShakeMap-based Product Suite
Earthquake Location
Did You Feel It?
ShakeMap
Finite Fault
Feeds
Notifications
ShakeCast
Moment Tensor
Web Services
API
Mobile friendly
Scenarios
PAGER
TED
Landslides
Liquefaction
2-PAGER
Aftershock Forecast
Multiperiod ShakeMap
ShakeMap Sampling Tool
Composite ShakeMap
ENS Shaking Notifications
PRE-1997
1998-2004
2005-2010
2011-2017
2018
2024

26


PAGER – Prompt Assessment for Global Earthquake Response
PAGER Summary Alerts (Sep 2010 to Mar 2019: 5,136 Alerts)
Estimated Fatalities
Estimated Economic Losses
USGS

27


USGS
Earthquake Shaking
Red Alert
USAID
ANSS
M 6.7, Northridge, California
Origin Time: Mon 1994-01-17 12:30:55 UTC (05:30:55 local)
Location: 34.16°N 118.56°W Depth: 19 km
Created: 870 weeks, 1 day after earthquake
Estimated Fatalities
Red alert level for economic losses. Extensive damage is probable and the disaster is likely widespread. Estimated economic losses are 0-4% GDP of the United States. Past events with this alert level have required a national or international level response.
Yellow alert level for shaking-related fatalities. Some casualties are possible.
Estimated Economic Losses
Estimated Population Exposed to Earthquake Shaking
ESTIMATED POPULATION EXPOSURE (k = x1000): --* | --* | 1,168k* | 5,178k | 7,233k | 2,885k | 2,093k | 74k | 0
ESTIMATED MODIFIED MERCALLI INTENSITY: I | II-III | IV | V | VI | VII | VIII | IX | X+
PERCEIVED SHAKING: Not felt | Weak | Light | Moderate | Strong | Very Strong | Severe | Violent | Extreme
POTENTIAL DAMAGE — Resistant Structures: none | none | none | V. Light | Light | Moderate | Moderate/Heavy | Heavy | V. Heavy
POTENTIAL DAMAGE — Vulnerable Structures: none | none | none | Light | Moderate | Moderate/Heavy | Heavy | V. Heavy | V. Heavy
*Estimated exposure only includes population within the map area.
Population Exposure
population per ~1 sq. km from Landscan
5 50 100 500 1000 5000 10000
Structures:
Overall, the population in this region resides in structures that are highly resistant to earthquake shaking, though some vulnerable structures exist.
Bakersfield
Los Angeles
Long Beach
Event ID: us199401171230

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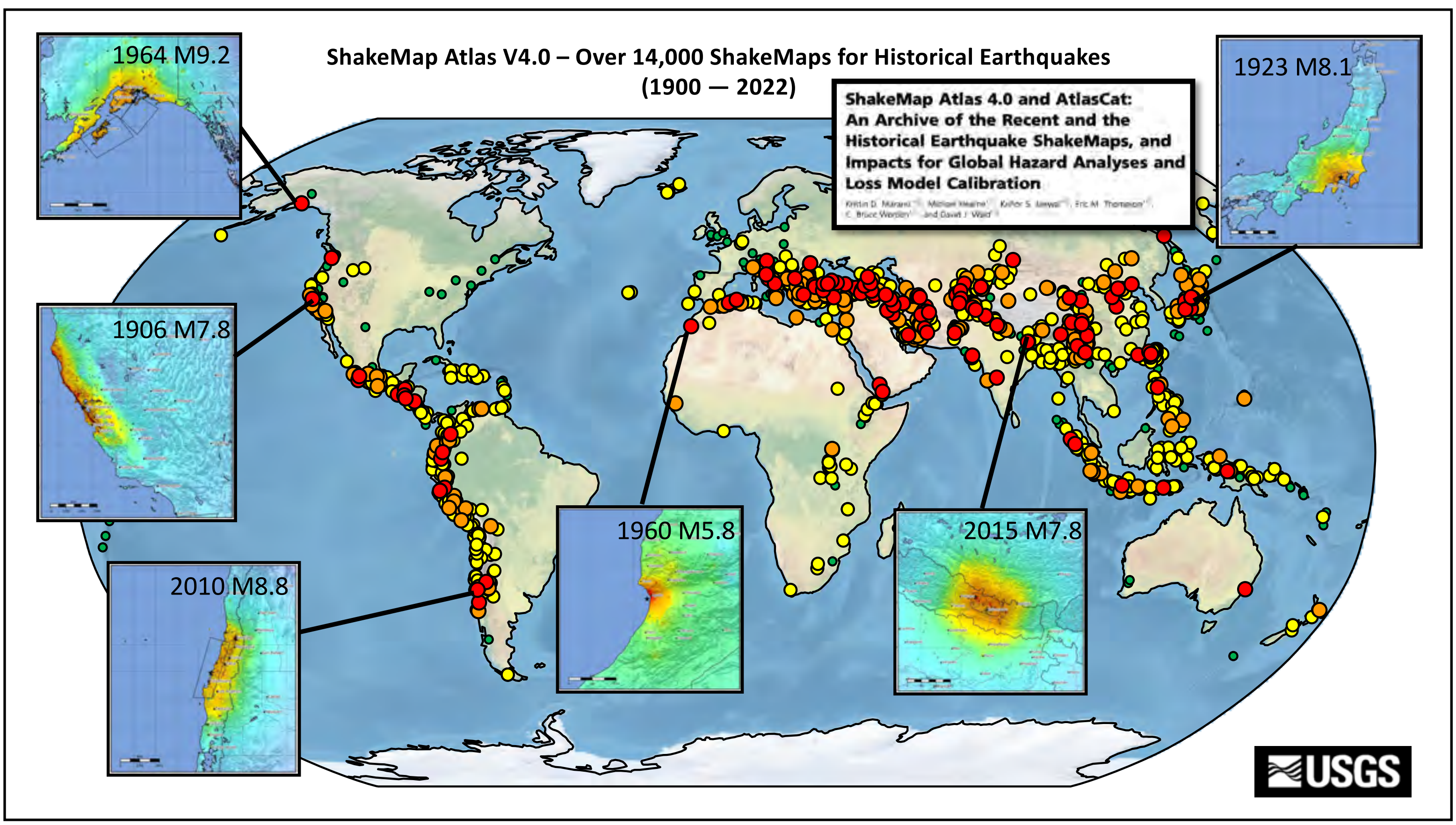
ShakeMap Atlas V4.0 – Over 14,000 ShakeMaps for Historical Earthquakes
(1900 — 2022)
ShakeMap Atlas 4.0 and AtlasCat: An Archive of the Recent and the Historical Earthquake ShakeMaps, and Impacts for Global Hazard Analyses and Loss Model Calibration
1964 M9.2
1906 M7.8
2010 M8.8
1960 M5.8
2015 M7.8
1923 M8.1
USGS

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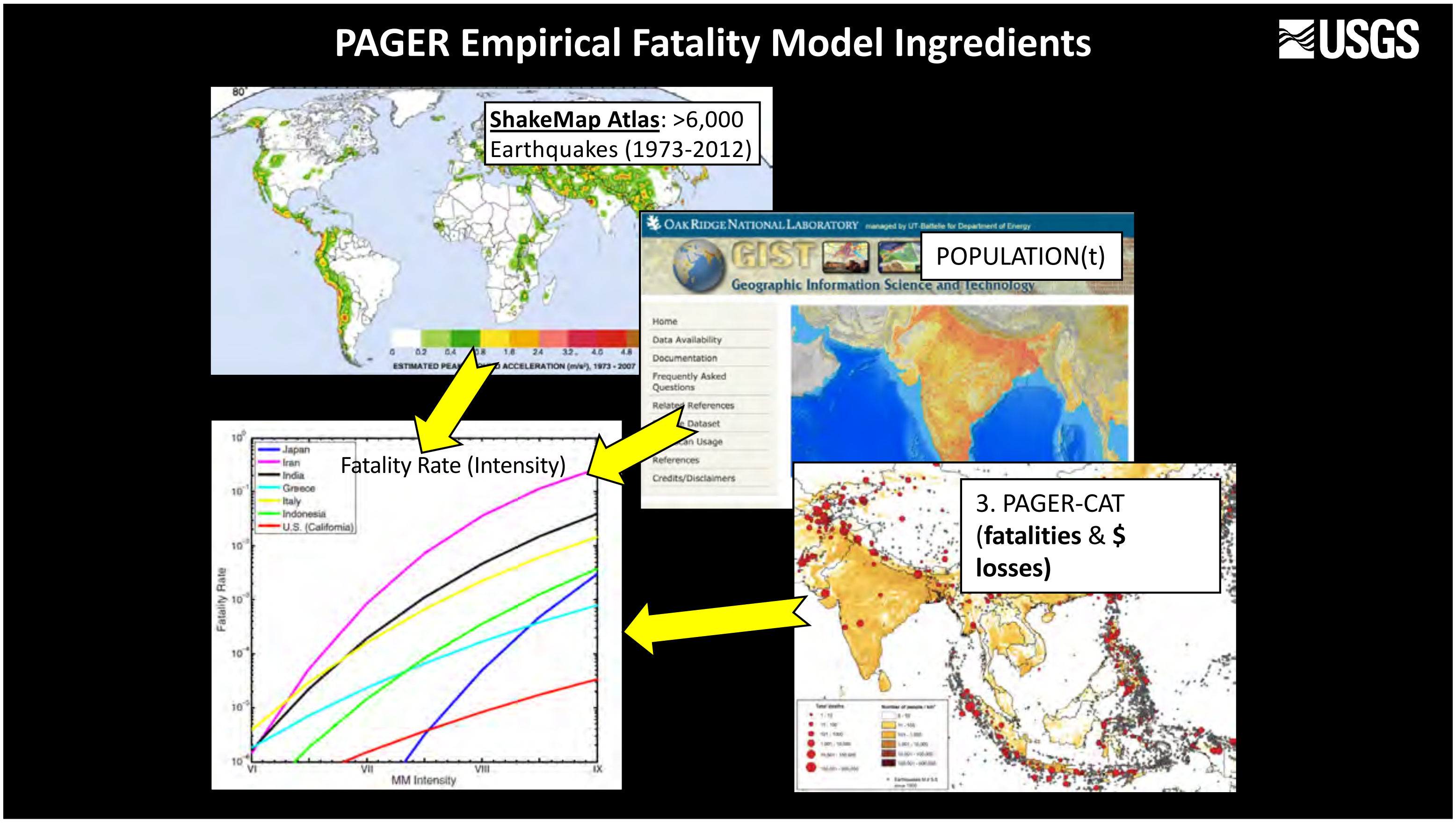
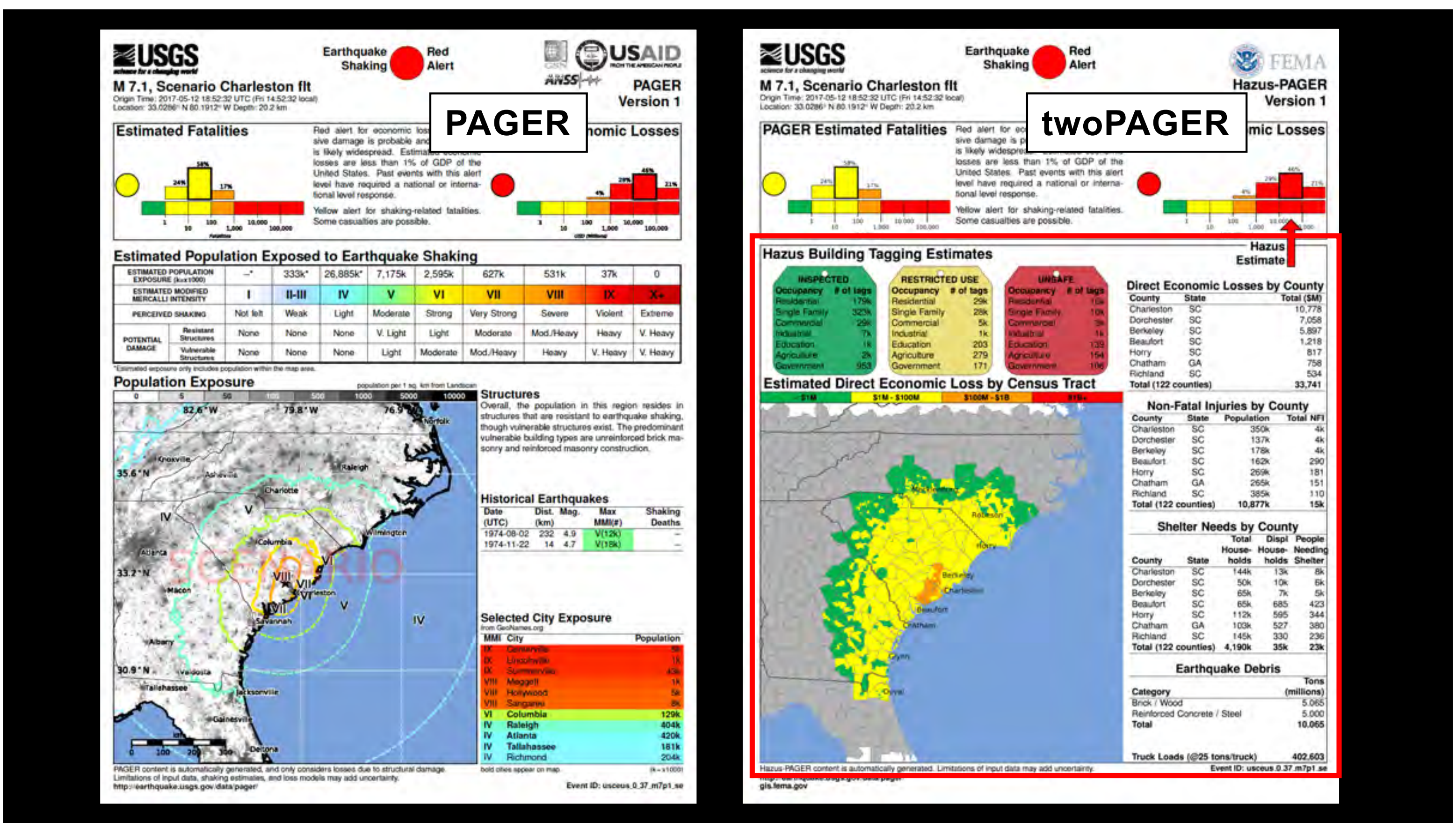


PAGER Empirical Fatality Model Ingredients
USGS
ShakeMap Atlas: >6,000 Earthquakes (1973-2012)
OAK RIDGE NATIONAL LABORATORY
GIST Geographic Information Science and Technology
POPULATION(t)
Fatality Rate (Intensity)
Japan
Iran
India
Greece
Italy
Indonesia
U.S. (California)
Fatality Rate
MM Intensity
3. PAGER-CAT (fatalities & $ losses)

30



USGS
Earthquake Shaking
Red Alert
USAID
M 7.1, Scenario Charleston flt
PAGER Version 1
PAGER
Estimated Fatalities
Estimated Economic Losses
Estimated Population Exposed to Earthquake Shaking
Population Exposure
Structures
Historical Earthquakes
Selected City Exposure
twoPAGER
FEMA
Hazus-PAGER Version 1
PAGER Estimated Fatalities
Hazus Building Tagging Estimates
Hazus Estimate
INSPECTED
RESTRICTED USE
UNSAFE
Direct Economic Losses by County
Estimated Direct Economic Loss by Census Tract
Non-Fatal Injuries by County
Shelter Needs by County
Earthquake Debris

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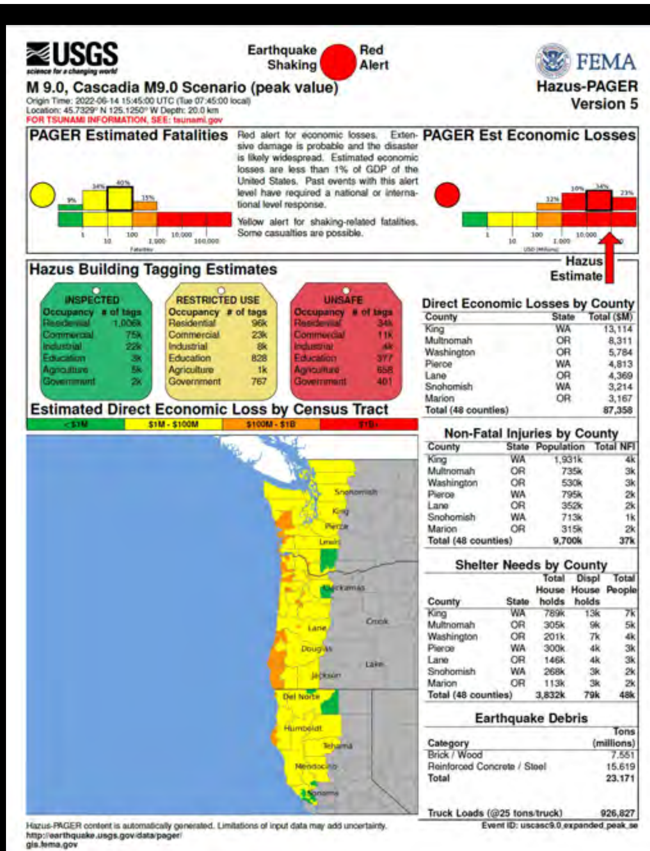
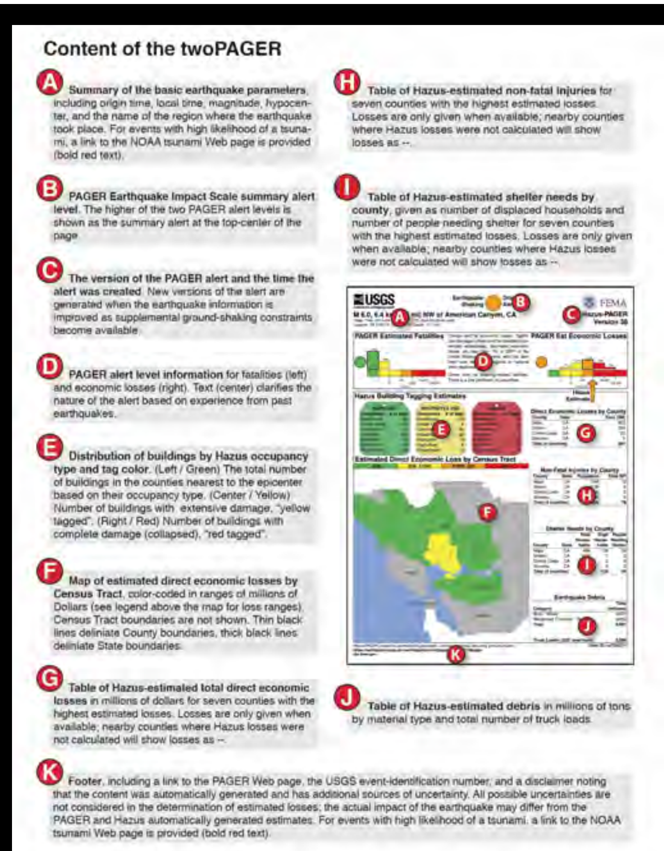




Content of the twoPAGER

A **Summary of the basic earthquake parameters**, including origin time, local time, magnitude, hypocenter, and the name of the region where the earthquake took place. For events with high likelihood of a tsunami, a link to the NOAA tsunami Web page is provided (bold red text).

B **PAGER Earthquake Impact Scale summary alert level**. The higher of the two PAGER alert levels is shown as the summary alert at the top-center of the page.

C **The version of the PAGER alert and the time the alert was created**. New versions of the alert are generated when the earthquake information is improved as supplemental ground-shaking constraints become available.

D **PAGER alert level information** for fatalities (left) and economic losses (right). Text (center) clarifies the nature of the alert based on experience from past earthquakes.

E **Distribution of buildings by Hazus occupancy type and tag color**. (Left / Green) The total number of buildings in the counties nearest to the epicenter based on their occupancy type. (Center / Yellow) Number of buildings with extensive damage, "yellow tagged". (Right / Red) Number of buildings with complete damage (collapsed), "red tagged".

F **Map of estimated direct economic losses by Census Tract**, color-coded in ranges of millions of Dollars (see legend above the map for loss ranges). Census Tract boundaries are not shown. Thin black lines deliniate County boundaries, thick black lines deliniate State boundaries.

G **Table of Hazus-estimated total direct economic losses** in millions of dollars for seven counties with the highest estimated losses. Losses are only given when available; nearby counties where Hazus losses were not calculated will show losses as --.

H **Table of Hazus-estimated non-fatal injuries** for seven counties with the highest estimated losses. Losses are only given when available; nearby counties where Hazus losses were not calculated will show losses as --.

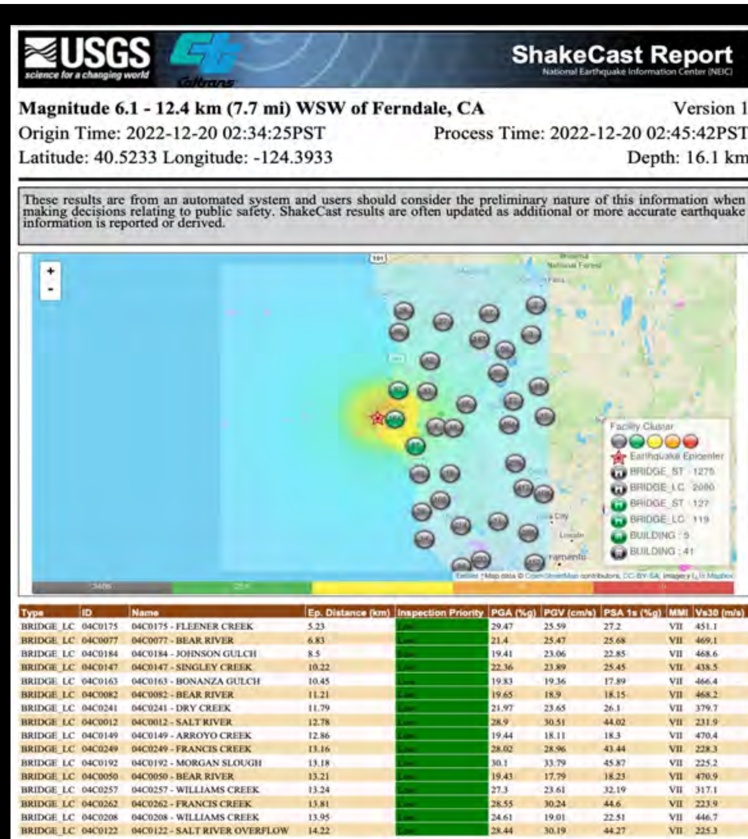
I **Table of Hazus-estimated shelter needs by county**, given as number of displaced households and number of people needing shelter for seven counties with the highest estimated losses. Losses are only given when available; nearby counties where Hazus losses were not calculated will show losses as --.

J **Table of Hazus-estimated debris** in millions of tons by material type and total number of truck loads.

K **Footer**, including a link to the PAGER Web page, the USGS event-identification number, and a disclaimer noting that the content was automatically generated and has additional sources of uncertainty. All possible uncertainties are not considered in the determination of estimated losses; the actual impact of the earthquake may differ from the PAGER and Hazus automatically generated estimates. For events with high likelihood of a tsunami, a link to the NOAA tsunami Web page is provided (bold red text).

What is ShakeCast?

- Open-source USGS software.
- ***Automates*** ShakeMap retrieval & comparison of shaking levels with unique facility fragilities.
- ***Generates*** web pages & hierarchical lists & maps of likely impacted facilities (see right →).
- ***Sends*** notifications to specified personnel/responders.
- ***Raises*** *post-earthquake situational awareness*; represents key information in first min to hours following an event.



ShakeCast Report

National Earthquake Information Center (NEIC)

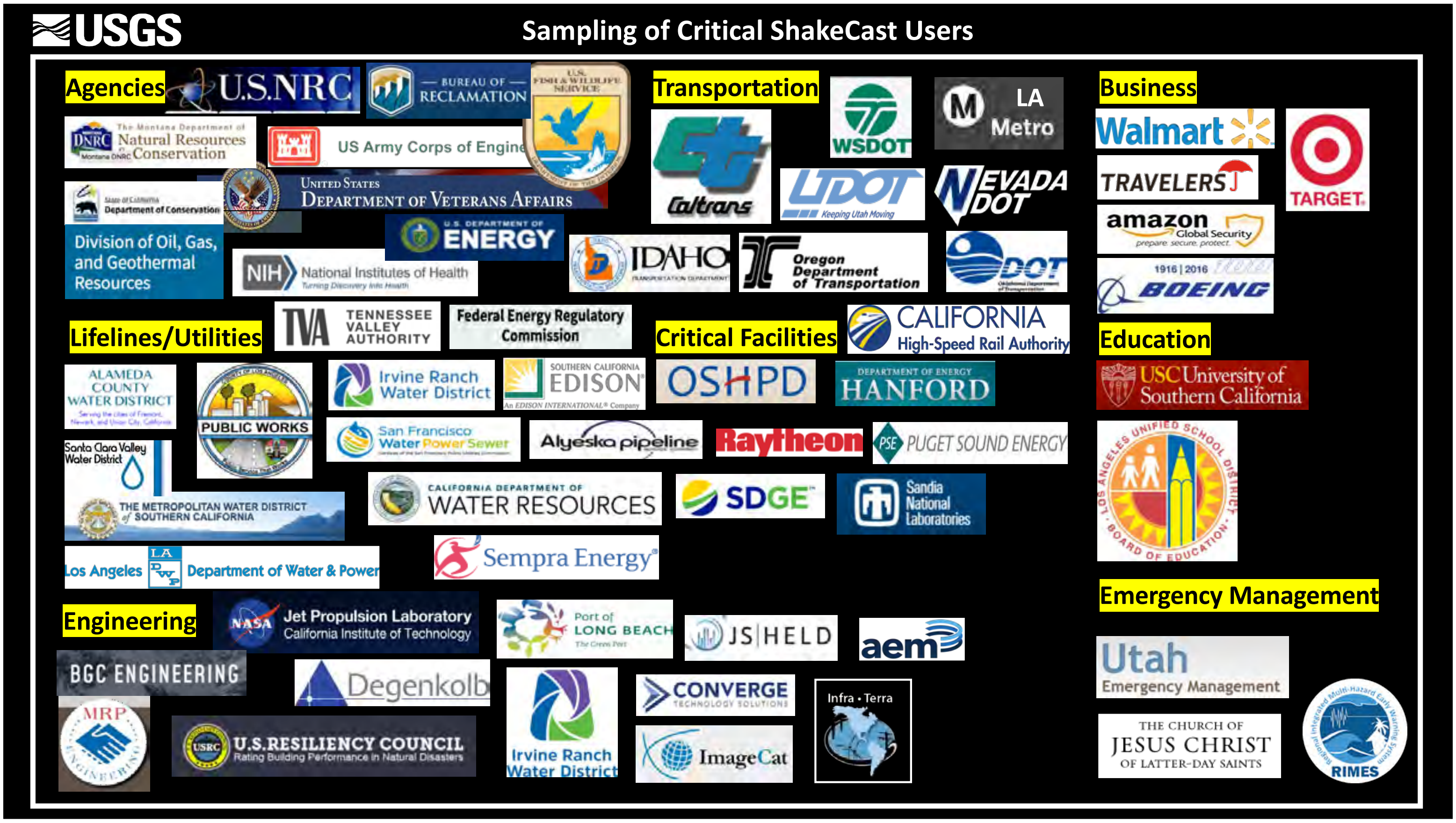
Magnitude 6.1 - 12.4 km (7.7 mi) WSW of Ferndale, CA Version 1

Origin Time: 2022-12-20 02:34:25PST Process Time: 2022-12-20 02:45:42PST

Latitude: 40.5233 Longitude: -124.3933 Depth: 16.1 km

These results are from an automated system and users should consider the preliminary nature of this information when making decisions relating to public safety. ShakeCast results are often updated as additional or more accurate earthquake information is reported or derived.

Type	ID	Name	Ep. Distance (km)	Inspection Priority	PGA (%g)	PGV (cm/s)	PSA 1s (%g)	MMI	Vs30 (m/s)
BRIDGE_LC	04C0175	04C0175 - FLEENER CREEK	5.23	Low	29.47	25.59	27.2	VII	451.1
BRIDGE_LC	04C0077	04C0077 - BEAR RIVER	6.83	Low	21.4	25.47	25.68	VII	469.1
BRIDGE_LC	04C0184	04C0184 - JOHNSON GULCH	8.5	Low	19.41	23.06	22.85	VII	468.6
BRIDGE_LC	04C0147	04C0147 - SINGLEY CREEK	10.22	Low	22.36	23.89	25.45	VII	438.5
BRIDGE_LC	04C0163	04C0163 - BONANZA GULCH	10.45	Low	19.83	19.36	17.89	VII	466.4
BRIDGE_LC	04C0082	04C0082 - BEAR RIVER	11.21	Low	19.65	18.9	18.15	VII	468.2
BRIDGE_LC	04C0241	04C0241 - DRY CREEK	11.79	Low	21.97	23.65	26.1	VII	379.7
BRIDGE_LC	04C0012	04C0012 - SALT RIVER	12.78	Low	28.9	30.51	44.02	VII	231.9
BRIDGE_LC	04C0149	04C0149 - ARROYO CREEK	12.86	Low	19.44	18.11	18.3	VII	470.4
BRIDGE_LC	04C0249	04C0249 - FRANCIS CREEK	13.16	Low	28.02	28.96	43.44	VII	228.3
BRIDGE_LC	04C0192	04C0192 - MORGAN SLOUGH	13.18	Low	30.1	33.79	45.87	VII	225.2
BRIDGE_LC	04C0050	04C0050 - BEAR RIVER	13.21	Low	19.43	17.79	18.23	VII	470.9
BRIDGE_LC	04C0257	04C0257 - WILLIAMS CREEK	13.24	Low	27.3	23.61	32.19	VII	317.1
BRIDGE_LC	04C0262	04C0262 - FRANCIS CREEK	13.81	Low	28.55	30.24	44.6	VII	223.9
BRIDGE_LC	04C0208	04C0208 - WILLIAMS CREEK	13.95	Low	24.61	19.01	22.51	VII	446.7
BRIDGE_LC	04C0122	04C0122 - SALT RIVER OVERFLOW	14.22	Low	28.44	30.19	44.27	VII	225.3



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NEAR-REAL-TIME EARTHQUAKE PRODUCTS

USGS science for a changing world

PAGER-related: Loss updating – InSAR change detection & recovering building-specific losses

nature communications

Article

https://doi.org/10.1038/s41467-022-35418-8

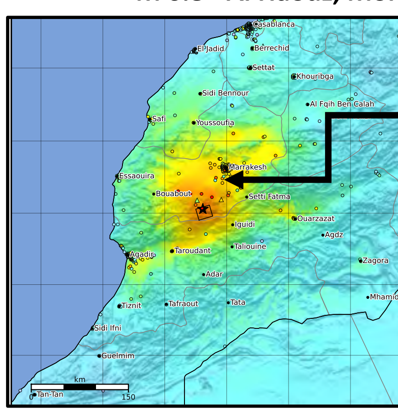
Seismic multi-hazard and impact estimation via causal inference from satellite imagery

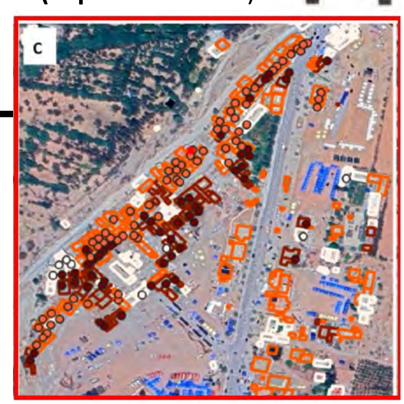
Received: 10 January 2022
Accepted: 1 December 2022
Published online: 17 December 2022
Check for updates

Susu Xu, J. Dimasaka, D. Wald & H. Noh

Rapid post-earthquake reconnaissance is important for emergency responses and rehabilitation by providing accurate and timely information about secondary hazards and impacts, including landslide, liquefaction, and building damage. Despite the extensive collection of geospatial data and satellite images, existing physics-based and data-driven methods suffer from low estimation performance due to the complex and event-specific causal dependencies underlying the cascading processes of earthquake-triggered hazards and impacts. Herein, we present a rapid seismic multi-hazard and impact estimation system that leverages advanced statistical causal inference and remote sensing techniques. The unique feature of this system is that it provides accurate and high-resolution estimations on a regional scale by jointly inferring multiple hazards and building damage from satellite images through modeling their causal dependencies. We evaluate our system on multiple seismic events from diverse countries around the globe. Our results corroborate that incorporating causal dependencies significantly improves large-scale estimation accuracy for multiple hazards and impacts compared to existing systems. The results also reveal quantitative causal mechanisms among earthquake-triggered multi-hazard and impact for multiple seismic events. Our system establishes a new way to extract and utilize the complex interactions of multiple hazards and impacts for effective disaster responses and advancing understanding of seismic geological processes.

M 6.8 - Al Haouz, Morocco (September 2023)





Building Damage Estimates

Estimates	Building Damage Ground Truth
Slightly Damaged Posterior	Slightly Damaged
Moderately Damage Posterior	Moderately Damage
Collapsed Posterior	Collapsed

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NEAR-REAL-TIME EARTHQUAKE PRODUCTS

USGS
science for a changing world

Earthquake Notification Service 2.0 (ENS2)

- Over 600,000 recipients globally (text & email earthquake notifications)
- **PAGER alert-based notifications added (user-selected)**
- **ShakeMap – shaking-based alerts for points of interest (POIs)**

→ Casual ShakeMap users can use the web pages, critical users use ShakeCast, & those who need simple notifications when shaking occurs at a site will be able to use ENS2 (grandma's house; facility, office, etc.)

Perspectives of Earth and Space Scientists

AGU ADVANCING EARTH AND SPACE SCIENCES

PERSPECTIVE
10.1029/2022CN000200

Alerting the Globe of Consequential Earthquakes

D. J. Wald[1]

[1]U.S. Geological Survey, National Earthquake Information Center, Golden, CO, USA

Key Points:

- This memoir covers a 25-year history of the scientific and development effort needed to improve rapid earthquake shaking hazard and impact assessments worldwide
- Developing the tools to alert the globe about destructive earthquakes rapidly entailed wide-ranging collaborative research and development among seismologists, earthquake engineers, geographers, social scientists, IT professionals, and communication experts
- Earthquake impact calculations require rapid hazard assessments and knowledge of the affected inhabitants' exposure and vulnerability of structures

Correspondence to:
D. J. Wald,
wald@usgs.gov

Citation:
Wald, D. J. (2023). Alerting the globe of consequential earthquakes. *Perspectives of Earth and Space Scientists*, *4*, e2022CN000200. https://doi.

Abstract The primary ingredients on the hazard side of the equation include the rapid characterization of the earthquake source and quantifying the spatial distribution of the shaking, plus any secondary hazards an earthquake may have triggered. On the earthquake impact side, loss calculations require the aforementioned hazard assessments—and their uncertainties—as input, plus the quantification of the exposure and vulnerability of structures, infrastructure, and the affected inhabitants. Lastly, effectively communicating uncertain estimates of the resulting impacts on society requires careful consideration of its function and form. All these aspects of rapid earthquake information delivery entailed wide-ranging collaborative research and development among seismologists, earthquake engineers, geographers, social scientists, Information Technology professionals, and communication experts, leveraging diverse components and ingredients not achievable without extensive collaboration. I was very fortunate to be able to work on interesting and useful projects with many colleagues who got involved with them. Advances in content, its rapid delivery, and our ability to better communicate uncertain loss estimates greatly expanded the range of users and critical decision-makers who could directly benefit from rapid post-earthquake information. Moreover, in the critical user–developer feedback loop, we have intently followed requests from users to develop new ways of delivering the most-requested post-earthquake information within the limitations of the science and technology. Such new avenues and tools then motivated and prioritized additional research directions and developments.

Plain Language Summary This memoir covers on a 25-year effort to improve rapid earthquake shaking hazard and impact assessments worldwide. Rapidly characterizing the hazards requires making ShakeMaps—the distribution of the shaking intensity—plus estimating any secondary hazards an earthquake may have triggered (such as landslides). For estimating earthquake impacts, loss calculations require the hazard

USGS

Links & Resources

ENS
Earthquake Notification Service (usgs.gov)

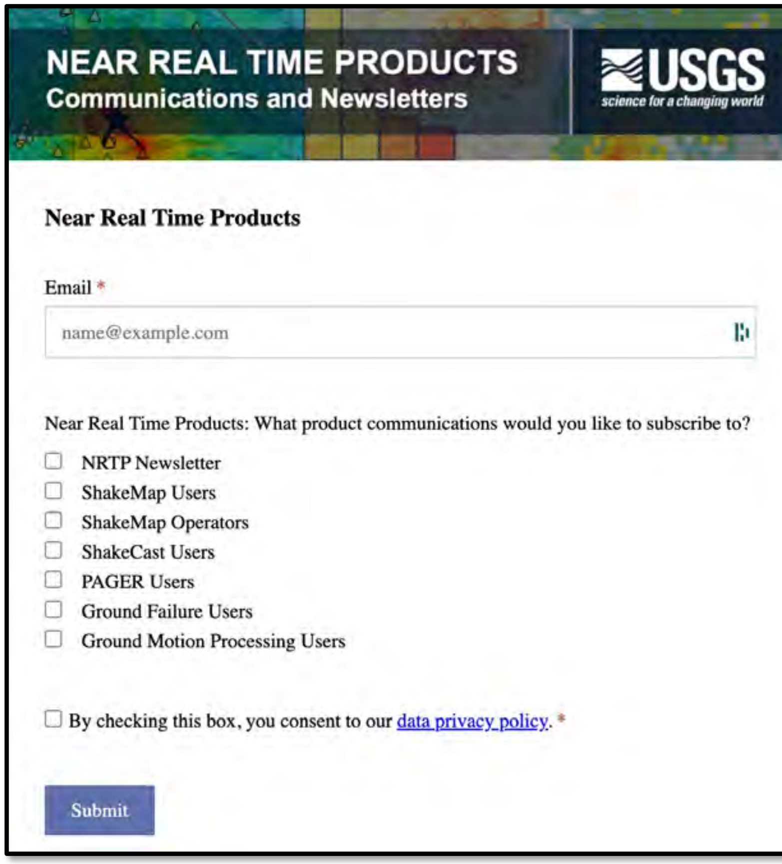
ShakeMap Manual
ShakeMap 4 Manual — ShakeMap Documentation documentation (usgs.github.io)

Composite ShakeMap Software
composite-sm · GitLab (usgs.gov) & composite-atlas

ShakeCast Software
ShakeCast GitLab Wiki (usgs.gov)

ShakeMap Communications and Newsletter
U.S. Geological Survey - Near Real Time Products (govdelivery.com)

David Wald – wald@usgs.gov



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The Northridge Earthquake - 30 Years Later

A Catalyst for Engineering Resilient Communities
2024 Webinar Series

Episode 5: Legacies of the Northridge Earthquake in Disaster Recovery Planning and Policy

August 28, 12-1pm | Register Now: EarthquakeCountry.org/northridge30-webinar5

Laurie Johnson, Principal, Laurie Johnson Consulting | Research

Robert Olshansky, Prof. Emeritus, Univ. of Illinois at Urbana-Champaign

NORTHRIDGE 30 1994 2024 | ASCE INFRASTRUCTURE RESILIENCE | ASCE LOS ANGELES SECTION | EERI SOUTHERN CALIFORNIA | SEAOSC STRUCTURAL ENGINEERS ASSOCIATION OF SOUTHERN CALIFORNIA | Earthquake Country Alliance

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