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United States Earthquake Insurance Overview: Risk and Coverages by Region with a Comparison to Canada and Puerto Rico

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United States Earthquake Insurance Overview:

Risk and Coverages by Region with a Comparison to Canada and Puerto Rico

AUTHOR Cody Webb, FCAS, CPCU, MAAA
Cuanto Consulting, LLC

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Owners of real estate secure their investments through insurance that financially protects them against the risk of physical loss. Physical losses fall into two categories. The first is unexpected occurrences to individual structures, like fires from faulty wiring, water damage from frozen pipes, or liability claims from injuries to visitors. The second category are widespread natural events that impact structures throughout a region. These include hurricanes in coastal communities, hailstorms that damage roofing, and wildfires in forested areas. Each affects a different geography, threatens properties with different vulnerabilities, and carries different nuances in the insurance market.

When property owners purchase insurance, it is their expectation that the policies include protection against a comprehensive list of perils that may affect their properties. Unfortunately, it is usually the case that earthquake coverage is bought separately and often may not even be considered, meaning that property owners may be unaware of exposure to seismic risk or the cost of coverage until after an event occurs.

The focus of this report is earthquake risk, one of the worst, yet often overlooked, natural hazards. Seismic events with widespread damage occur less frequently than other catastrophes, which may explain this lack of attention. Despite this, the earthquake peril should be a major point of focus in certain regions, as the damage can be severe, and there are opportunities for improvement in insurance availability and procedures throughout the United States and Canada.

It is understood that earthquakes pose a major threat in California, but there are other states and regions exposed to seismic risk, and it can be difficult to find comprehensive information on the risk, exposure, insurance availability, and regulatory procedures for earthquake insurance coverage across all the fault zones.

This report will serve as a guide for actuaries, insurance companies, and regulators to understand the scope of earthquake-exposed areas in the United States, along with the approaches taken by insurers and regulators to communicate the risk to homeowners, provide coverage, and eliminate undesirable coverage gaps. Some comparisons for Canada and Puerto Rico are also provided in the report.

The first section provides a broad overview of seismic risk – regions affected, risk measurements, available data, and residual or connected threats. The second focuses on the United States insurance industry – which carriers provide coverage, how policies are priced and sold, and property characteristics relevant for risk measurement. The third section looks at Canada and Puerto Rico, which are separated due to differences in the insurance industry and data availability. The fourth section details the governmental policies adopted at state and federal levels – insurance regulations, awareness campaigns, mitigation programs, and recommendations on best practices. There are two appendices – the first appendix provides greater detail on state and federal programs to address earthquake risk, the second appendix provides more detailed state-level data on earthquake risk and insurance.

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Executive Summary

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1. Earthquake is one of the biggest catastrophic perils in the United States and Canada. According to the Federal Emergency Management Agency's (FEMA's) National Risk Index (NRI), earthquakes pose the second greatest financial threat among natural catastrophes to buildings in the United States, exceeded only by hurricanes.
2. Earthquake risk measurements serve different purposes. Some are forward-looking, like those for building engineering and design, or those that provide estimates the probabilities that of certain physical circumstances, or those that provide estimates of potential financial losses if an earthquake were to occur. Other measures are backward-looking, like those that quantify the energy associated with historical earthquakes, or the financial or economic consequences associated with them.
3. Most of the risk in the United States and Canada is on the West Coast, especially coastal California, but many other fault zones exist. In this report, the seismic risk is classified into several different regions for focus. Beyond coastal California, these areas include Nevada, which contains substantial risk in its Sierra Nevada mountains along its shared border with California; the Cascadia Subduction Zone, which threatens the Pacific Northwest including Oregon, Washington, and British Columbia; Utah's Wasatch Fault, which is located near its population centers, including Salt Lake City; the Midwest's New Madrid Seismic Zone, for which seismic risk is most intense at the intersection of several states – Missouri, Illinois, Kentucky, Tennessee, and Arkansas; the Middleton Plate, which is near Charleston, South Carolina; Seismic Risk near the St. Lawrence River, which jeopardizes properties mostly in Quebec and Ontario; and finally, the risk in peripheral U.S. states and territories – Alaska, Hawaii, and Puerto Rico.
4. Beyond direct risk from shaking, earthquakes are associated with other residual risks. These include financial risks to owners of uninsured or underinsured properties, risk to structures and life from tsunamis or fires that follow earthquakes, economic disruptions, or threats to vulnerable populations like the poor, the elderly, or those in unprepared communities.
5. Despite living in areas where seismic activity could damage their properties, many owners go without insurance for it. Earthquake insurance is sold separately from other property insurance. This improves coverage availability for non-quake risks while leaving an undesirable coverage gap for earthquakes. Like seismic risk in general, this coverage gap is concentrated in the West. Many homeowners in other regions lack coverage, but the potential severity, and thus potential damage, is usually smaller.
6. For policymakers and insurance professionals, there are many elements to understand about how earthquake insurance is sold – whether there is a mandatory offer of coverage, commercial vs. residential policies, endorsements vs. standalone policies, admitted vs. non-admitted insurers, primary insurance vs. reinsurance, and the property characteristics that are used to differentiate risk in pricing plans.
7. State and Federal governments take different approaches to earthquake risk insurance and preparedness. These include insurance regulations, awareness campaigns, mitigation programs, and monitoring of insurance take-up rates. Policymakers could consider the approaches taken in other areas and consider whether to adopt them.
8. Each State, Province, and Territory is composed of a unique population, and has a unique geography. Policymakers could consider the characteristics of properties, citizens, and insurers to craft the most appropriate procedures to mitigate earthquake risk.

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1 Earthquake Property Risk in the United States

Earthquake risk is one of the most important natural perils that threatens the United States, but the hazard is not present everywhere throughout the continent. Instead, the chance of a damaging earthquake exists in certain seismically active regions. Outside of these, the chance of a major earthquake is improbable.

This section provides an overview of earthquake risk in the United States. First is an estimate of the size of the risk. Next, the data and metrics used to estimate earthquake risk and damage are introduced. The earthquake regions are defined using these metrics- these will be the focus of the report. This is followed by a history of earthquakes by quantifying and mapping prior events and describing past events which offer important lessons. Finally, there is a description of follow-on risks like fire and tsunami, or the risk to underprepared or vulnerable communities.

1.1 HOW EARTHQUAKE RISK COMPARES WITH OTHER NATURAL PERILS

Table 1

NATIONAL RISK INDEX - NATIONAL EXPECTED ANNUAL LOSSES TO BUILDINGS BY NATURAL PERIL AS OF 2023[1]

Hazard	Expected Annual Losses to Buildings ($ Millions)	% of Total
Hurricane	$20,988.14	39.39%
Earthquake	**$14,783.70**	**27.75%**
Riverine Flooding	$4,530.47	8.50%
Tornado	$4,222.97	7.93%
Wildfire	$3,415.66	6.41%
Hail	$1,784.43	3.35%
Strong Wind	$1,179.60	2.21%
Coastal Flooding	$1,146.95	2.15%
Ice Storm	$557.47	1.05%
Winter Weather	$221.40	0.42%
Volcanic Activity	$209.68	0.39%
Landslide	$147.31	0.28%
Lightning	$70.94	0.13%
Heat Wave	$11.94	0.02%
Tsunami	$3.82	0.01%
Cold Wave	$3.48	0.01%
Avalanche	$0.07	0.00%
Total	**$53,278.04**	**100%**

[1] Zuzak, C., E. Goodenough, C. Stanton, M. Mowrer, A. Sheehan, B. Roberts, P. McGuire, and J. Rozelle. 2023. National Risk Index for Natural Hazards. Federal Emergency Management Agency, Washington, DC. Downloaded from hazards.fema.gov/nri/data-resources#csvDownload/

Data in Figure is the aggregated expected loss to buildings for each hazard type, aggregated from the county-level dataset.

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How does the risk of earthquakes compare with other natural perils? One resource to answer this question, which will be heavily relied upon throughout this report, is the National Risk Index for Natural Hazards (NRI), a series of datasets and tools produced by the Federal Emergency Management Agency (FEMA).

The NRI is a combination of hazard estimates and risk scores for all the natural perils that FEMA considers significant in the United States. It provides a variety of tools, including by-peril data at the county or census tract level.

Table 1 displays FEMA's estimates for the "expected annual loss" (EAL), in millions of dollars, to buildings in the United States. Earthquake represents 27.75% of expected losses and is the second most significant peril based on FEMA's estimates, surpassed only by Hurricane (which is inclusive of related storm surge flooding). Other significant perils include riverine flooding, wildfire, tornado, and hail, all over 3% of the total.

The remaining perils are smaller, but many pose a threat of hundreds of millions of dollars annually. Note that FEMA is only one source of estimates. A number of private companies also produce models, and estimates may vary widely depending on the source. Nevertheless, FEMA's methodology is comprehensive, and most model estimates would broadly concur that earthquake is one of the biggest risks in the United States.

Despite its threat, earthquake does not receive the same attention as other perils. This may stem from the fact that events do not happen often, so earthquakes are rarely a topic of discussion in the media, which could contribute to a lower level of risk management relative to the other hazards. As this report will show, there are regions where a major event is quite possible, though they have not witnessed a major earthquake in over 100 years.

1.2 HOW EARTHQUAKE RISK IS MEASURED

Understanding the array of metrics and measurements involved with earthquake risk can be difficult. This section clarifies risk measurement by describing some of these metrics. Some are prospective and relate to different potential consequences of future earthquakes; others are retrospective and provide quantification of past events. Some describe physical parameters of earthquakes, such as the probability of intense forces at a site, or the energy release from an earthquake. Others relate to human measures, such as dollars of loss, economic loss, or fatalities.

PROSPECTIVE – ENGINEERING MEASURES

One set of earthquake metrics are those used for engineering. These describe the probability of shaking potential at a given location and guide the needed characteristics for buildings. Examples of these metrics appear in the following maps, published by the United States Geological Survey (USGS). While many metrics are used, two examples are given to provide an idea of their meaning and parameters.

Peak Ground Acceleration (PGA) – Is the maximum force of acceleration expected at a given location, expressed as a multiple of the force of gravity. PGA is a probabilistic metric, with different parameters:

- Probability – The likelihood of a given acceleration within a return period. Common selections are 2% and 10%.
- Return Period – The period for the probability of exceedance. USGS often defaults to a 50-year period.
- Site Condition – The soil underlying an exposed structure and its propensity to transmit seismic waves, and the speed with which a wave of given energy would travel. USGS risk maps default to 760 meters per second.

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The following map displays USGS estimates for PGA in the contiguous United States using a probability of 2%, a return period of 50 years, and a site condition of 760 meters per second. The figure provides the approximate damage expected from a given acceleration, as estimated by the Modified Mercalli Intensity Scale.

Figure 1
USGS PEAK GROUND ACCELERATION HAZARD MAP FOR THE CONTIGUOUS UNITED STATES[2]

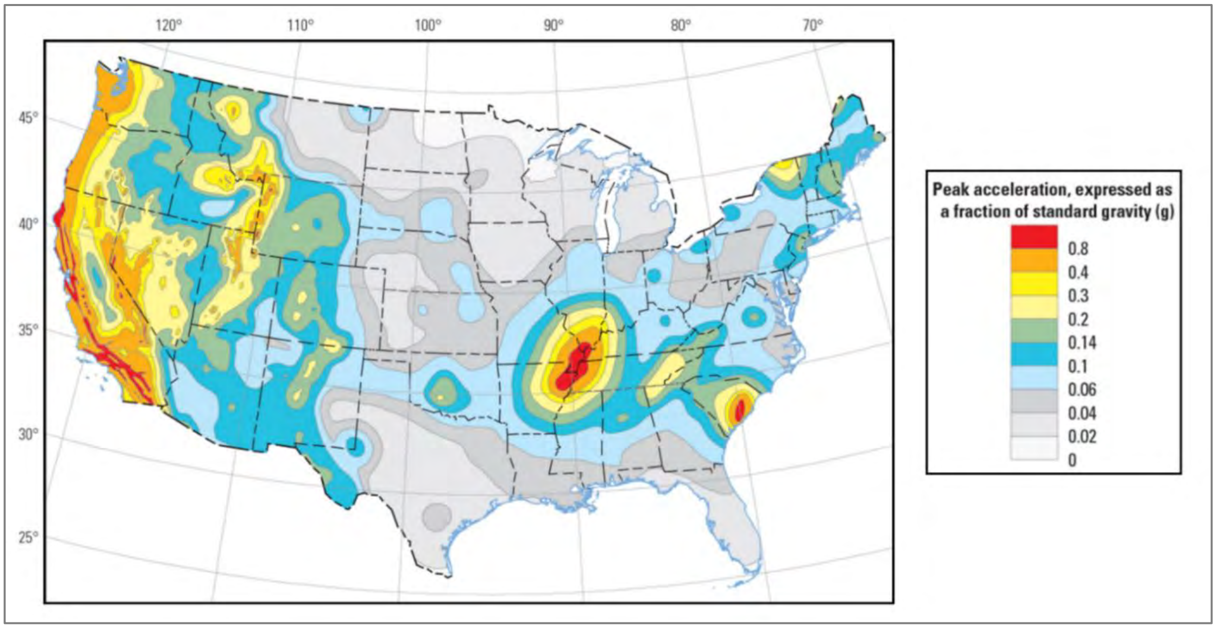

Table 2
MODIFIED MERCALLI INTENSITY SCALE[3]

Instrumental Intensity	Acceleration (g)	Perceived Shaking	Potential Damage
I	< 0.000464	Not felt	None
II–III	0.000464 – 0.00297	Weak	None
IV	0.00297 – 0.0276	Light	None
V	0.0276 – 0.115	Moderate	Very light
VI	0.115 – 0.215	Strong	Light
VII	0.215 – 0.401	Very strong	Moderate
VIII	0.401 – 0.747	Severe	Moderate to heavy
IX	0.747 – 1.39	Violent	Heavy
X+	> 1.39	Extreme	Very heavy

[2] Petersen, M.D., Moschetti, M.P., Powers, P.M., Mueller, C.S., Haller, K.M., Frankel, A.D., Zeng, Yuehua, Rezaeian, Sanaz, Harmsen, S.C., Boyd, O.S., Field, Ned, Chen, Rui, Rukstales, K.S., Luco, Nico, Wheeler, R.L., Williams, R.A., and Olsen, A.H. 2014. *Documentation for the 2014 update of the United States national seismic hazard maps: U.S. Geological Survey Open-File Report 2014–1091.*

Map displayed is Figure 1 (Page 6) of the USGS report. As stated in the USGS report, information displayed is public domain.

[3] See United States Geological Survey. *Magnitude/Intensity Scale.* https://web.archive.org/web/20110623113247/http://earthquake.usgs.gov/learn/topics/mag_vs_int.php

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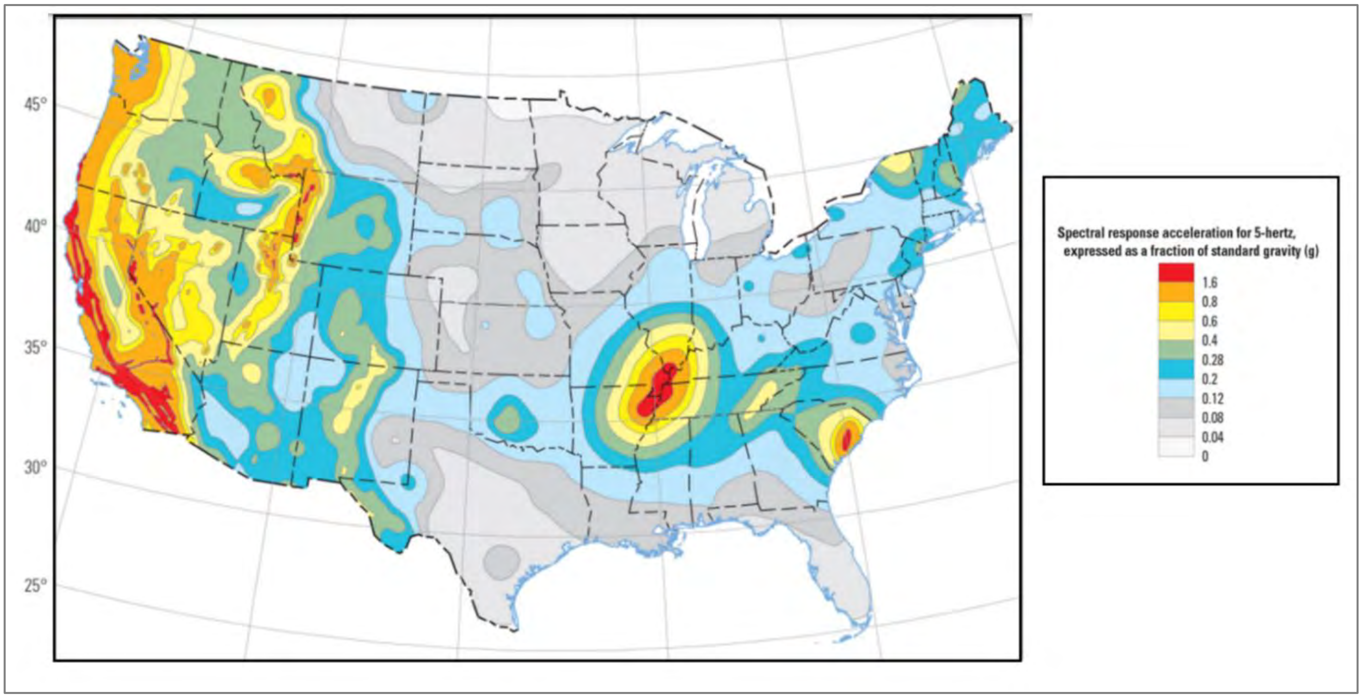
Spectral Acceleration - Like PGA, Spectral Acceleration (SA) provides a probability estimate of the forces expected at a given site. However, instead of forces on the ground-level, SA is a metric more appropriate for tall buildings and is "modeled by a particle mass on a massless vertical rod having the same natural period of vibration as the building."[4] Since the risk to tall buildings is more dependent on their own physical characteristics (such as vibration period), SA is often used instead of PHA, using the same parameters, but replacing site condition with hertz. The map below displays SA estimates for the contiguous United States, again using a probability of 2% and a return period of 50 years, but with a vibration period of five hertz.

Figure 2
USGS SPECTRAL ACCELERATION HAZARD MAP FOR THE CONTIGUOUS UNITED STATES [5]



PROSPECTIVE – LOSS MEASURES
The next type of metric, used more often in actuarial applications, is financial estimates of loss. These metrics typically result from simulation of scenarios considering events with different parameters like PGA or SA, applied to a stock of buildings, infrastructure, or population, to derive estimates of the total potential cost associated with seismic events. The data that underlies these models includes actual or representative buildings and their locations, their characteristics such as construction materials and qualities, and geological data like soil type.

Outputs of these models can include expected annual losses (average losses expected to occur in any given year, referred to as "EAL" in this report, also commonly referred to as "AAL" throughout the insurance industry). These losses may include total losses, losses to buildings, economic losses (which include estimates for economic disruptions), insured losses (which require they be modeled using insurance parameters such as deductible and

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[4] USGS. Earthquake Hazards 201 – Technical Q &A.
https://www.usgs.gov/programs/earthquake-hazards/science/earthquake-hazards-201-technical-qa#overview

[5] Petersen et al. Map displayed is Figure 2 (Page 7) of the USGS report. As stated in the USGS report, information displayed is public domain.

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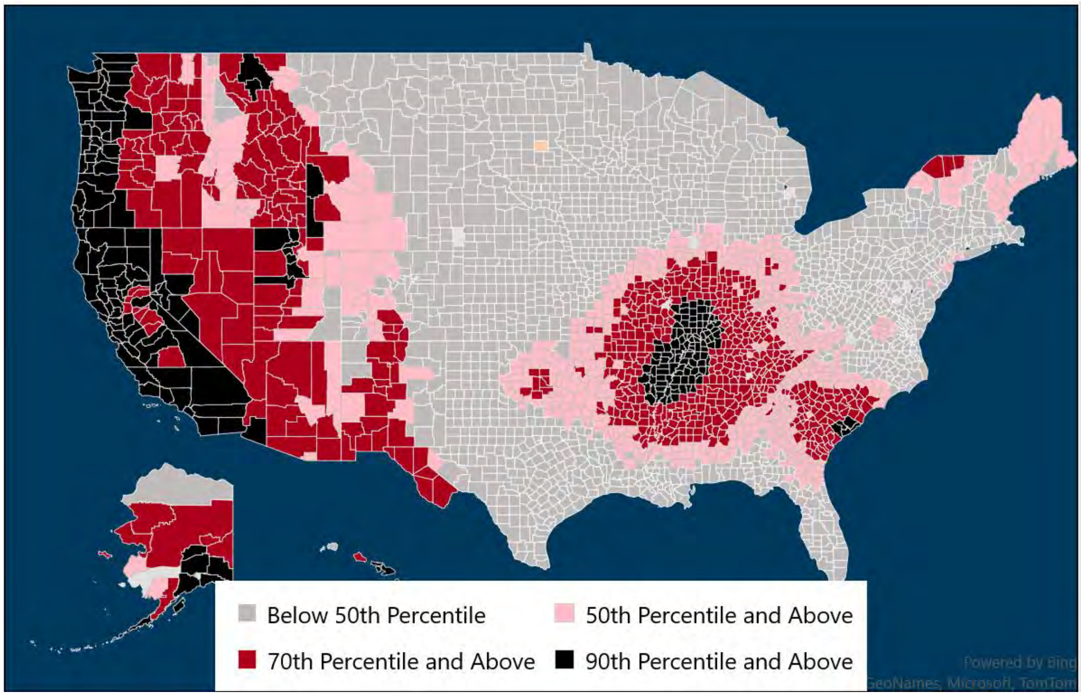
policy limit), or aggregate probability measures such as Value at Risk (VaR), which estimate the total losses at remote probabilities.

For this report, EAL is frequently used to buildings as modeled by FEMA's NRI. FEMA provides this metric in percentiles, mapped at the county level in Figure 3.

Figure 3
NRI - EXPECTED DAMAGE COUNTY PERCENTILE GROUPS FOR THE CONTIGUOUS UNITED STATES[6]



The map identifies similar regions with earthquake risk as the USGS map. These will be explored in a later section.

RETROSPECTIVE – EVENT MAGNITUDE

Another metric used to describe earthquakes is "Magnitude." Types of magnitude include the Richter scale or Moment Magnitude Scale. In general, magnitude measures represent the energy release associated with a given event and are on a logarithmic scale (where a 1-point increase in scale represents a 10X energy release.) The specific calculations and parameters of these scales are too complex for this report, but it is important to understand that high-magnitude events are rare. The following rough scale from "Earthquakes Canada" (the Canadian agency responsible for measuring earthquake risk), gives a rough guide to the damage associated with a given magnitude:

[6] Zuzak et al. FEMA NRI county-level data, EAL percentile rank for buildings, aggregated by percentile group.

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Table 3
DAMAGE POTENTIAL BY EARTHQUAKE MAGNITUDE[7]

Magnitude	Effects
< 3.5	Recorded on local seismographs, but generally not felt.
3.5 - 5.4	Often felt, but rarely cause damage.
5.5 – 6.0	Slight damage to well-designed buildings. Major damage to poorly constructed buildings.
6.1 - 6.9	Damage to poorly constructed buildings and other structures in areas up to about 100 kilometers across.
7.0 - 7.9	"Major" earthquake. Can cause serious damage over larger areas.
8.0 - 8.9	"Great" earthquake. Can cause serious damage and loss of life in areas several hundred kilometers across.
>9.0	Rare great earthquake. Can cause major damage over a large region over 1,000 km across.

RETROSPECTIVE – DAMAGE AND FATALITY ESTIMATES

Historical earthquakes are also measured in terms of damage. This can be in dollars, inflation-adjusted dollars, or human costs such as injuries or fatalities. Table 4 depicts damage estimates for the 10 costliest earthquakes in United States history, ranked by inflation-adjusted cost.

It is not necessarily the case that the highest magnitude earthquakes cause the most damage. Instead, the most damaging earthquakes are typically those with fairly high magnitude, but that occur in or near urban centers, particularly the San Francisco Bay or Los Angeles areas. The costliest earthquake in U.S. history was the 1994 Northridge earthquake, which caused $32.2 billion in inflation-adjusted losses.

[7] Earthquakes Canada. *Earthquake Magnitude Scales.* https://earthquakescanada.nrcan.gc.ca/info-gen/scales-echelles/magnitude-en.php

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Table 4
DAMAGE MEASUREMENTS FOR COSTLIEST HISTORICAL EARTHQUAKES[8]

Event	General Location	Magnitude	Losses ($ Millions) When Occurred	Losses ($ Millions) Inflation Adjusted	Fatalities
1994 Northridge	Los Angeles Area	6.7	$15,300	$32,210	57
1906 San Francisco	San Francisco	7.9	$235	$8,295	3,000
1989 Loma Prieta	San Francisco Bay Area	6.9	$960	$2,353	63
2001 Longbranch	Seattle Area	6.8	$315	$551	0
2020 Puerto Rico	Puerto Rico	6.4	$425	$507	1
2014 Napa	Northern California	6.0	$200	$259	2
1971 San Fernando	Los Angeles Area	6.6	$32	$244	64
1987 Whittier Narrows	Los Angeles Area	5.9	$75	$200	8
2018 Pt. MacKenzie	Anchorage, Alaska	7.1	$150	$183	0
2011 Virginia	Washington DC Area	5.8	$100	$136	0

Another notable event was the 1906 San Francisco earthquake. While the physical damage from this earthquake was not as widespread as Northridge, the death toll of approximately 3,000 was the highest in U.S. history. Fortunately, given improvements in building standards and emergency response, it is unlikely that U.S. earthquakes in the future will cause similar death tolls, even if they are just as severe in terms of magnitude and damage.

1.3 WHAT REGIONS ARE SEISMICALLY ACTIVE?

Using the metrics mentioned above, I sought to identify states and regions with significant enough risk for further focus. First, I used the maps to identify the states and provinces with risk. Then I used the maps for PGA, SA, and EAL to identify the severity of risk in each area. I also identified the fault types associated with each region, the size of the population at risk, and the presence of significant urban areas in each seismic zone. Using these complied statistics, I decided which states and regions would receive further attention in the report. My decision for exclusion or exclusion is in the rightmost column of the table:

[8] Earthquake damage estimates from:
Insurance Information Institute. *A Firm Foundation: How Insurance Supports the Economy*.
https://www.iii.org/publications/a-firm-foundation-how-insurance-supports-the-economy/supporting-resiliency-and-disaster-recovery/earthquakes

Magnitudes from:
United States Geological Survey. Search Earthquake Catalog.
https://earthquake.usgs.gov/earthquakes/search/

Fatalities data compiled from various online sources.

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Table 5
SELECTION CRITERIA FOR FOCUS ZONES

Region	Major Faults (Type) [9]	Areas at Risk		Maximum Acceleration[10]		Population in EAL zone "Very High" or above[11]		Included for Focus In Report[12]
		States and Provinces	Population Centers	Peak Ground	Spectral	Total	%	
California Coast and Sierra Nevada Faults	San Andreas (Strike-Slip) Hayward (Strike-Slip) Calaveras (Strike-Slip) Carson Range (Normal)	California	Los Angeles San Francisco San Diego	>.8	>1.6	29,525,635	75%	Yes
		Nevada	Reno/Sparks	>.8	>1.6	687,140	22%	Yes
Cascadia Subduction Zone	(Megathrust)	British Columbia	Vancouver	>.8	>1.6	Note[13]		Yes
		Washington	Seattle	.4 to .8	.8 to 1.6	4,920,693	64%	Yes
		Oregon	Portland	.4 to .8	>1.6	2,972,193	70%	Yes
Wasatch Fault	(Normal)	Montana	Bozeman Helena	.4 to .8	.8 to 1.6	56,349	5%	No
		Idaho	Boise	.3 to .4	.8 to 1.6	1,513	0%	No
		Wyoming	Jackson	>.8	>1.6	26,624	5%	No
		Utah	Salt Lake City Provo	.4 to .8	>1.6	1,818,013	56%	Yes
New Madrid Fault	(Intraplate)	Missouri	St. Louis	>.8	>1.6	405,259	7%	Yes
		Illinois	Carbondale	>.8	>1.6	467,436	4%	Yes
		Indiana	Evansville	.3 to .4	.6 to .8	57,508	1%	No
		Kentucky	Paducah	>.8	>1.6	225,326	5%	Yes
		Tennessee	Memphis	>.8	>1.6	731,437	11%	Yes
		Mississippi	Oxford	.4 to .8	.8 to 1.6	149,841	5%	No
		Arkansas	Jonesboro	>.8	>1.6	300,867	10%	Yes
Middleton Seismic Zone	(Intraplate)	North Carolina	Charlotte	.14 to .2	.28 to .4	4,920,693	0%	No
		South Carolina	Charleston	>.8	>1.6	2,972,193	13%	Yes
		Georgia	Atlanta	.14 to .2	.28 to .4	29,525,635	0%	No
Eastern Tennessee	(Unknown)	Tennessee	Chattanooga Knoxville	.2 to .3	.4 to .6	687,140	11%	No
St. Lawrence River/ Charlevoix Seismic Zone	(Intraplate)	New York	Buffalo	.3 to .4	.4 to .6	0	0%	No
		Vermont	Burlington	.2 to .3	.4 to .6	0	0%	No
		New Brunswick	Fredericton	.4 to .6	>1.6	Note[14]		No
		Ontario	Ottawa	.4 to .8	.8 to 1.6			Yes
		Quebec	Quebec City Montreal	>.8	>1.6			Yes
Alaska	Denali (Strike Slip) Totschunda (Strike Slip)	Alaska	Fairbanks Anchorage	Note[15]		456,745	62%	Yes
Hawaii	Hilina Volcanic Fault System (Normal)	Hawaii	Hilo Honolulu			236,810	16%	Yes
Puerto Rico	Puerto Rico Trench (Strike Slip)	Puerto Rico	San Juan			1,867,437	57%	Yes
Oklahoma	Suspected connection with human activity	Oklahoma	Oklahoma City	.2 to .3	.28 to .4	0	0%	No
Rocky Mountain	General intraplate stresses	New Mexico	Albuquerque Santa Fe	.2 to .3	.4 to .6	0	1%	No

[9] Fault types were populated using various online sources.
[10] Spectral Acceleration at 5hz, Peak Ground Acceleration at .2 seconds, both at 2%/50-year exceedance probability.
[11] Population in census tracts with this designation. Based on FEMA CRI census tract level data.
[12] States proposed for study inclusion.
[13] EAL data not available for Canadian provinces, so PGA and SA maps used for determination.
[14] EAL data not available for Canadian provinces, so PGA and SA maps used for determination.
[15] PGA and SA maps could not be readily obtained for the noncontiguous United States, so EAL data relied upon for determination.

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Based on this information, included are states and regions that either had severe risk, a high population at risk, or a high percentage of population at risk. Other areas appearing significant on the map were not included because these elements were not present. Indiana, for example, while appearing to have similar maximum intensity as Illinois, has a smaller population at risk (57,508 - the at-risk population of 467,436 in Illinois is over 8 times larger).

With these states and regions selected, it was decided to focus on the counties which registered in NRI's 70th percentile and above. Aggregating building values and expected losses for those counties/states, the total risk was tabulated and compared to the national total in Table 6.

Table 6

NATIONAL RISK INDEX - EARTHQUAKE RISK AS PERCENTAGE OF NATIONAL TOTAL FOR SELECTED REGIONS[16]

Zone	State	Building Value ($ Billions)	Expected Earthquake Losses ($ Millions)	% of National Total	
				Expected Losses	Building Value
California and Sierra Nevada	California	$6,898	$9,615	65.0%	11.1%
	Nevada	$560	$297	2.0%	0.9%
Cascadia Subduction	Washington	$1,458	$1,191	8.1%	2.3%
	Oregon	$898	$745	5.0%	1.4%
Wasatch	Utah	$463	$366	2.5%	0.7%
New Madrid	Missouri	$890	$181	1.2%	1.4%
	Illinois	$586	$148	1.0%	0.9%
	Kentucky	$606	$104	0.7%	1.0%
	Tennessee	$1,187	$283	1.9%	1.9%
	Arkansas	$430	$112	0.8%	0.7%
Middleton	South Carolina	$940	$191	1.3%	1.5%
Alaska	Alaska	$167	$121	0.8%	0.3%
Hawaii	Hawaii	$213	$127	0.9%	0.3%
National Total		**$62,375**	**$14,784**	**100.0%**	**100.0%**
Selection Total		**$15,296**	**$13,481**	**91.2%**	**24.5%**

Using the 70th percentile and above, counties in these states capture a large majority of national earthquake risk, accounting for 24.5% of total building value, but comprising 91.2% of total risk to buildings. Given its large share of earthquake risk, this is an appropriate set of regions to consider, and that the earthquake risk is insignificant enough in other regions throughout the country that no additional policies are necessary to address it.

Earthquake risk, while present in different regions, is mostly Western. California accounts for 65.0% of the EAL in the United States. Adding Washington (8.1%), and Oregon (5.0%) would total 78.1% of risk, with only 14.8% of building value. Including Nevada and Utah would total 82.6% of risk and only 16.4% of building value.

1.4 EARTHQUAKE RISK IN KEY CITIES

Another comparison to understand the relative earthquake risk in each region is its potential intensity in urban areas. USGS provides a "Unified Hazard Tool" with probabilistic estimates of physical parameters, given a set of coordinates. For this comparison, the USGS default coordinates are used in the Table 7 for the population centers

[16]Data aggregated from county-level NRI. "Selection Total" includes all counties identified as being in the 70th percentile and above for earthquake risk. "National Total" includes all counties in the United States.

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associated with the regions in the previous section, along with the default site class assumption of 760 m/s. Please note, while this comparison is useful, it is important to specify that both earthquake risk and site can vary significantly within each city, so these default assumptions do not capture the full range of risk in any of them.

Table 7
SAMPLE CITY COORDINATES FOR CITY COMPARISON[17]

Region	State	Sample City	Sample Latitude	Sample Longitude
California and Sierra Nevada	California	Los Angeles	34.054	-118.245
	California	San Francisco	37.777	-122.420
	Nevada	Reno	39.258	-119.814
Cascadia	Washington	Seattle	47.604	-122.329
	Oregon	Portland	45.512	-122.676
Wasatch	Utah	Salt Lake City	40.760	-111.888
New Madrid	Missouri	St. Louis	38.628	-90.200
	Illinois	Carbondale	37.727	-89.216
	Kentucky	Paducah	37.806	-88.596
	Tennessee	Memphis	35.150	-90.049
Middleton	South Carolina	Charleston	32.781	-79.932
Hawaii	Hawaii	Honolulu	21.305	-157.858

The result was the following exceedance probabilities.

[17] Default Coordinates for each city using USGS Unified Hazard Tool: https://earthquake.usgs.gov/hazards/interactive/

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Table 8

SAMPLE CITY PEAK GROUND ACCELERATION: 50-YEAR EXCEEDANCE PROBABILITIES[18]

	Ground Acceleration (g)							
	0.0896	0.134	0.202	0.302	0.454	0.68	1.02	1.53
City	Light Damage		Moderate Damage		Moderate to Heavy		Heavy Damage	
Los Angeles	77.1%	56.4%	35.5%	19.7%	9.4%	3.8%	1.2%	0.3%
San Francisco	78.6%	59.3%	38.0%	20.4%	8.7%	2.9%	0.7%	0.1%
Reno	69.5%	47.6%	27.9%	14.5%	6.5%	2.4%	0.7%	0.2%
Seattle	56.1%	37.4%	21.4%	10.7%	4.5%	1.5%	0.4%	0.1%
Portland	19.5%	12.4%	7.1%	3.6%	1.6%	0.6%	0.2%	0.0%
Salt Lake City	22.2%	15.8%	11.2%	7.5%	4.3%	2.0%	0.7%	0.2%
St. Louis	13.8%	8.5%	4.7%	2.3%	1.1%	0.5%	0.2%	0.1%
Carbondale	22.5%	15.9%	10.5%	6.2%	3.2%	1.4%	0.5%	0.2%
Paducah	27.2%	19.8%	13.9%	9.0%	5.0%	2.4%	1.0%	0.3%
Memphis	22.7%	17.1%	12.2%	8.1%	4.7%	2.4%	1.1%	0.4%
Charleston	21.1%	16.5%	12.3%	8.8%	5.8%	3.5%	1.9%	0.9%
Honolulu	15.8%	8.3%	3.9%	1.6%	0.6%	0.2%	0.1%	0.0%

As Table 8 shows, there are city-specific differences from the regional comparisons. Consistent with the regional comparison, Western cities usually show higher probabilities at various intensities, however, there are reversals. For example, although Oregon is one of the riskiest states in the regional comparison, the exceedance probabilities for Portland are lower than for certain Midwestern and Eastern cities like Memphis and Charleston. Charleston, while associated with small probabilities in the “light damage” and “moderate damage” categories, has an even higher probability of exceeding “heavy damage” values than San Francisco or Los Angeles. The figure below illustrates this.

[18] Peak Ground Acceleration exceedance probabilities calculated for USGS Unified Hazard Tool using sample coordinates for site class 760m/s. Damage categories given by the Modified Mercalli Intensity Scale.

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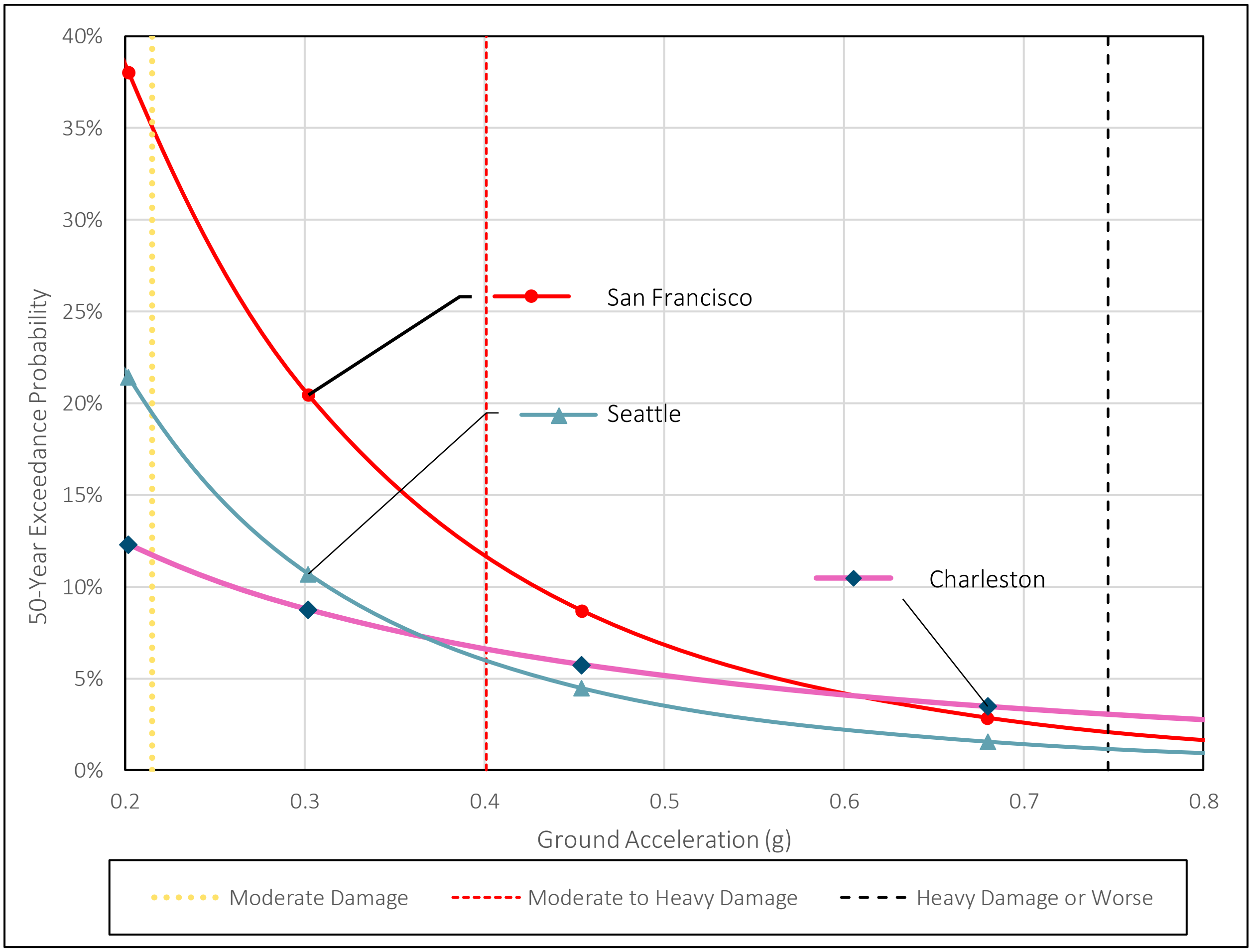
Figure 4

COMPARISON OF LOW SEVERITY AND HIGH-SEVERITY PROBABILITIES FOR 3 CITIES



1.5 HISTORY OF EARTHQUAKES

Next, is a look at the history of earthquakes to see where they have occurred and how they align with risk maps, and consider lessons learned. Earthquakes since 1900 are in the map in Figure 5 and Table 9.

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Figure 5

EARTHQUAKES SINCE 1900 - MAP FOR THE CONTIGUOUS UNITED STATES

Table 9

UNITED STATES EARTHQUAKES SINCE 1900 OCCURRING IN COUNTIES OF 70TH PERCENTILE EAL AND ABOVE[19]

		Magnitude						Total	
Zone	States	4.5 to 5.0	5.0 to 6.0	6.0 to 7.0	7.0 to 8.0	8.0 to 9.0[20]	Above 9.0	Count	%
California and Sierra Nevada	California Nevada	1,136	583	73	7	0	0	1,799	43.8%
Cascadia Subduction	Oregon Washington	112	38	6	0	0	0	156	3.8%
Wasatch	Utah	18	17	2	0	0	0	37	0.9%
New Madrid	Missouri Illinois Kentucky Tennessee Arkansas	29	5	0	0	0	0	34	0.8%
Middleton	South Carolina	1	0	0	0	0	0	1	0.0%
Alaska	Alaska	881	409	76	12	0	0	1,378	33.6%
Hawaii	Hawaii	108	96	10	1	0	0	215	5.2%
	National Total	2,579	1,310	189	24	1	0	4,103	100.0%
	Selected Regions	2,285	1,148	167	20	0	0	3,620	88.2%

[19] Data from United States Geological Survey. Search Earthquake Catalog https://earthquake.usgs.gov/earthquakes/search/

[20] Note that the data displayed only includes earthquakes with an epicenter on land. If earthquakes occurring off the coast with epicenters in water were included, they were Alaskan earthquakes in the 8.0 to 9.0 range during this period.

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Aligned with measures of risk, the activity in California, Washington, and Nevada is significant, while activity in the rest of the country is sparse. Please find detailed state-level data for historical earthquakes in the appendix.

HISTORICAL EARTHQUAKES AND LESSONS LEARNED

The data provided so far gives a sense of the overall frequency and locations of earthquakes, but there are specific events worth considering for the lessons learned from them.

Cascadia Earthquake and Tsunami, 1700[21]

On January 26, 1700, a major earthquake occurred off the coast of Washington and British Columbia. While there was no western record of this event at the time, it was confirmed using records from Japan, where a small tsunami occurred. In Cascadia, it has been studied via geological records.

The population of the Pacific Northwest region was small at the time, so it is likely the death toll was also small. However, the region has become heavily populated in the ensuing centuries, and the threat today could be significant. Scientists consider it inevitable that such an event will occur and could threaten urban centers such as Vancouver, Victoria, Portland, and Seattle. Most of these are situated inland, and thus not at extreme risk. Nevertheless, it is possible that a Cascadia tsunami could cause a mass casualty event.

Charleston Earthquake, 1886[22]

In the table of historical earthquakes (Table 9) South Carolina has only experienced one earthquake above magnitude 4.5 since 1900, and it below a magnitude of 5.0, barely enough to cause damage. If earthquakes rarely happen in this region, why is it significant?

As shown in the city comparison (Table 8, Figure 4), the expectation for this region is low frequency of mild events, but a material risk of major ones. This was demonstrated by the August 31, 1886, earthquake which occurred near Summerville, SC. Although earthquake measurement was not advanced enough to adequately capture its physical parameters, scientists estimate a magnitude of at least 7.0, which is rare for this part of the country, but always a possibility.

San Francisco Earthquake, 1906[23]

This massive earthquake devastated the young city of San Francisco. With a magnitude of 7.9, it was one of the most powerful seismic events recorded in California history. Beyond damage from the shaking, it was notable for the ensuing fire, which caused structures to burn throughout the city, and underscoring the importance of understanding follow-on effects to earthquakes.

Loma Prieta Earthquake, 1989[24]

Another major earthquake to strike the San Francisco Bay Area, this event is notable for the unexpected damages that occurred. It exposed the relative lack of preparation of the region’s infrastructure, and resulted in the collapse of major highways, including the San Francisco Bay Bridge.

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[21] Description relies on: Earthquakes Canada. *The M9 Cascadia Megathrust Earthquake of January 26, 1700.* https://earthquakescanada.nrcan.gc.ca/historic-historique/events/17000126-en.php

[22] Description relies on: Earth Magazine. *Benchmarks: August 31, 1886: Magnitude-7 earthquake rocks Charleston, South Carolina.* *https://www.earthmagazine.org/article/benchmarks-august-31-1886-magnitude-7-earthquake-rocks-charleston-south-carolina/*

[23] Description relies on: United States Geological Survey. *The Great 1906 San Francisco Earthquake.* https://earthquake.usgs.gov/earthquakes/events/1906calif/18april/

[24] Description relies on: National Geographic. *Oct 17, 1989 CE: Loma Prieta Earthquake.* https://education.nationalgeographic.org/resource/loma-prieta-earthquake/

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Northridge Earthquake, 1994[25]

This was the single most damaging earthquake in United States history. Beyond monetary damage, this event played a key role in shaping the current earthquake insurance landscape.

Prior to this, and due to the high earthquake risk in the state, California homeowners insurers were required to offer earthquake coverage with every policy. There was no centrally organized insurer, so the mandatory offer meant that insurers must provide the coverage themselves. Insurers incurred significant losses from Northridge, and reevaluated the potential risk they faced due to earthquakes, revising their risk estimates upward. Since earthquake coverage was attached to homeowners policies, many insurers significantly limited their underwriting appetites in the homeowners line, resulting in an availability crisis.

The solution was the disaggregation of earthquake insurance from homeowners. Insurance companies and policymakers formed the California Earthquake Authority (CEA), which today is the single largest writer of earthquake insurance in the country. The CEA is owned and managed as a public/private partnership between state authorities and the largest homeowners insurers. Instead of combining earthquake coverage with homeowners, these policies are sold separately, allowing insurers to offer underwriting capacity without the fear of accumulating undesirable concentrations of earthquake risk. Insurers are no longer required to write earthquake insurance but are required to offer it to all customers in an effort to promote availability. As mentioned, the main benefit of these policies is to encourage the availability of non-earthquake coverage, and also to promote earthquake coverage through the mandatory offer. On the other hand, one drawback of the program may be limited take-up rates of earthquake coverage, as consumers are able to obtain homeowners coverage while opting out of earthquake protection.

1.6 OTHER RISKS CONNECTED WITH EARTHQUAKES

Beyond physical risk from shaking, there are adjacent or follow-on risks in connection with seismic activity.

THE INSURANCE GAP

The first risk is underinsurance, or lack of insurance. There are many homeowners and owners of other property in the United States that do not carry insurance for the risk of earthquakes, even in seismically active regions. Contributing factors include: the price of insurance, lack of risk awareness, the separation of earthquake from standard policies, and the infrequent nature of events.

To provide an initial understanding of the size and magnitude of the earthquake insurance gap, data from NRI EAL is compared with Direct Written Premium data for U.S. Insurers.

[25] Description relies upon: California Earthquake Authority. *History of the California Earthquake Authority.* https://www.earthquakeauthority.com/about-cea/cea-history

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Table 10

EARTHQUAKE DIRECT WRITTEN PREMIUM AND NATIONAL RISK INDEX EXPECTED ANNUAL LOSSES BY STATE[26]

State	Earthquake Direct Written Premium (DWP)	Expected Annual Losses (EAL)	% of Country		DWP to EAL Ratio
			DWP	EAL	
California	$2,959,391	$ 9,614,544	57.5%	65.0%	31%
Nevada	61,117	297,403	1.2%	2.0%	21%
Washington	365,264	1,191,743	7.1%	8.1%	31%
Oregon	162,088	744,979	3.1%	5.0%	22%
Utah	117,289	366,714	2.3%	2.5%	32%
Missouri	137,690	188,476	2.7%	1.3%	73%
Illinois	114,174	178,825	2.2%	1.2%	64%
Kentucky	56,610	110,538	1.1%	0.7%	51%
Tennessee	128,858	284,250	2.5%	1.9%	45%
Arkansas	50,713	116,006	1.0%	0.8%	44%
South Carolina	61,840	193,976	1.2%	1.3%	32%
Alaska	55,277	120,717	1.1%	0.8%	46%
Hawaii	25,630	126,956	0.5%	0.9%	20%
Puerto Rico	130,597	326,809	2.5%	2.2%	40%
National Total	**$5,150,043**	**$ 14,783,698**	**100.0%**	**100.0%**	**35%**

U.S. insurers wrote around $5.15 billion of earthquake premiums in 2022, compared with an NRI EAL to buildings of $14.78 billion. As a general rule of thumb, property insurers generally devote 35% of premiums to underwriting expenses and margins for risk and profits, with the other 65% going to cover expected losses and reinsurance. Thus, for earthquake risk to be fully insured, it would be expected for written premiums to total approximately ($14.78 billion) / (65%) = $22.74 billion. Comparing this figure to the current premium of $5.15 billion, it can be estimated that only ($5.15) / ($22.74) = 22.6% of earthquake risk in the United States is insured.

These are rough estimates. Some uninsured risk is covered by foreign insurers who do not report their writings on U.S. financial statements. Additionally, most earthquake policies include high deductibles and low limits, meaning that a higher fraction of properties could carry some insurance than would be implied by the estimates above, albeit with a substantial fraction of risk retained by the property owner. Finally, it is important to note that NRI and the statutory financial data from which the written premium totals were obtained were made for different purposes and not intended for comparison, casting doubt on the precision of these estimates. Similarly, vendor models typically trusted by the insurance industry would yield different estimates than NRI. Nevertheless, given the large gap between insurance premiums and risk, it can be concluded that a large share of earthquake risk is uninsured. The spread of this problem varies significantly by state, with some New Madrid states like Missouri, Illinois, and Kentucky showing comparatively better coverage than West Coast states or Hawaii. More comprehensive data on these coverage gaps is difficult to obtain, as few states have undertaken comprehensive programs or studies to understand the prevalence of coverage. However, there have been efforts to obtain this information:

[26] Direct Written Premium data obtained from the S&P Global Capital IQ platform and is from the statutory annual statements of all U.S. insurers who filed such statements. EAL data is aggregated from the NRI.

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- A 2016 report by the Organisation for Economic Co-operation and Development (OECD)[27] estimated that between 5% and 10% of all U.S. households, and between 10% and 20% of U.S. households in the West carry earthquake coverage. This finding is consistent with the estimate above.
- For Canada, the same report estimated that under 5% of households in the East have coverage; but encouragingly, that between 60% and 70% of households in the West carry earthquake insurance.

- A 2017 study by Washington State[28] estimated that 11.3% of all homeowners policies were also associated with an earthquake policy, ranging between 18.1% for the highest county, to .02% for the lowest county. It should be noted that, given the steep risk gradient in the state, the .02% for the lowest county may be appropriate, where the 18.1% in the highest county represents significant underinsurance.

    - Consistent with this study, a 2018 report by the National Association of Insurance Commissioners (NAIC)[29] estimated that 14% of residences in Western Washington carried earthquake insurance, compared with over 60% in the lower mainland of British Columbia.

- A 2022 study by the California Department of Insurance[30] estimates that the count of earthquake policies is about 12.7% of the count of homeowners policies in the state. However, focusing purely on single family homeowners policies (excluding renters, condominium, dwelling fire, and mobile home), yields a better estimate of around 15%.

    - While the NRI estimates above indicate that Missouri has the highest level of coverage relative to risk among all states, a 2022 report by the Missouri Department of Commerce and Insurance[31] reports a worrying decline in the take-up of residential policies, with the total percentage of residences with coverage declining from 43.6% in 2000 to 23.8% in 2021.

Though data is limited, the above studies corroborate the overall conclusion suggested by the comparison of EAL with Direct Written Premium. It is clear that a minority of homeowners purchase coverage for earthquakes, even in the country's riskiest regions. In Canada, especially in British Columbia, the indications are more encouraging.

PHYSICAL RISKS: TSUNAMI AND FIRE FOLLOWING EARTHQUAKE

Besides the risk from shaking, earthquakes can lead to other phenomena which can be just as devastating. Tsunamis occur when offshore earthquakes cause oceanic waves to come ashore, causing damage to property and loss of life. Since the timing of earthquakes is unknown, tsunamis often catch populations by surprise, compounding the devastation. Examples include Japan's 2011 Tohoku Earthquake and Tsunami, for which the follow-on effects included not only substantial casualties, but a nuclear disaster which contaminated the surrounding environment

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[27] OECD (2018), *Financial Management of Earthquake Risk*.
https://web-archive.oecd.org/2018-06-04/485307-financial-management-of-earthquake-risk.htm

[28] Office of the Insurance Commissioner of Washington State. *2017 Earthquake Data Call Report.*
https://www.insurance.wa.gov/sites/default/files/2018-02/earthquake-data-call-report.pdf

[29] Cole, Cassandra and McCullough, Kathleen. *The Earthquake Insurance Protection Gap: A Tale of Two Countries.* Journal of Insurance Regulation.
https://content.naic.org/sites/default/files/jir-za-39-11-el-earthquake-protection.pdf

[30] California Department of Insurance. *Residential Earthquake Insurance Coverage Study.* Numbers referenced are calculated as 1,624,479 total earthquake policies compared to 12,782,020 homeowners policies, and 961,862 single family residential earthquake policies compared to 6,396,971 single family residential homeowners policies.
https://www.insurance.ca.gov/0400-news/0200-studies-reports/0300-earthquake-study/

[31] Missouri Department of Commerce and Insurance. *Residential Earthquake Coverage in Missouri.*
https://insurance.mo.gov/earthquake/documents/OverviewofResidentialEarthquakeInsurancein2021.pdf

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and cost billions in remediation costs;[32] and the 2004 tsunami that occurred near Indonesia, which caused over 230,000 deaths.[33]

As described in the 1906 San Francisco quake, fires that follow earthquakes can also cause damage. Earthquakes can damage power lines or gas mains and impair response services, allowing fires to spread and causing damage.

Relying on the NRI, which provides tsunami estimates directly, a quantification of the susceptible areas of the United States is provided. NRI provides no data directed at fires following earthquakes, but it does provide EALs for wildfire, which is a connected risk. Although many of the fires that follow earthquakes may occur in urban settings, and therefore be unrelated to wildfire risk, downed powerlines are a known cause of many significant wildfires and can be caused by earthquakes. Thus, although wildfire is a flawed proxy for fire following earthquake, it will be helpful to provide an estimate of it. NRI tsunami and wildfire EALs are in Table 11.

Table 11
NRI - EARTHQUAKE EAL COMPARED TO TSUNAMI AND WILDFIRE

			Expected Annual Losses ($ Millions)		
Zone	State	Building Value ($ Billions)	Earthquake	Tsunami	Wildfire
California and Sierra Nevada	California	$6,898	$9,615	$0.58	$1,419
	Nevada	$560	$297	$0.00	$110
Cascadia Subduction	Washington	$1,458	$1,191	$0.39	$90
	Oregon	$898	$745	$0.33	$67
Wasatch	Utah	$463	$366	$0.00	$191
New Madrid	Missouri	$890	$181	$0.00	$14
	Illinois	$586	$148	$0.00	$1
	Kentucky	$606	$104	$0.00	$17
	Tennessee	$1,187	$283	$0.00	$3
	Arkansas	$430	$112	$0.00	$22
Middleton	South Carolina	$940	$191	$0.00	$14
Alaska	Alaska	$167	$121	$0.52	$24
Hawaii	Hawaii	$213	$127	$1.92	$34

The states with tsunami risk are coastal ones – California, Washington, Oregon, Hawaii, and Alaska. While EAL estimates appear small relative to earthquake, note that the most severe tsunamis can result in substantial casualties. For wildfire, the risk is also most significant in the West, with California, Nevada, and Utah all registering wildfire EALs more than $100 million. However, wildfire risk is not negligible compared to earthquake risk in nearly every state, so the risk of a significant fire following an earthquake could also occur.

[32] Britannica. *Japan Earthquake and Tsunami of 2011.* https://www.britannica.com/event/Japan-earthquake-and-tsunami-of-2011

[33] World Vision. 2004 Indian Ocean Earthquake and Tsunami: Facts and FAQs. https://www.worldvision.org/disaster-relief-news-stories/2004-indian-ocean-earthquake-tsunami-facts#:~:text=Approximately%20230%2C000%20people%20died%20in,23%2C000%20Hiroshima%2Dtype%20atomic%20bombs.

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FINANCIAL RISKS: OCCUPANCY AND ECONOMIC LOSS

Another set of risks connected with earthquakes stem from property ownership patterns or economic disruptions. Table 12 shows various occupancy characteristics for the selected seismically active states, as well as economic potential losses, as estimated by the NRI.

Table 12

OCCUPANCY CHARACTERISTICS AND ECONOMIC VULNERABILITY FOR THE UNITED STATES[34]

		Occupancy Characteristics				Economic Vulnerability
Zone	State	Owner Occupancy Rate	Single Family Occupancy Rate	2 to 19 Units	>19 Units	Economic Losses Per $1k Income
California and Sierra Nevada	California	55%	67%	19%	13%	$7.40
	Nevada	57%	69%	22%	10%	$3.52
Cascadia Subduction	Washington	63%	71%	16%	13%	$4.41
	Oregon	63%	74%	16%	10%	$6.49
Wasatch	Utah	70%	77%	15%	8%	$4.80
New Madrid	Missouri	68%	78%	17%	5%	$1.69
	Illinois	70%	81%	14%	5%	$2.48
	Kentucky	66%	78%	18%	4%	$1.41
	Tennessee	66%	79%	16%	6%	$1.69
	Arkansas	67%	82%	15%	3%	$2.17
Middleton	South Carolina	70%	79%	14%	6%	$1.62
Alaska	Alaska	65%	75%	20%	5%	$5.05
Hawaii	Hawaii	60%	63%	17%	20%	$3.07
	National Total	**58%**	**72%**	**18%**	**10%**	**$1.50**
	Selection Total	**61%**	**72%**	**18%**	**10%**	**$5.05**

One of the key risks associated with earthquakes is underinsurance of homeowners' properties. However, occupancy can vary, so the most important risks related to residences may also vary by state. Utah, Illinois, and South Carolina lead all states in terms of their rate of owner occupancy, at 70% each. California and Nevada, on the other hand, are comprised more substantially of renters, with owner occupancy rates at 55% and 57%, respectively. Because of this variance, the ultimate consequences of underinsurance may vary by state. If a homeowner suffers an uninsured loss, this could cause significant financial hardship, as well as temporary displacement, but it is likely the owner will return to their house. For renters, disasters could result in seeking new residences or relocating.

Similarly, the type of dwellings present could affect the consequences of an earthquake, and thus guide the optimal strategy for preparedness. For example, states in the interior like Illinois, Missouri, and Arkansas are comprised mostly of single-family residences, whereas California, Washington, or Hawaii have heavier concentrations of multifamily dwellings. Additionally, some states feature heavier concentrations in large (>19 unit) buildings. These buildings are often more resilient to shaking, but on the other hand could cause bigger displacements if damaged.

Finally, there is a wide variance in potential economic losses among states. If a major earthquake were to occur, it would disrupt local economies, causing losses beyond just those to buildings. Unsurprisingly, Western states lead this metric. However, there are some interesting reversals. For example, in most measures of risk Washington

[34] Occupancy and per capita income obtained from the S&P Global Capitol IQ platform, via Claritas, via the American Community Survey. Potential Economic losses obtained from NRI data.

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appears worse than Oregon. However, when risk is recast as economic losses per GDP, Oregon ends up more at risk than Washington, likely due to the fact that it is less affluent.

POPULATION RISKS: VULNERABILITY AND RESILIENCE

The final non-physical set of risks related to earthquake exposure relates to human vulnerability. Different territories feature different population characteristics, which could lead to different consequences from an earthquake. Metrics comparing each exposed state appear in Table 13.

Table 13

POPULATION VULNERABILITY CHARACTERISTICS FOR AFFECTED COUNTIES IN THE UNITED STATES[35]

Zone	State	Population Vulnerability			
		Family Poverty Rate	% Population over 65	Social Vulnerability Score	Community Resilience Score
California and Sierra Nevada	California	9%	16%	72	40
	Nevada	9%	18%	80	18
Cascadia Subduction	Washington	6%	17%	48	68
	Oregon	7%	20%	57	64
Wasatch	Utah	6%	12%	33	81
New Madrid	Missouri	9%	19%	41	66
	Illinois	9%	20%	40	81
	Kentucky	11%	18%	54	63
	Tennessee	10%	18%	56	53
	Arkansas	12%	19%	63	42
Middleton	South Carolina	10%	20%	69	59
Alaska	Alaska	6%	15%	55	39
Hawaii	Hawaii	6%	20%	54	73
	National Total	**9%**	**18%**	**58**	**57**
	Selection Total	**9%**	**17%**	**62**	**51**

While there are many potential dimensions to population vulnerability, poverty rates and the elderly population are a good starting point to look at. Impoverished families and individuals have a reduced capacity to evacuate, rebuild, or prepare. Elderly citizens may have physical impairments or medical needs that would cause extra difficulties in the aftermath of a catastrophe. While the region is not the most seismic, the New Madrid area features several states with substantial poverty, including Kentucky, Tennessee, and Arkansas. These states may be better served by adopting policies to assist with evacuation and relocation, rather than encouraging insurance purchases. In terms of elderly populations, results are similar across states, but those with high rates like Hawaii and Oregon may be best focused on recovery efforts to ensure that emergency services can reach those in need.

The NRI provides two tools for evaluating this type of risk: a Social Vulnerability Score and a Community Resilience Score. Instead of analyzing individual dimensions, these scores allow a broad assessment, inclusive of many variables.

[35] Poverty Rates and Population over 65 obtained from the S&P Global Capitol IQ platform, via Claritas, via the American Community Survey. Potential Economic losses obtained from NRI data. Social Vulnerability and Community Resilience Score aggregated from NRI data for counties in the top 70th percentile of earthquake risk.

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The Social Vulnerability Score (SVI)[36] combines elements of socioeconomic status, household characteristics, racial and ethnic minority status, and housing type and transportation to yield a single score of the vulnerability of the population in a given region, state, county, or census tract. As shown, the SVI varies significantly by state, with Nevada scoring the highest and Utah scoring the lowest. Thus, instead of considering individual metrics, policymakers could use SVI or similar tools to assess their individual districts and direct mitigation or recovery resources where they are needed.

Like SVI, the Community Resilience Score (CRS) is an even more comprehensive metric that includes the elements of SVI, plus measures related to each community's adaptation capabilities. According to FEMA, the CRS "includes a set of 49 indicators that represent six types of resilience: social, economic, community capital, institutional capacity, housing/infrastructure, and environmental. It uses a local scale within a nationwide scope, and the national dataset serves as a baseline for measuring relative resilience. The data are used to compare one place to another and determine specific drivers of resilience."[37]

Th advantage of CRS is that it is inclusive of most of the relevant metrics for assessing a community's risk. Considering the seismically active states, Utah, Hawaii, and Illinois are particularly resilient, while Nevada, Alaska, and California score lower. Policymakers in these states could consider the specific components of CRS to see where the resilience of their states is deficient or compare county-level scores with their states to determine where resources could be directed to improve the resilience of their vulnerable communities. While the CRS may be an invaluable tool for policymakers, a disadvantage may be that it includes many inputs, so it is difficult to determine the specific drivers of a community's score.

[36] Agency For Toxic Substances and Disease Registry. *CDC SVI Documentation 2020.* https://www.atsdr.cdc.gov/placeandhealth/svi/documentation/SVI_documentation_2020.html

[37] FEMA. National Risk Index: Technical Documentation. https://www.fema.gov/sites/default/files/documents/fema_national-risk-index_technical-documentation.pdf

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2 Earthquake Insurance

One of the risks mentioned in the previous section was the coverage gap, where many property owners in seismically active regions of the United States and Canada do not purchase coverage for earthquakes.

Despite this gap, there is a fairly large insurance industry, which consists of many carriers, and has experienced significant recent growth. This section will provide more details about earthquake insurance, including the companies involved, history and premium growth, different policy types, and pricing methodologies.

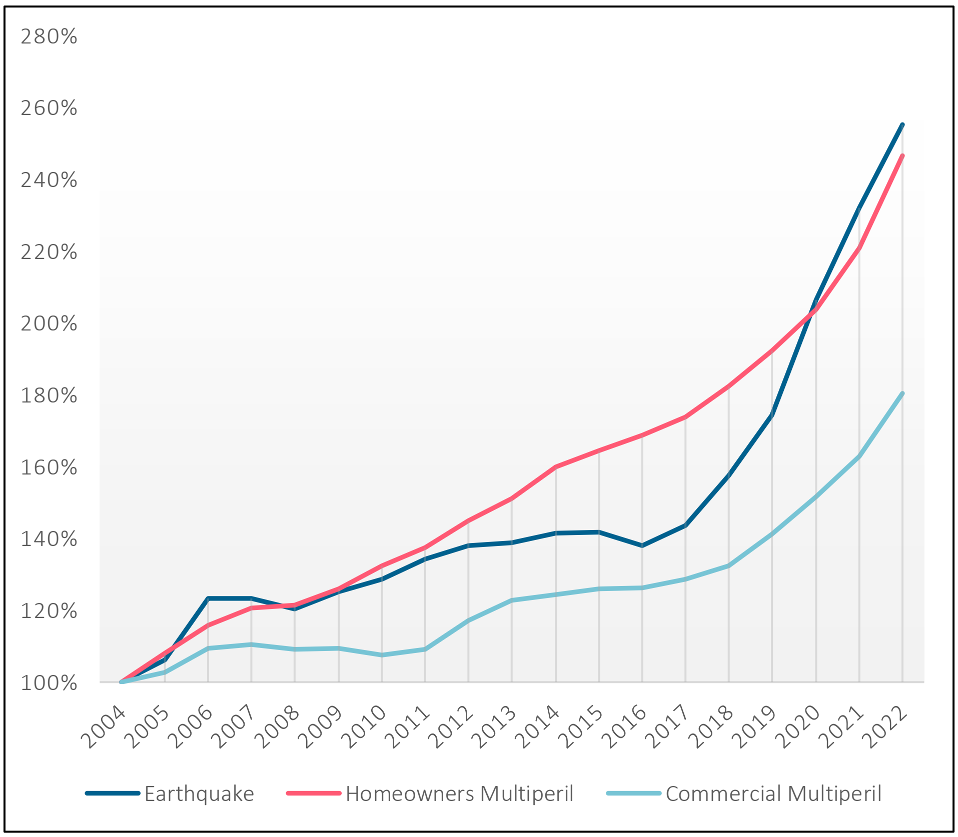
2.1 THE EARTHQUAKE INSURANCE INDUSTRY IN THE UNITED STATES

As shown below, growth in earthquake premiums has been substantial in recent years, especially after 2016, where premiums nearly doubled in 6 years. Despite this encouraging growth, the growth rate has been similar to the homeowners line since 2004, suggesting that the gap may not be closing, and that the growth is attributable to other factors such as increased premium rates. Nevertheless, earthquake premiums are on an upward trajectory, and interested parties should watch reporting closely in subsequent years to assess whether this trend will continue.

Figure 6

US EARTHQUAKE WRITTEN PREMIUM AND GROWTH SINCE 2004 COMPARED TO OTHER PROPERTY LINES[38]

Year	Written Premium
2004	2,063,814
2005	2,190,174
2006	2,545,341
2007	2,543,813
2008	2,486,601
2009	2,582,814
2010	2,656,978
2011	2,771,392
2012	2,847,490
2013	2,866,487
2014	2,921,779
2015	2,924,458
2016	2,846,469
2017	2,964,847
2018	3,250,557
2019	3,596,234
2020	4,262,478
2021	4,793,356
2022	5,150,043



The industry is comprised of a large number of carriers, offering different policy types, covering different risks, and operating in different geographies. As mentioned, the CEA is the single largest provider of earthquake insurance in the country, and focuses on residential policies, entirely in California. The second largest provider, Factory Mutual, focuses on commercial risks, has a portfolio distributed throughout the country, and is most commonly providing earthquake coverage in connection with commercial multiperil policies. The third largest, State Farm, is the

[38] Data from S&P Global Capital IQ platform. Aggregate earthquake Direct Written Premiums for all U.S. insurers.

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country's largest writer of homeowners policies, and the bulk of its earthquake coverage is written as an endorsement to its homeowners policies. The top 10 U.S. carriers of earthquake insurance, along with their market shares, are shown in Table 14.

Table 14
TOP 10 UNITED STATES EARTHQUAKE INSURERS BY DIRECT WRITTEN PREMIUM FOR 2022

Rank	Insurer	Written Premium	Market Share
1	California Earthquake Authority	$956,388	18.6%
2	Factory Mutual Insurance Company	$403,034	7.8%
3	State Farm Fire and Casualty Company	$308,434	6.0%
4	Palomar Specialty Insurance Company	$220,603	4.3%
5	Zurich American Insurance Company	$161,174	3.1%
6	National Fire & Marine Insurance Company	$144,782	2.8%
7	Palomar Excess and Surplus Insurance Company	$139,851	2.7%
8	Endurance American Specialty Insurance Company	$139,666	2.7%
9	Steadfast Insurance Company	$115,331	2.2%
10	Everest Indemnity Insurance Company	$99,103	1.9%
	Selection Total	**$2,688,366**	**52.2%**
	National Total	**$5,150,043**	**100%**

The remaining carriers in the top 10 represent a mix of residential and commercial coverage, with some writing standalone policies, and some writing endorsements. While it may be possible to investigate the specific writings of each, there seems to be no comprehensive data source for all.

To investigate the rapid growth of premiums in the prior figure, premium writings by different carrier groups and geographies were taken into consideration (this data is on a state-by-state basis in the closing section). The specific reasons for this rapid growth remain unknown, but Figures 7 and 8 provide some insight.

The figures separate the industry into three segments: 1) the top three carriers, discussed above, 2) the next seven, also displayed, and 3) the remaining carriers, which account for approximately 50% of the market. Figure 7 provides Written Premium by year for each segment. Figure 8 translates this into market shares.

As the first figure shows, there has been substantial growth in all three segments. However, the second segment (carriers #3 through #10 in terms of market share), has emerged as significant, growing from little premium in 2014-2015, to more significant in 2022. Figure 8 makes this relationship clearer, where these seven carriers comprised under 6% of premiums as recently as 2013 and have expanded to nearly 20% of premiums in 2022. Thus, at least part of the growth is attributable to the growth in these seven companies, who may have added underwriting capacity, added marketing focus to earthquake, or both.

This observation is encouraging in relation to the coverage gap, as more carriers writing significant coverage may offer the ability to reach more customers with different policy types, thus closing the gap more quickly than a handful of large carriers, or a plethora of small carriers, would be able to.

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Figure 7

EARTHQUAKE WRITTEN PREMIUM SINCE 2004 BY MARKET SHARE SEGMENT[39]

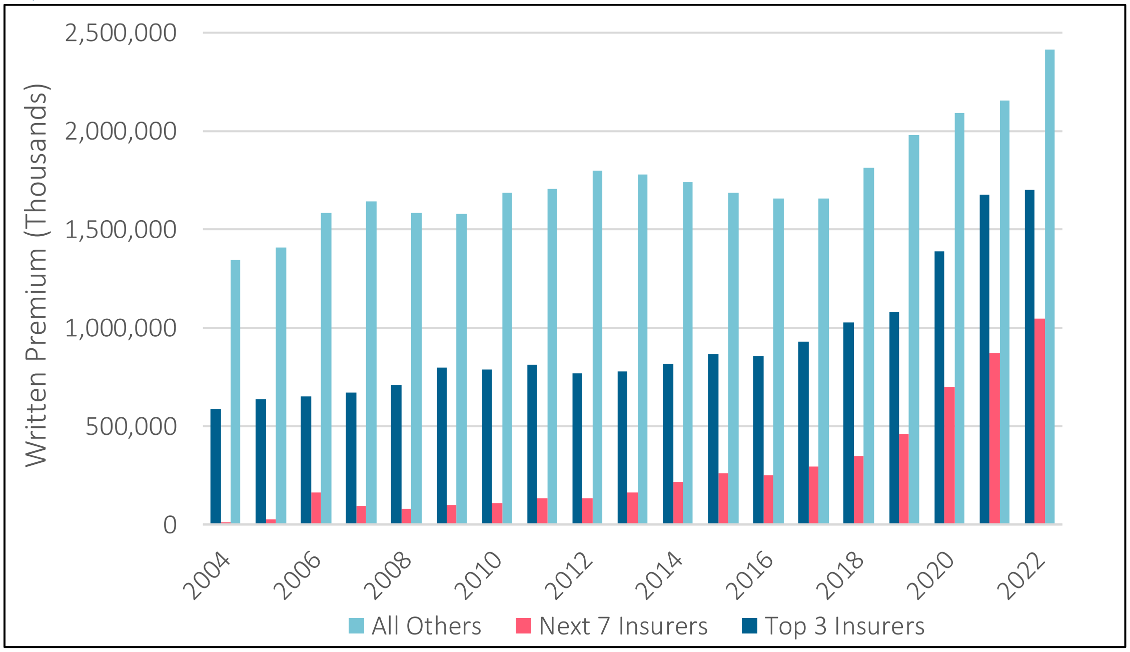
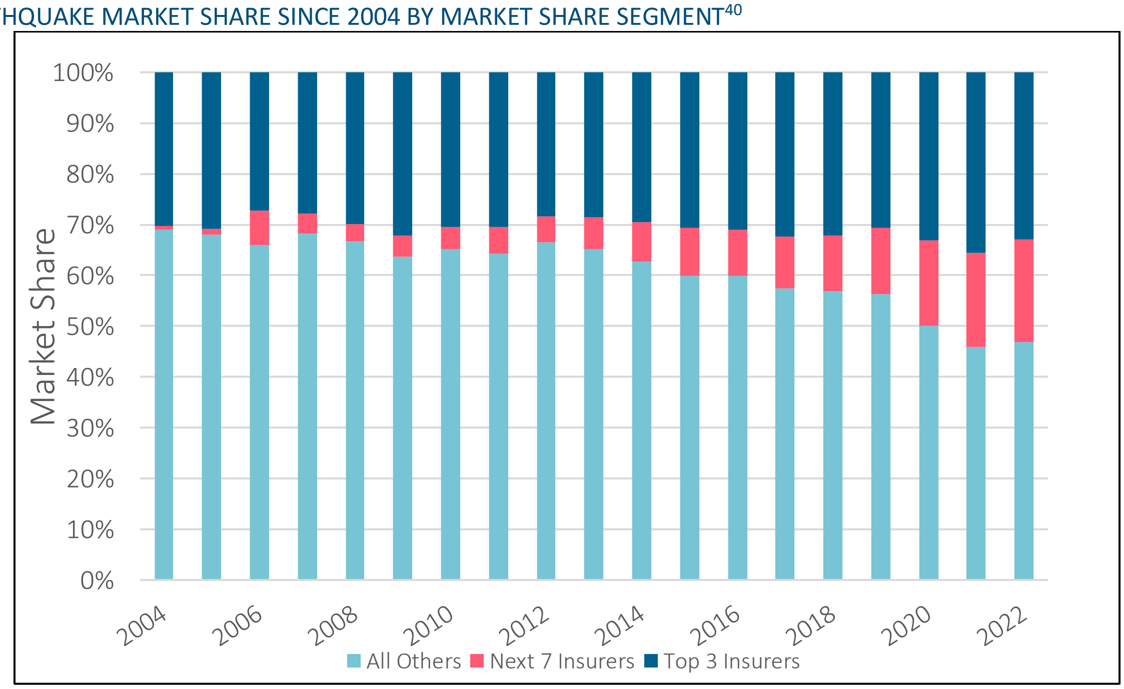


Figure 8

EARTHQUAKE MARKET SHARE SINCE 2004 BY MARKET SHARE SEGMENT[40]



[39]Data from S&P Global Capital IQ platform. Aggregate earthquake Direct Written Premiums for all U.S. insurers.

[40]Data from S&P Global Capital IQ platform. Aggregate earthquake Direct Written Premiums for all U.S. insurers.

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2.2 HOW EARTHQUAKE INSURANCE IS SOLD

To understand the earthquake insurance products in the marketplace, it is important to recognize certain differences between them. This section provides a brief description of product differences.

RESIDENTIAL VS. COMMERCIAL POLICIES

As described, the Earthquake line of business on the NAIC annual statement contains premiums for both residential and commercial policies. Most carriers focus on either residential or commercial insurance, although some offer both. In both cases, earthquake insurance is often sold alongside a comprehensive "multiperil" policy, which provides coverage for both catastrophic (like hurricane, hail, or wildfire), and non-catastrophic (like water damage, theft, or electrical fire) events. Like earthquake, flood coverage is usually sold separately from a multiperil policy.

Commercial properties are less homogeneous and more valuable than residential ones. As a result, they are typically subject to more underwriting scrutiny, and pricing flexibility via credits or debits based on the condition or individual characteristics of the property.

Residential policies are more homogenous and tend to be priced purely based on a pre-defined algorithm and set of rating characteristics. Residential earthquake is typically sold alongside certain policy "forms," which differ based on the type and occupancy of the residence. Residential forms include single family residential (HO-3), renter's (HO-4), condominium (HO-6), and dwelling fire (DP-3, a form typically utilized by landlords). Residential earthquake policies are designed to match these forms, and are sold in single-family, condominium, and renter's varieties.

ENDORSEMENT VS. STANDALONE POLICIES VS. INCLUDED COVERAGE

In rare cases, coverage for earthquakes may be included with a property policy. More often, it is either sold as an endorsement to a multiperil policy, or as a standalone policy, which may be purchased from a different insurer. In areas where the risk is low, coverage is more likely to be sold as an endorsement. In these cases, residential carriers are able to offer the endorsement at an attractive price, without retaining excessive risk. Additionally, because earthquake premiums tend to be lower cost in these regions, there is limited incentive and opportunity for carriers to sell standalone coverage.

In states with higher risk, like California, it is more likely that coverage will be purchased standalone. As described, CEA is the nation's largest provider of earthquake insurance, which is a standalone policy (but typically marketed and sold by carriers of residential multiperil policies). Because the market, and individual premiums, are large, a number of specialty carriers have emerged to compete with CEA and offer alternative standalone policies.

HIGH DEDUCTIBLE VS. LOW DEDUCTIBLE COVERAGE

While homeowners multiperil policies typically come with fairly low deductibles (like $500, $1,000, or $2,500), it is more common for earthquake policies to come with high deductibles, denominated in terms of a percentage of the coverage limit (like 5%, 10%, or 25% of the coverage limit).

It is rare for earthquakes, especially those at low magnitudes, to cause total losses to properties. Instead, expected severities are limited, and thus these deductibles have the effect of significantly limiting risk transfer to the insurer, leaving the consumer with substantial risk. However, they also have the effect of limiting risk concentrations to insurers, which allows them to offer more underwriting capacity than if they sold lower deductibles.

These deductibles are not only common, but are required by insurers in most cases, so low deductible coverage is virtually unavailable. For example, the Missouri Department of Commerce and Insurance reports that over 98% of

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policies sold in the New Madrid seismic region carry deductibles over 10%, as do nearly 60% outside the region.[41] In California, the CEA mandates deductibles of at least 5%, but imposes a minimum of 15% for homes built before 1980, or with a limit above $1,000,000.[42]

ADMITTED VS. NON-ADMITTED INSURERS

Another difference between earthquake policies is whether they come from carriers licensed to operate in the state of coverage. “Admitted” insurers hold licenses in each state where they sell. This means that they fall under the supervision of state regulators who review and approve contracts and rates, monitor solvency, and oversee insurer conduct. Because of the protection provided by comprehensive regulation, admitted policies are preferred over non-admitted policies. Admitted policies also generally receive protection from state guaranty funds, which means policyholders will receive claims payments in the event of an insurer insolvency.

Non-admitted carriers are unlicensed and are subject to minimal regulatory oversight. Non-admitted carriers are prevalent in lines of business where admitted carriers have limited underwriting appetites, and serve to provide extra capacity in the marketplace, albeit with some drawbacks and limitations. To ensure most business is placed with admitted carriers, agents or brokers are generally prohibited from placing business with non-admitted carriers unless they can show that coverage was not available in the admitted market (for example, if a risk is declined by several admitted carriers).

Despite being cut off from risks that are acceptable to admitted carriers, non-admitted carriers enjoy the flexibility of limited regulatory oversight. For example, they have the ability to change rates or policy contract provisions without applying for regulatory approval. Because of the catastrophic, non-standard, and limited capacity nature of earthquake risk, non-admitted coverage is more common for earthquake insurance than it is for homeowners (see the market share tables in the closing section for the prevalence of non-admitted coverage in each state).

REINSURANCE

Like for other catastrophes, earthquake insurers typically protect their balance sheets via reinsurance. This adds cost to the policies, but also allows insurers to expand their underwriting capacities by limiting the losses that could occur from any given event. For insurers who sell both multiperil and earthquake coverage, reinsurance cover may apply to all perils, or they may carry a separate coverage for earthquake risk. Earthquake reinsurance is priced using catastrophe simulation models in conjunction with an insurer’s portfolio. However, a different type of coverage that has gained acceptance is “parametric insurance,” which pays out based on the physical parameters of an event (for example, the magnitude of an earthquake occurring in a specific region).

Catastrophe bonds are another solution used in earthquake reinsurance. In these cases, investors purchase bonds and earn returns, unless a catastrophe occurs, in which case investors lose their underlying principle, which is used to pay for the event. CEA heavily relies on catastrophe bonds to structure its reinsurance program.[43]

Because of the sizeable amount of earthquake risk that is underwritten, and ultimately borne by, reinsurers, there may be a concern that the reinsurers could lack sufficient capitalization to absorb a major event, ultimately endangering indemnity payments. However, there is a low probability of this threat materializing, as reinsurers are

[41] Missouri Department of Commerce & Insurance. *Residential Earthquake Coverage in Missouri*. https://insurance.mo.gov/earthquake/documents/OverviewofResidentialEarthquakeInsurancein2021.pdf

[42] California Earthquake Authority. *CEA Homeowners Policy Coverages & Deductibles*. https://portal.earthquakeauthority.com/earthquake-policies/homeowners/homeowner-coverages-deductibles

[43] Evans, Steve. *CEA returns to add $400m of quake cover with Ursa Re 2023-3 cat bond.* https://www.artemis.bm/news/cea-returns-to-add-400m-of-quake-cover-with-ursa-re-2023-3-cat-bond/

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typically well diversified across different regions and catastrophic perils, and earthquake risk is not correlated with other catastrophe types like hurricanes or floods.

2.3 HOW EARTHQUAKE INSURANCE IS PRICED

This section provides a basic understanding of pricing algorithms for earthquake insurance by summarizing those of a sample of insurers and providing details on rate differentials, rating variables, and property characteristics. As described, earthquake insurance comes in different forms, across a variety of geographies.

EARTHQUAKE RATING FACTORS AND ALGORITHMS

To analyze the variety of pricing approaches that exist, the rating algorithms from a sample of insurers with different policy types in different states were selected. The rating algorithms were obtained from the NAIC's System for Electronic Rates & Forms Filing (SERFF), which is the system through which insurers file rates with regulators, and with which regulators make these filings available to the public. The rating algorithms specified in Table 15 were used.

Table 15

INSURER RATING ALGORITHMS CONSIDERED IN COMPARISON[44]

Carrier	Policy Type	State	SERFF Filing #	Filing Date
Palomar Specialty Insurance Company	Standalone Policy	Oregon	PALO-132518109	9/14/2020
California Earthquake Authority	Standalone Policy	California	CAEQ-133896917	12/17/2023
American Strategic Insurance Corp	Endorsement	South Carolina	AMSI-133438789	4/7/2023
State Farm Fire and Casualty Company	Endorsement	Missouri	SFMA-133743607	8/4/2023
Safeco Insurance Company of America	Endorsement	Washington	LBPM-133864423	10/26/2023

Using these, Table 16 was created, which details the rating structure, territorial pricing, and rating variables. All plans share certain characteristics, with some notable differences. All include factors for:

- Construction Type
- Year Built
- Dwelling Coverage Limit (Coverage A)
- Territory

Note substantial differences, specifically:

- Territory – All of these carriers use a table-driven approach, but it can be based either on ZIP code or county. Some classify the ZIP code/county into territory, with an associated factor. Others have a factor directly associated with each ZIP or county. These manuals do not contain more granular approaches common in homeowners, such as custom territories, distances to hazards, or census block/tract classifications.
- Variables used by some, but not all, carriers include slope/grade, foundation type, number of stories, and hazard mitigation discounts.
- While Dwelling Limit is a component of all the plans, some carriers price the coverage amount on a curve that increases with the coverage limit at a decreasing rate. Other carriers charge a flat rate per $1,000 of coverage.
- The rate structure for the standalone policies generally starts with a base rate and applies rating factors multiplicatively. For endorsements, approaches vary. Two carriers develop the earthquake premium

[44] All pricing plans obtained through SERFF's public access system. https://www.serff.com/serff_filing_access.htm

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separately from the homeowners rate, and then add the two together to arrive at the final premium. One carrier develops the earthquake premium as a peril in a by-peril structure, in parallel with the other perils (fire, water, wind).

- There is significant variation in the use of interaction terms. For example, construction type sometimes appears as an interaction term with year built, and sometimes with foundation or territory.
- While some carriers omit common variables, they may use underwriting restrictions to exclude risky classes entirely from their portfolios. Safeco's Washington manual, for example, contains no rating factors for construction type, and instead has underwriting restrictions which entirely exclude coverage for the masonry type.

Table 16

INSURER RATING ALGORITHM FEATURES[45]

Carrier	State	Rating Structure	Territory	Rating Variables
Palomar Specialty Insurance Company	Oregon	Rate per $1,000 of Dwelling limit is determined by Territory/Construction/Year built. Credits/Debits given for other attributes.	12 Territories based on ZIP code.	-Dwelling Coverage Limit (Coverage A) -Territory x Construction x Year Built -Number of Stories -Grade (Slope) Under House -Foundation Type -Deductible
California Earthquake Authority	California	Rate per $1,000 of Dwelling limit is determined by Territory. Rating factors applied multiplicatively. Coverages A, B, C, and D are rated separately and added for total rate.	28 Territories based on ZIP code.	-Territory -Dwelling Coverage Limit (Coverage A) -Deductible -Number of Stories -Construction x Year Built x Foundation -Hazard Reduction Discount -Roof Type
American Strategic Insurance Corp	South Carolina	Earthquake rates incorporated as standalone peril in by-peril homeowners rating plan.	Factor applied directly based on ZIP code.	-Dwelling Coverage Limit (Coverage A) -Type of Construction -Number of Stories -Other Structures Limit (Coverage B) -Loss of Use (Coverage D) -Personal Property Limit (Coverage C) -Territory -Year Built -Deductible -Substructure (Foundation)
State Farm Fire and Casualty Company	Missouri	Earthquake rate added to homeowners rate when endorsed.	5 Territories based on county.	-Deductible x Territory x Construction -Year Built x Construction -Increased Limits for Other Structures -Loss Assessment Coverage -Fixed Expense Charge
Safeco Insurance Company of America	Washington	Rate applied per $1,000 of dwelling limit is determined by year of construction.	Factor applied directly based on county.	-Dwelling Coverage Limit (Coverage A) -Year Built -Deductible -Many risk types (such as types of construction) are excluded from coverage.

Table 16 describes the general structure of each plan but does not detail the variables. Table 17 has a more complete description of the function of the variables. As before, while the variables can differ by carrier, there are some common themes:

[45] Summary based on examination of filed rating plans. Entries with an "x" between variables denotes an interaction term, where factors are based on the given levels of more than one variable.

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- Variables like construction, roof type, or foundation recognize the difference between flexible and solid materials, which can withstand shaking, vs. brittle or heavy materials, which are vulnerable to cracking.
- Similarly, the number of stories, foundation, or slope recognize the vulnerability that exists when one part of the structure is stacked on top of another.
- Year built is an important rating variable, as it relates not only to the cumulative attrition to a structure, but also to the building code that was in place at the time of construction. These building codes often mandate other attributes such as slope, foundation, or construction materials in seismically active areas, and as a result year built may serve as a proxy for these attributes in cases where they are omitted.
- Similarly, the hazard reduction factors (mitigation) used by the California Earthquake Authority are in place to recognize retrofits to these attributes to bring older construction up to the latest standards. As a result, deep discounts are available for older construction and discounts are not available for the newest construction, which is instead given credit via the factors for year built.

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Table 17
EARTHQUAKE RATING VARIABLE COMPARISON[46]

Rating Variable	Description, Direction, and Rationale	Common Levels of Variables	Common Variable Interactions
Coverage Limit: Dwelling, Other Structures, Personal Property, Loss of Use (Coverages A, B, C, D)	Coverage increases with the value and replacement cost of the property, and insurers charge more for higher coverage. Some insurers use graduated coverage curves, so the rate increases at a decreasing rate. Others charge a flat rate per $1,000 of coverage, so premium scales linearly with coverage.	Dwelling Coverage is generally continuous, and any value can be rated, subject to a minimum and maximum. Coverages B, C, and D may be reflected as dollar values, or as a percentage of Dwelling Coverage.	N/A
Territory	In any given state, some areas may be closer to fault zones than others. Territory factors are used to reflect this difference in risk.	Based on ZIP code or county.	Deductible
Year Built	As earthquake risk measurement has improved, building codes have been implemented to mandate more resilient standards in hazardous areas. Year built is often used to differentiate properties built before and after building code changes.	Depends on the year building codes were implemented in each state.	Construction Mitigation Foundation
Construction	Frame construction has some flexibility and can withstand shaking. Masonry (brick) is more brittle and heavier, and thus is prone to collapse during seismic activity. Other types (such as Masonry Veneer) mix characteristics of frame and masonry.	Frame Masonry Masonry Veneer Fire Resistive	Year Built Foundation Slope/Grade
Roof	Like with construction, some roof types are more brittle than others and less resilient to shaking. Additionally, some roof types are heavier than others, placing stress on the dwelling structure.	Tile/Slate Composition/Shingle Wood Shake	N/A
Foundation or Substructure	Spaces between the foundation and dwelling structure expose the property to an extra vulnerability that solid foundation types do not.	Concrete Slab Slab-On-Ground With Crawl Space Pilings/Raised Post, Pier, and Stilts	Construction Year Built
Deductible	As deductible increases, the risk shifts from the insurer to the policyholder. Often, earthquake insurance requires high deductibles, expressed as a percentage of Coverage A.	Percent of Coverage A (5%, 10%, 20%)	Territory
Number of Stories	Higher stories place stress on the structure and foundation. For a property of a given square footage, single story construction subjects to structure to the least risk.	1, 1.5, 2, 2.5, 3	N/A
Hazard Reduction and Mitigation	While building codes have caused newer construction to be more resilient, retrofitting is often possible to bring the risk on older construction closer to that of newer construction.	Anchored to Foundation Secured Water Heater Bracing for Cripple Walls Foundation Modified to Current Building Code	Foundation Type Year Built
Slope/Grade	Properties built on a slope may be subject to shifting with seismic activity. Properties built on flat land are not exposed to this risk.	0°, 1° to 20°, >°20	Construction Year Built

[46] Summary based on examination of filed rating plans.

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2.4 RATE LEVELS AND OTHER CONSIDERATIONS FOR EARTHQUAKE PRICING

The earthquake ratemaking process involves not only setting rating factors for different risk classes but also determining an overall rate level. The overall rate level is generally calculated by developing an estimate for losses, then loading for expenses and other costs. While this process is similar to other Property and Casualty lines of business, which are covered in other texts, there are a few earthquake-specific differences described below.

TYPE OF INSURER AND INVOLVEMENT WITH EARTHQUAKE INSURANCE

As described, there are a few different types of companies involved with earthquake insurance. The CEA is the largest writer in the country, has exposure exclusively in the costliest geography, and writes no other lines, so it must carefully monitor its earthquake risk and set rate levels accordingly. Other specialty writers of standalone policies, particularly on the West Coast, are similarly sensitive to earthquake-specific changes in expected costs. Much of the rest of the earthquake premiums are written as endorsements by homeowners insurers in lower-risk areas. In these cases, the earthquake premium is usually small compared to the main policy premium, and earthquake risk does not have significant implications for the company's aggregate risk or reinsurance program, and thus is not a significant point of focus for insurers. Nevertheless, these insurers are likely to make periodic changes to their earthquake rates commensurate with expected increases in cost.

RELIANCE ON MODEL DATA

Because earthquakes sparsely occur, rates rely almost entirely on model data instead of historical claims. Expected results vary from model to model, so final rate levels can be highly dependent upon model selection by the insurer, and expected losses can change as model updates are released. Some insurers temper sensitivity to model changes by using averages of various vendor models.

REINSURANCE MARKET PRICING AND CAPACITY

As described, for some insurers with heavy concentrations in earthquake risk, reinsurance costs represent a significant fraction of the cost to provide coverage. Insurer reinsurance programs are generally negotiated annually or semiannually, and there can be fluctuations in the price of reinsurance based on capital in the reinsurance industry and other macroeconomic facts (known as the insurance cycle, or "hard markets" and "soft markets"). Additionally, an insurers' reinsurance costs can vary based on its aggregate exposure (the likelihood of a big loss occurring), which can be driven by its geographic concentration of risk, which can dynamically change as the insurer grows. Because of the ongoing changes to reinsurance cost that can occur, insurers for which these costs are significant must continually monitor changes in them and adjust their rates accordingly.

2.5 OPPORTUNITES TO INNOVATE EARTHQUAKE INSURANCE PRICING

In addition to the pricing practices mentioned above, there exist a number of potential enhancements that insurers could make to improve the accuracy or granularity of their rates. Please note, some of these practices have already been adopted in the marketplace, but simply have not been adopted by the limited number of rating plans surveyed. Similarly, due to the flexibility and lack of filing requirements enjoyed by non-admitted carriers, it is easier for them to implement more advanced pricing algorithms, but those are kept confidential and thus are beyond the reach of this examination.

GRANULAR OR GEOSPATIAL TERRITORIAL RATING

Most property insurance pricing algorithms use "table-driven" pricing, where a rate relativity is applied via a lookup table. The location of the risk is placed into a geographic territory such as ZIP code or county, which is either reported by the insured or assigned using geocoding software based on their address. Once this territory is assigned, the associated rate relativity is obtained from the filed rate table and is used to carry out the rate calculation.

This approach has limitations. First, the geographic assignments do not necessarily bear a relationship with the risk. For example, a fault line could run near the border between two ZIP codes. For ideal pricing accuracy, it would be beneficial to differentiate between the properties in each ZIP code which lie close to the fault zone and the less-risky

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properties farther away. The second limitation is that the territories themselves can be quite large, meaning there is a large spread of risks within each.

There are two approaches to address these limitations. The first approach is still table-driven but uses a more granular (smaller units) territory definition such as census tract, census block, or 9-digit ZIP code. For context, according to the United States Census Bureau,[47] there are 3,143 Counties, 32,989 Zip Code Tabulation Areas, 73,057 Census Tracts, 217,740 Census Block Groups, and 11,078,297 Census Blocks in the United States. Thus, an insurer switching from county-based rating to ZIP code-based rating would have roughly 10 times as many territories, and an insurer switching from ZIP code-based rating to census tract or census block-based rating would have between two and 336 times as many territories. In other lines of business, insurers will often start with a granular unit like census block, then cluster the blocks together based on earthquake risk to end up with fewer territories that are better aligned with the risk. Before endeavoring to improve their territories in this way, pricing actuaries should investigate the insurer's production systems and geocoding capabilities to verify that census block can be obtained at the time of quote and policy renewal.

While this table-driven approach can substantially improve the match between rate and risk, it is still limited in that it relies on territories that at a fundamental level were not designed to capture earthquake risk.

Another approach is to use geospatial features that are independent of a table-driven approach. For example, a rate can be applied based on a calculated distance between the risk and a hazard like a fault line. Additionally, insurers can use multiple features of this type, for example by incorporating the soil type underlying the property and soil types in close proximity to it. These approaches are usually designed and validated using catastrophe models and with precise geographic layers that describe the geological and other features relevant to earthquake risk. Similar to granular table-driven approaches, but more complex, these approaches typically require special IT capabilities for insurer systems to query geographic layers and calculate various values to apply the rate. Thus, while these approaches are among the most advanced and accurate, they also require production implementation capabilities which may put them out of reach of many insurers today.

INSURTECH VENDORS

There are a number of third-party solutions emerging from the "Insurtech" industry, which insurers can use to supplement their in-house capabilities. As these specialized offerings evolve, it is expected that insurers may be able to expand their underwriting appetites or gain competitive advantages. The full spread of these offerings is out of scope for this report, but a sample of the existing or potential offerings is listed below:

- *Production catastrophe model queries* – Allows an insurer to obtain real-time simulation results for a quoted location and take some automated business action such as assigning a price, referring a risk for underwriting, or assessing how the risk fits within the insurers existing geographic concentration.
-
- *Seismic monitoring services* – Allows insurers to deploy claims adjusters quickly and efficiently in cases where shaking has occurred, or to place additional underwriting scrutiny in areas where events have recently happened, allowing them to avoid underwriting properties with existing damage.
-
- *Geospatial data and data processing* - Given the difficulties faced by many insurers with implementing advanced geographic rating approaches, some vendors have created offerings that enable them to outsource this via Application Programming Interfaces (APIs). The vendor provides the insurer with detailed geographic layers for the purpose of setting rates, and the ability to obtain geographically driven calculations via API.

[47] United States Census Bureau. *2010 Census Tallies.* https://www.census.gov/geographies/reference-files/2010/geo/tallies.html

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-
- *Characteristic data vendors* – aggregate property characteristics to allow insurers to determine attributes such as construction type, retrofitting permits, date of roof replacement, etc. These attributes allow them to verify customer-reported values, or to impute the values in cases where the customer does not know.

CONCENTRATION OR REINSURANCE COST LOADINGS

Finally, beyond pricing for expected loss at a location, some insurers may choose to assign an additional risk load based on their geographic risk concentration, which ultimately drives the price of reinsurance. Because earthquake losses are spatially correlated (an event happening in one location will affect many risks in its proximity), and because reinsurance prices often consider the aggregate distribution of losses, it is often costlier for an insurer to underwrite a risk in close proximity to the locations in its existing portfolio than one that is farther away. As a result, insurers may calculate territory-based concentration loads. The methodology to do this often requires simulation models and relies on "marginal" approaches. For example, an insurer may calculate the 90^{th} percentile loss on its existing portfolio. Then, if the insurer had ZIP code-based rating with 100 ZIP codes, rerun the simulation 100 times, with a single risk added in each ZIP code for each run. This would allow the insurer to determine how its aggregate risk distribution is affected by growth in each ZIP code, and the resulting change in the aggregate could be used to assign risk loads that represent the cost of growth due to the additional concentration of diversification that results from taking on additional risks in different locations throughout the state.

Because of the importance and cost of reinsurance for many earthquake portfolios, approaches such as this may provide substantial lift in terms of the match between premium and total cost to insure, even if there is already a good match between premium and expected risk in place.

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3 Outside the 50 States: Earthquake Risk in Puerto Rico and Canada

The 50 states can be considered together because of the availability of consistent data about their earthquake risk. However, the goal of this report is to address earthquake risk throughout the United States, including territories like Puerto Rico where significant risk exists, as well as Canada. This section will address these regions.

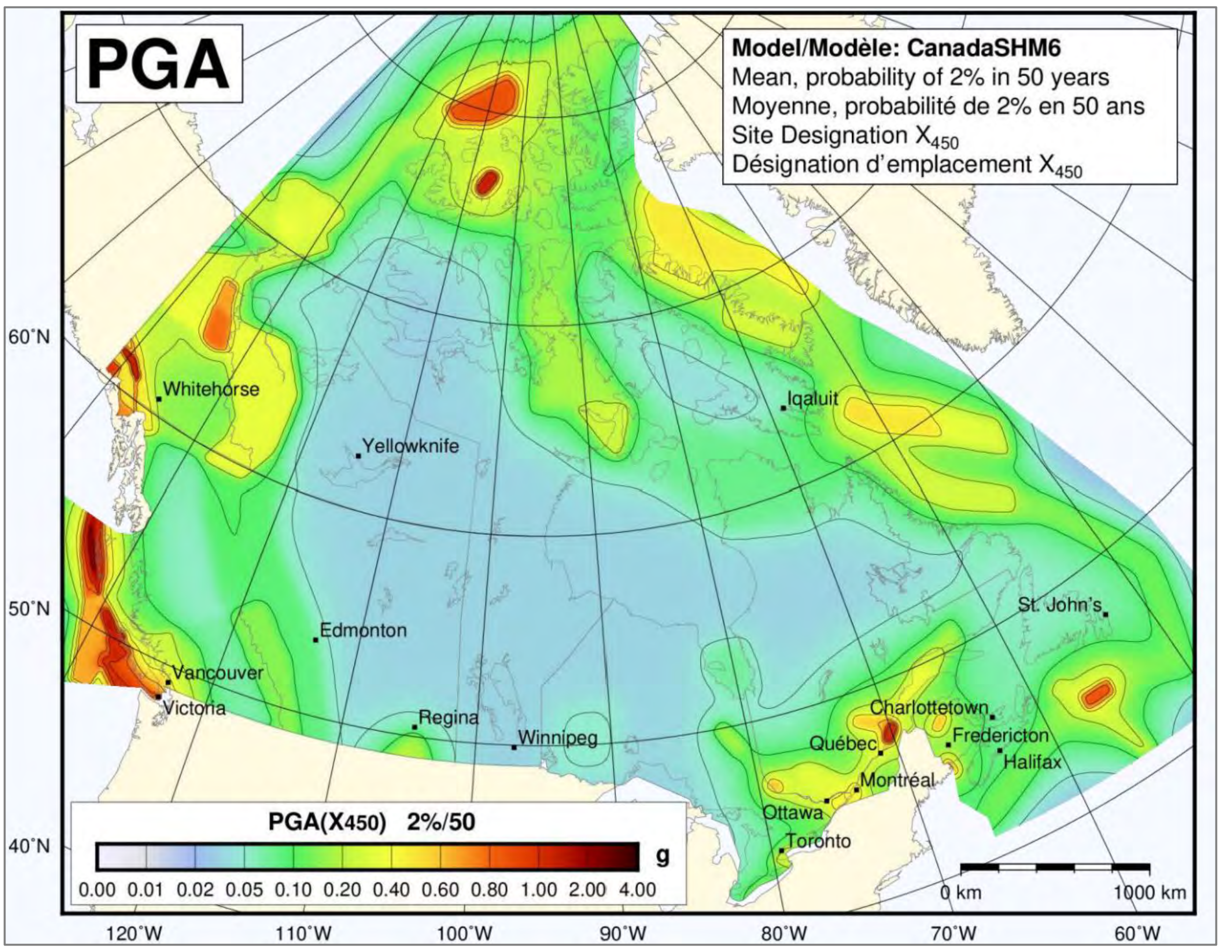
3.1 CANADA

CANADA'S TWO EARTHQUAKE REGIONS

Like in the United States, there is more awareness of earthquake risk in Canada's West, but there are also important Eastern faults that are rarely discussed. As part of the Cascadia Subduction Zone, British Columbia and its major population centers are exposed to substantial risk. The other Canadian risk zone is near the lower St. Lawrence River, and spans across the populous provinces of Ontario and Quebec. Figure 9 provides a PGA map for Canada .

Figure 9

PEAK GROUND ACCELERATION FOR CANADA[48]



[48] Earthquakes Canada. *2020 National Building Code of Canada Seismic Hazard Maps.* This reproduction is a copy of the version available at: https://earthquakescanada.nrcan.gc.ca/hazard-alea/zoning-zonage/NBCC2020maps-en.php#pga

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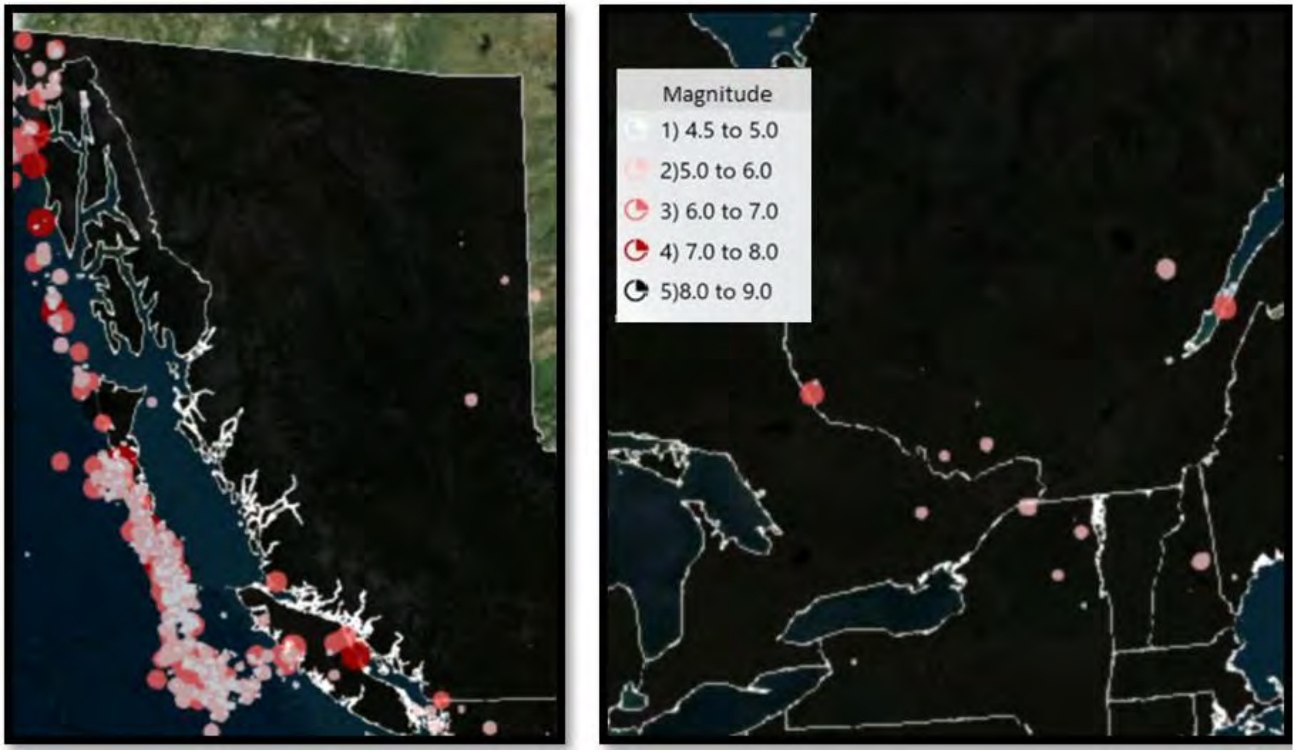
CANADIAN EARTHQUAKE HISTORY

Figure 10

CANADIAN EARTHQUAKES SINCE 1900 FOR BRITISH COLUMBIA (LEFT) AND LOWER ST. LAWRENCE (RIGHT)[49]



Consistent with the PGA map, the bulk of Canadian Earthquakes have occurred in British Columbia, especially off the coast. Despite the significant estimated risk associated with the St. Lawrence region, historical earthquakes have been limited.

RISK BY CANADIAN CITY

Since an equivalent to EAL data for Canada is not available, the risk is estimated at discrete points in population centers in each earthquake region, selecting two cities from each of Ontario, British Columbia, and Quebec, similar to the approach for U.S. cities, and using a similar tool provided by the Canadian government.

Table 18

SAMPLE COORDINATES FOR CANADIAN CITIES[50]

Sample Coordinates	Victoria	Vancouver	Montreal	Ottawa	Toronto	Quebec City
Latitude	48.428	49.261	45.509	45.333	43.742	50.191
Longitude	-123.365	-123.114	-73.554	-75.584	-79.373	-66.634

The sample coordinates for each city appear in Table 18, and modeled PGA exceedance probability curves appear in Figure 11.

[49] Data from United States Geological Survey. *Search Earthquake Catalog*. https://earthquake.usgs.gov/earthquakes/search/

[50] Default coordinates for each city.

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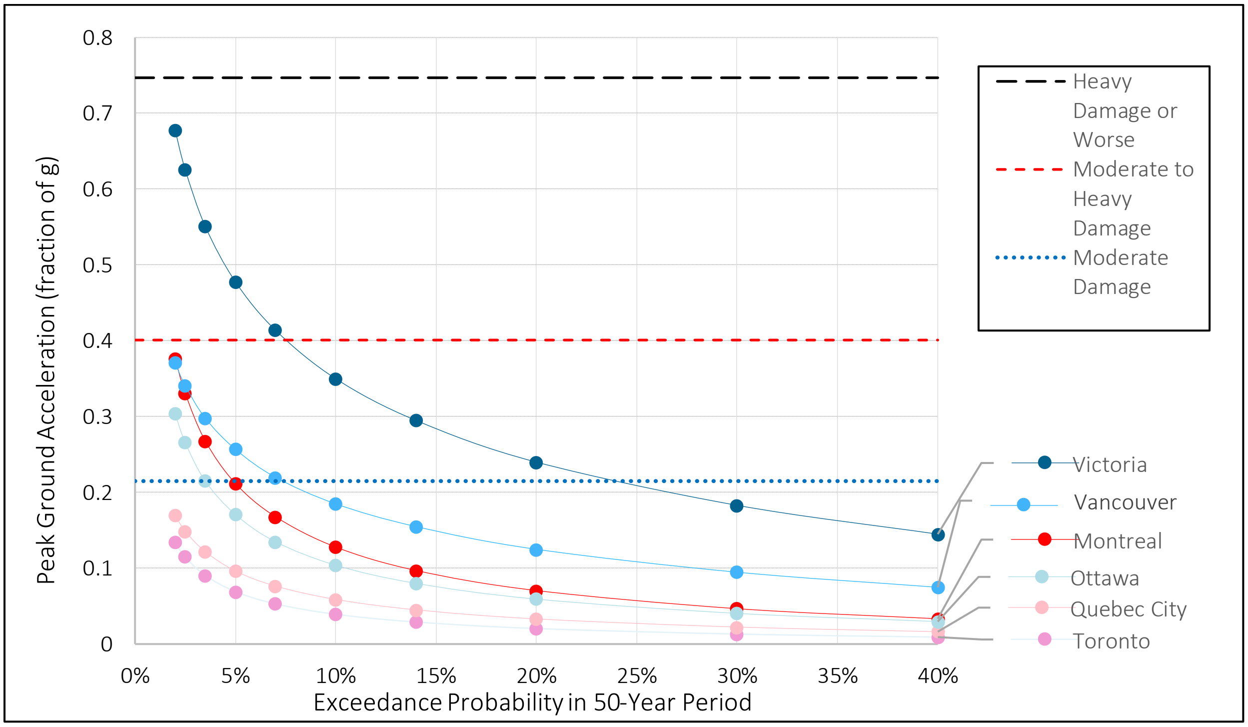
Figure 11
GROUND ACCELERATION PROBABILITY GRAPH BY CANADIAN CITY[51]



50-Year Exceedance Probability	Peak Ground Acceleration by City					
	Victoria	Vancouver	Montreal	Ottawa	Toronto	Quebec City
2%	0.68	0.37	0.38	0.30	0.13	0.17
3%	0.63	0.34	0.33	0.27	0.12	0.15
4%	0.55	0.30	0.27	0.22	0.09	0.12
5%	0.48	0.26	0.21	0.17	0.07	0.10
7%	0.41	0.22	0.17	0.14	0.05	0.08
10%	0.35	0.19	0.13	0.10	0.04	0.06
14%	0.30	0.16	0.10	0.08	0.03	0.05
20%	0.24	0.13	0.07	0.06	0.02	0.03
30%	0.18	0.09	0.05	0.04	0.01	0.02
40%	0.15	0.07	0.03	0.03	0.01	0.02
Key	Moderate to Heavy Damage			Moderate Damage		

[51] Acceleration exceedance curve at default coordinates for each city with a site designation of 760m/s obtained using:

Earthquakes Canada. *2020 National Building Code of Canda Seismic Hazard Tool.* https://earthquakescanada.nrcan.gc.ca/hazard-alea/interpolat/nbc2020-cnb2020-en.php

Damage categories given by the Modified Mercalli Intensity Scale.

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Like the analysis of United States cities, note that this represents a default site condition, only one point in each city, and there could be substantial variations in each parameter throughout each city. Nevertheless, note that Victoria has by far the most hazardous profiles among the Canadian cities. As expected, the other western city, Vancouver, is the next most hazardous. However, Montreal and Ottawa are not far behind Vancouver, and each show material risk of moderate damage. For Toronto and Quebec City, the modeled risk is much lower, indicating that these cities may be of secondary importance.

CANADIAN INSURANCE COVERAGE

Like in the United States, no complete source exists for take-up rates in Canada. However, a number of studies and articles have been conducted, which share results that are approximately consistent. Estimates are shown in Table 19.

Table 19

ESTIMATES OF EARTHQUAKE INSURANCE TAKE-UP RATES BY CANADIAN REGION[52]

	Canadian Insurance Take-Up Rate Estimates		
Estimator	British Columbia	Lower St. Lawrence	Canada Overall
Intact Financial Corporation	64.4% (Victoria) 49.9% (Vancouver)	3.6% (Ottawa) 4.3% (Montreal)	2% (Other Regions)
OECD	60%-70%	2% (Eastern Ontario/Quebec)	
NAIC	60% (Lower Mainland BC)		
J.D. Power	56% (British Columbia)	10% (Atlantic/Ontario)	31% (BC and Quebec)

As described in the first section, accounts of earthquake coverage within British Columbia are fairly high compared to U.S. figures, ranging between 50% and 60%. In the country's East, estimates appear even lower than in the United States, with <5% of homeowners purchasing earthquake coverage.

The risk of damaging shaking in Montreal and Ottawa is not far behind Vancouver, so the difference in take-up rates likely signals a need for more awareness of potential risk in Canada's East. However, like in many states, a shortcoming of these estimates is their lack of geographic specificity. Estimates may include earthquake-specific regions of Eastern Canadian provinces, which are huge land areas, most of which is not exposed. Even in British Columbia, much of the Eastern portion of the state is not significantly exposed, meaning estimates for the province could understate the degree of coverage held by those who are significantly exposed. At the same time, most of the estimates are more specific, and are not targeted at entire provinces. The NAIC study for example was isolated to "Lower Mainland" British Columbia, and the financial disclosure from Intact Financial Corporation was specific to the Canadian cities with the biggest exposure. Thus, despite the limitations of these estimates, it is safe to conclude that earthquake insurance penetration in British Columbia is very high and is very low in Canada's Eastern seismic region.

[52] Table Sources:

Intact Financial Corporation. *Consultation Submission: Second Consultations for the Review of Federal Financial Sector Framework*. 2017. https://www.canada.ca/content/dam/fin/migration/consultresp/pdf-pssge-psefc/pssge-psefc-76.pdf

OECD: OECD (2018), *Financial Management of Earthquake Risk*. https://web-archive.oecd.org/2018-06-04/485307-financial-management-of-earthquake-risk.htm

NAIC: Cole, Cassandra and McCullough, Kathleen. *The Earthquake Insurance Protection Gap: A Tale of Two Countries.* Journal of Insurance Regulation. https://content.naic.org/sites/default/files/jir-za-39-11-el-earthquake-protection.pdf

J.D. Power: Insurance Business Magazine. *Should Earthquake Coverage by Mandatory?* https://www.insurancebusinessmag.com/ca/news/property-insurance/should-earthquake-coverage-be-mandatory-47147.aspx

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CANADIAN FINANCIAL EXPOSURE

While the high earthquake insurance take-up rate in British Columbia is encouraging compared to the United States and Eastern Canada, it also carries additional financial exposures that are likely not present in those other regions.

Specifically, there has been growing concern about the financial resiliency of Canadian insurers with portfolios concentrated in British Columbia, and the residual financial effects that could occur in the event of a major earthquake.

Like U.S. guaranty funds, Canadian insurer's solvency risk is backstopped by the Property and Casualty Insurance Compensation Corporation (PACICC). If an insurer fails, PACICC will pay claims to the non-indemnified policyholders, and recoup losses later via assessments to solvent insurers. Because PACICC's mechanisms do not isolate earthquake-exposed insurers and lines of business from others, there is concern that a major earthquake could have downstream effects on the entire industry. Thus, while PACICC mechanisms are likely sufficient in the case of individual insurer insolvencies, there is growing concern that they may not be in the event of a major earthquake.

To understand its exposure, Canada has adopted some earthquake-specific regulatory procedures. For example, Canadian insurers are required to disclose their earthquake risk to the Office of the Superintendent of Financial Institutions (OSFI).[53] Based on the information it collects, OSFI has recently warned of serious earthquake-related threats to the country's insurance industry.[54] Efforts to study this problem have yielded similar results. For example, a 2016 study by the Conference Board of Canada[55] estimated a $127.5 billion economic loss associated with a 1-in-500-year earthquake, which would cause $42 billion in insured losses. Similar accounts have placed possible losses in the $30 billion to $35 billion range, compared with a total industry capitalization closer to $50 billion,[56] meaning the losses from a single event could cause capital impairment throughout the industry.

While it is clear the potential downside of a Canadian earthquake to its insurance system is significant, work remains to determine the materiality of the threat. First, although it appears insured losses could rival industry capitalization, it is likely that a substantial fraction of these potential losses is reinsured at the insurer level, and thus the exposure to PACICC could be much smaller. Second, many of the accounts of large potential losses use exceedingly high return periods (such as the 500-year period used by the Conference Board), meaning that while possible, such an event is extremely unlikely, and thus may not be of imminent concern.

Recommendations for Canada

Because of the major differences in earthquake insurance take-up rates in Canada's East and West, my recommendations are different for each region.

In the East, it appears that very few homeowners purchase earthquake insurance. Since the risk of a damaging quake is significant, I recommend efforts be made to improve take-up rates. As with the many states, the risk is not present throughout Quebec and Ontario, but rather affects much smaller regions, especially the population centers Montreal and Ottawa. Accordingly, I recommend Canadian Authorities make efforts to quantify take-up rates and

---

[53] Office of the Superintendent of Financial Institutions Canada. Guideline: *Earthquake Exposure Sound Practices.* https://www.osfi-bsif.gc.ca/sites/default/files/import-media/guidance/guideline/2021-06/en/b9.pdf

[54] Financial Post. *Major Disaster Could Pose 'Systemic' Problem for Insurance Industry, Warns OSFI head*. https://financialpost.com/fp-finance/insurance/disaster-systemic-problem-insurance-industry-osfi

[55] Conference Board of Canada. *Canada's Earthquake Risk: Macroeconomic Impacts and Systemic Financial Risk.* https://www.conferenceboard.ca/product/canadas-earthquake-risk-macroeconomic-impacts-and-systemic-financial-risk/

[56] Canadian Underwriter. *Where the Feds Stand with an Earthquake Backstop*. https://www.canadianunderwriter.ca/insurance/where-the-feds-stand-with-an-earthquake-backstop-1004241007/#:~:text=Industry%20estimates%20in%202019%20suggested,than%20%24100%20billion%20in%20losses.

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spread awareness of risk specifically in these regions. For example, authorities could request data from insurers to quantify policy counts and could create awareness materials targeted at making the most exposed Eastern Canadian homeowners aware of the risk to their specific properties.

In the Canadian West, earthquake awareness and insurance penetration are quite high, so efforts to bolster take-up rates may not be needed. However, the high take-up rate has exposed other financial vulnerabilities, such as the solvency risk to Western Canadian insurers, and the consequent financial threat to the Canadian insurance industry. Efforts have been made to quantify this exposure and one approach to ameliorate it could be to adopt additional risk management mechanisms, such as:

- Comprehensive capital and risk modelling to fully understand the potential exposure from earthquakes within reasonable return periods, including modeling the effect of reinsurance that Canadian insurers currently carry.
-
- Increased risk management requirements for companies with high exposure in British Columbia. While solvency regulation typically focuses on capital requirements, given the long-tailed nature of earthquake risk, it is unlikely such insurers will ever be able to hold sufficient capital to protect against the worst earthquakes. Instead, regulators could consider requiring increasing reinsurance requirements (for example, carrying protection for up to a 1-in-100-year event.)
-
- Direct federal backstops to systemic earthquake exposure or purchase of catastrophe reinsurance protection for PACICC.

3.2 PUERTO RICO

Although the seismicity of Puerto Rico is not as extreme as Western U.S. states, it is still significant, and the island has some additional vulnerabilities given its demographic characteristics and separation from the mainland.

PUERTO RICO EARTHQUAKE RISK

Like with Canada, a city-based approach and the USGS hazard tool are used to compare the probabilities of certain levels of PGA in its capital, San Juan, to a number of other U.S. cities. The results appear Figure 12.

At the lower end, shaking in San Juan is quite common, with modeled probabilities for PGA below 2.0 exceeding those for Salt Lake City, and comparable to those found in Seattle. However, at the higher end, there is little risk of extreme ground acceleration, with modeled probabilities below all Western U.S. cities, including Salt Lake City.

Despite the comparatively lower risk of extreme shaking, Puerto Rico buildings face similar EALs as Washington, Oregon, and Alaska, as modeled by NRI. Thus, although the likely parameters of seismicity in Puerto Rico are more limited, the financial risk of damage to buildings is comparable to the United States West. This may be attributable to the quality of building stock there.

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Figure 12
PUERTO RICO GROUND ACCELERATION: COMPARISON WITH MAINLAND CITIES[57]

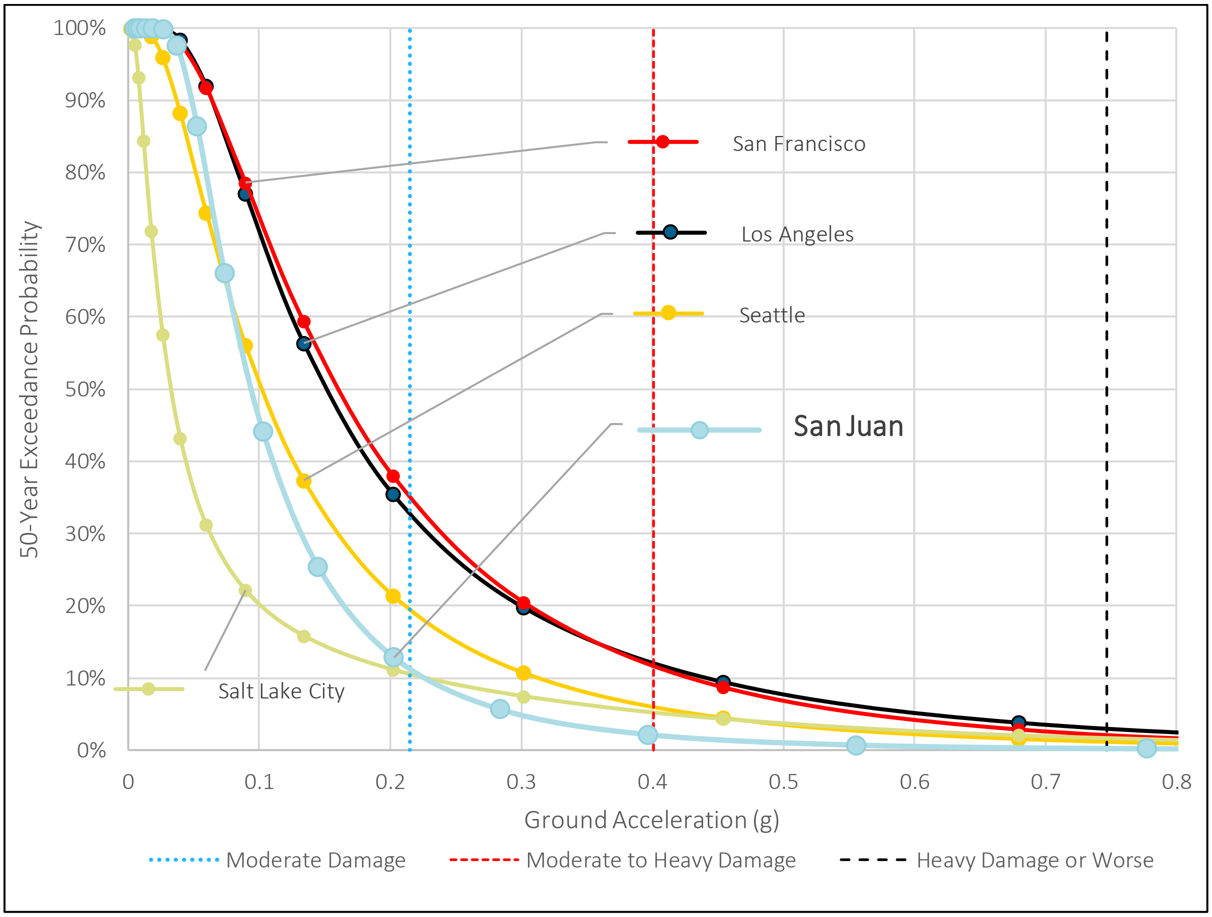

Table 20
PUERTO RICO TSUNAMI AND EARTHQUAKE EAL COMPARED TO OTHER STATES[58]

		EAL ($ Millions)		EAL Per $1k
State	Building Value ($ Billions)	Earthquake	Tsunami	Earthquake
California	$6,898	$9,615	$0.58	$1.39
Washington	$1,458	$1,191	$0.39	$0.82
Oregon	$898	$745	$0.33	$0.83
Alaska	$167	$121	$0.52	$0.72
Hawaii	$213	$127	$1.92	$0.60
Puerto Rico	$459	$327	$0.04	$0.71

[57] Peak Ground Acceleration exceedance probabilities calculated for USGS Unified Hazard Tool using sample coordinates for site class 760m/s. Damage categories given by the Modified Mercalli Intensity Scale.

San Juan coordinates are 18.465 latitude, -66.117 longitude.
[58] Aggregated form NRI county level dataset

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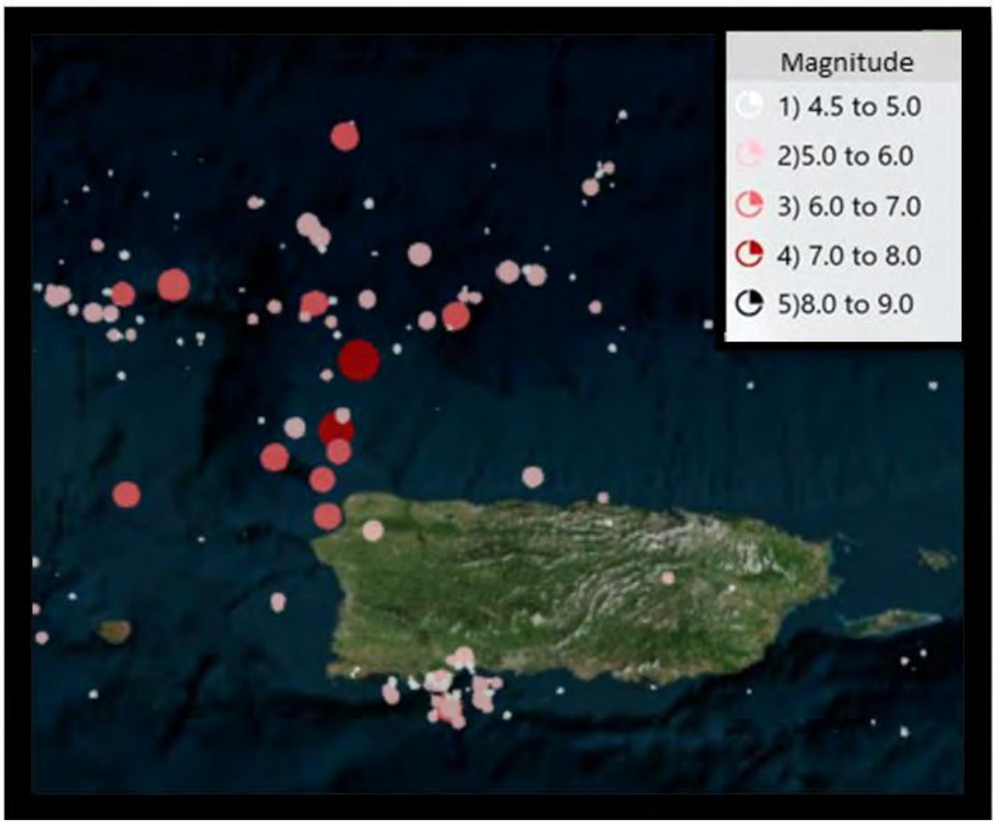
PUERTO RICO EARTHQUAKE AND DISASTER HISTORY

Earthquake risk to Puerto Rico, even when shaking is not extreme, most recently manifested in 2020, where a 6.4 magnitude earthquake caused $425 million in damages ($507 million in inflation-adjusted dollars).[59] This was the 5th most damaging earthquake in U.S. history, despite the event's limited magnitude, and the island's limited size.

The map in Figure 13 displays Puerto Rico earthquakes since 1900, including offshore earthquakes. As shown, events with epicenters on the island are very rare, but offshore events are fairly common. Despite the prevalence of offshore events, tsunami risk on the island is considered fairly low (see the previous table) and does not match that of Western states.

Figure 13
PUERTO RICO EARTHQUAKES SINCE 1900[60]



[59] See Figure 7 in section 1.
[60] Data from United States Geological Survey. *Search Earthquake Catalog*. https://earthquake.usgs.gov/earthquakes/search/

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PUERTO RICO EARTHQUAKE INSURANCE INDUSTRY

Table 21

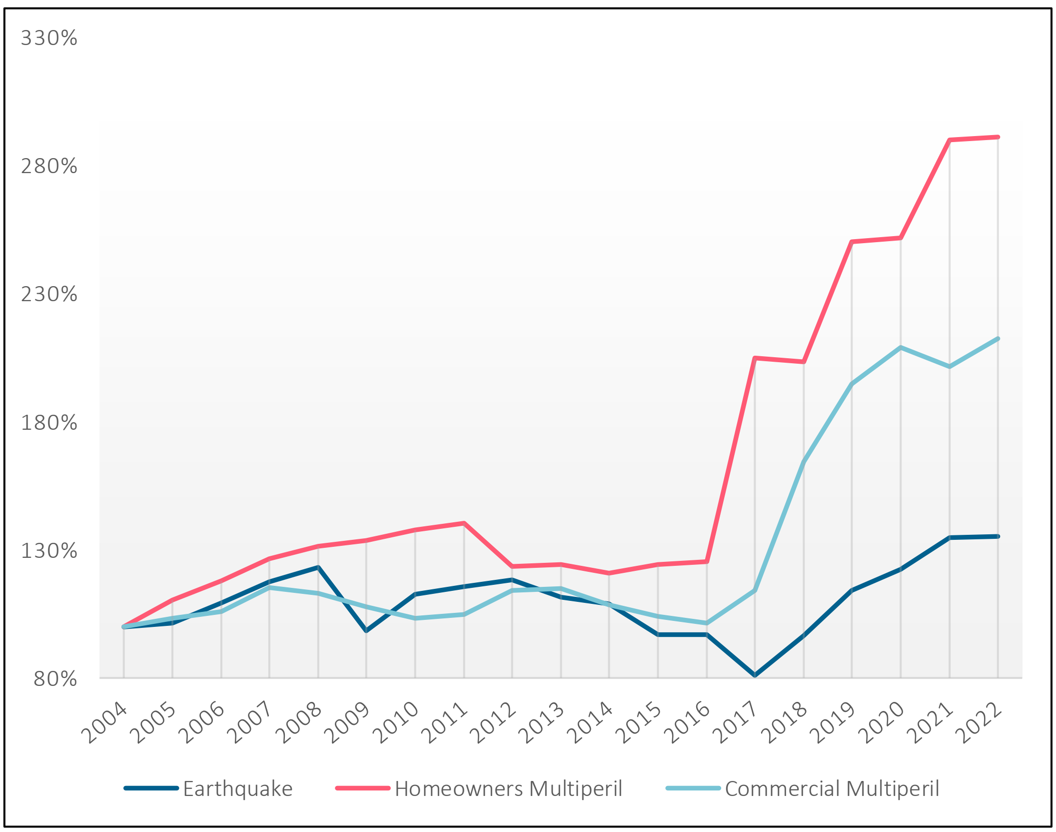
TOP 10 PUERTO RICO EARTHQUAKE INSURERS BY WRITTEN PREMIUM FOR 2022[61]

Rank	Insurer	Written Premium	Market Share	Active License
1	MAPFRE PRAICO Insurance Company	$29,037	22%	
2	Multinational Insurance Company	$24,526	19%	
3	Caribbean American Property Insurance Company	$11,161	9%	
4	Factory Mutual Insurance Company	$9,437	7%	X
5	Cooperativa de Seguros Multiples de Puerto Rico	$8,985	7%	
6	Universal Insurance Company	$8,458	6%	
7	AIG Insurance Company - Puerto Rico	$8,225	6%	
8	United Surety and Indemnity Company	$8,019	6%	
9	MAPFRE Pan American Insurance Company	$6,557	5%	
10	Triple-S Propiedad, Inc.	$5,820	4%	
	Industry Total	$130,597		

Figure 14

PUERTO RICO EARTHQUAKE WRITTEN PREMIUM SINCE 2004 COMPARED TO OTHER PROPERTY LINES[62]

Year	Written Premium
2004	96,557
2005	97,994
2006	105,571
2007	113,559
2008	118,898
2009	95,133
2010	108,769
2011	111,639
2012	114,176
2013	107,746
2014	105,199
2015	93,484
2016	93,576
2017	78,205
2018	93,356
2019	110,131
2020	118,186
2021	130,192
2022	130,597



[61]Data from S&P Global Capital IQ platform. Aggregate Puerto Rico Earthquake Direct Written Premiums for all U.S. insurers.
[62]Data from S&P Global Capital IQ platform. Aggregate Puerto Rico Direct Written Premiums for all U.S. insurers.

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Statistics for Puerto Rico's insurance industry are provided in the figures above. As shown, unlike most states, Puerto Rico's insurance industry is dominated by non-admitted carriers.

Additionally, and unlike other states, earthquake insurance has not seen substantial growth in Puerto Rico. Homeowners and Commercial multiperil lines of business have witnessed 3x and 2x growth, while earthquake premiums have only risen by approximately 30% during the same period.

PUERTO RICO DEMOGRAPHICS

While the earthquake risk itself in Puerto Rico is comparable to moderately-exposed states, the demographic characteristics of the island present some additional challenges, as displayed below.

Table 22

PUERTO RICO DEMOGRAPHICS COMPARED TO U.S. STATES[63]

Metric	Puerto Rico	U.S. Average
DWP: EAL Ratio	40%	35%
Social Vulnerability Score	89	58
Media Value of Owner-Occupied Housing Units	$121,800	$281,900
Owner-Occupied Housing Unit Rate	68.0%	64.8%
Median Household Income	$24,002	$75,149
Poverty Rate	41.7%	11.5%

While insurance penetration and home ownership rates in Puerto Rico are similar to the countrywide average, its social vulnerability score and poverty rate are much higher. Incomes are much lower in Puerto Rico, and so are home values.

Given the high degree of poverty on the island, encouraging more insurance purchase may not be effective, as its citizens are less able to afford it than those on the mainland. At the same time, home values are lower, so earthquake premiums may also be lower, partially explaining the average rate of insurance penetration.

SPECIAL PROGRAMS FOR PUERTO RICO

Given its relative poverty, Puerto Rico has received extensive assistance from FEMA in its rebuilding efforts.[64] Additionally, given the islands hurricane exposure, global reinsurers and brokers have crafted unique risk-management programs for its catastrophe risk, for example, parametric cover that combines the risks of earthquake and hurricane.[65] Given its unique exposure and risks, it is recommended that the island's insurers and federal policymakers continue to pursue solutions tailored to Puerto Rico.

[63] Table Sources:
DWP:EAL Ratio – National Risk Index.

Social Vulnerability Score – National Risk Index.

Other values from U.S. Census Bureau. Quick Facts. Housing values are 2018-2022 median values.
Puerto Rico – https://www.census.gov/quickfacts/fact/table/PR/HCN010217
United States - https://www.census.gov/quickfacts/fact/table/US/PST045223

[64] FEMA. *FEMA and Other Federal Agencies Supporting Earthquake Response in Puerto Rico*.
https://www.fema.gov/press-release/20230425/fema-and-other-federal-agencies-supporting-earthquake-response-puerto-rico

[65] The Insurer. *Aon Secures Earthquake and Hurricane Parametric Cover for Puerto Rico*.
https://www.theinsurer.com/news/aon-secures-earthquake-and-hurricane-parametric-cover-for-puerto-rico/

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4 Government Policies for Earthquake Risk

This section focuses on government programs and policies that address earthquake risk. First, the presence or absence of various programs in each state will be a provided, followed by a description of each type of program, then recommendations for which states (or federal/countrywide entities) could consider adopting additional programs or modifying their existing ones. Later in the report, an appendix provides references and links to these programs.

Table 23 provides a summary of the different insurance-related policies in place for earthquake risk. Please note that this represents the author's best effort to capture all of the different programs in place at the time of this writing. However, it is possible that not all of them were found.

Table 23

PRESENCE OF ACTIVE GOVERNMENT EARTHQUAKE PROGRAMS BY TYPE AND JURISDICTION[66]

		Insurance Policies				Other Than Insurance Policies: Safety		Other Than Insurance Policies: Retrofitting			Other Than Insurance Policies: Property	
Zone	State	Mandatory Offer or Disclosure	Residual or Public Insurer	Consumer Guide - Insurance	Coverage Study	Consumer Guide - Safety	Shakeout Program/Preparedness Campaign	Retrofit Studies	Risk Reduction / Retrofit Grant	Streamlined Permitting	Lending Standards	Seismic Building Codes
California and Sierra Nevada	California	X	X	X	X	X	X		X			Latest IBC
	Nevada			X			X					Non-IBC
Cascadia Subduction	Washington			X	X	X	X			X		Old IBC
	Oregon			X		X	X			X		Latest IBC
Wasatch	Utah			X		X	X	X	X			Latest IBC
New Madrid	Missouri			X	X	X	X					Non-IBC
	Illinois			X		X	X					Non-IBC
	Kentucky			X		X	X					Old IBC
	Tennessee						X					Old IBC
	Arkansas			X	X	X	X					Old IBC
Middleton	South Carolina			X		X	X					Latest IBC
	Alaska			X		X	X					Old IBC
	Hawaii					X	X					Old IBC
	Federal/Countrywide			X		X			X		X	X

"X" Represents that an active program exists at the state or federal level.

[66] Compiled from online sources. Links provided later in this section.

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4.1 TYPES OF GOVERNMENT POLICIES AND PROGRAMS

INSURANCE GOVERNMENT POLICIES

- *Mandatory Offer or Disclosure* – One way to increase the number of consumers who buy earthquake insurance is to require agents to provide an offer of coverage with property insurance. A weaker form of this requirement is for the agent to simply disclose that coverage is not included. California is the only state that imposes this.
- *Residual or Public Insurers* – In other lines of business, it is common for states to create and utilize residual insurers where availability is not widespread in the private marketplace. For earthquake, California has adopted this approach with the CEA. No other states have a similar program in place.
- *Consumer Information Guides* – State departments of insurance publish a shopping guide with information for consumers such as earthquake insurance terminology, coverage types, and a list of insurers offering coverage in the state. Most state departments of insurance provide this, as well as the NAIC at the countrywide level.
- *Coverage Studies* – A handful of states have commissioned studies or issued data calls to determine the extent of coverage or underinsurance for earthquake risk in their states. Most states make the results of these studies publicly available.

GOVERNMENT POLICIES FOR AREAS OTHER THAN INSURANCE

Government Safety Programs

- *Consumer Safety Guides* – A guide to instruct consumers what to do in the event of an earthquake, how to prepare your house and belongings, emergency equipment, and important contact information for emergency services. Most states make this available. FEMA also creates and publishes these guides at the federal level.
- *Shakeout Programs/Preparedness Campaigns* – Shakeout programs are awareness campaigns where the public participates in readiness drills. Shakeout programs are in place in every state. Some states have other similar readiness campaigns.

Government Retrofitting Programs

- *Retrofit Studies* – Utah conducted research into their building stock assess retrofitting in Salt Lake City.
- *Risk Reduction / Retrofit Grants* – California and the federal government have programs to provide financial assistance for property retrofitting. The federal government has created a comprehensive program to reduce risk throughout the country, the National Earthquake Hazard Reduction Program,[67] which provides resources and conducts studies to determine where federal funds should go.
- *Retrofit Permitting* –Oregon and Washington have streamlined their retrofit permitting processes.

[67] See https://www.nehrp.gov/

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<u>Government Programs Related to Real Estate</u>

- *Lending Standards* - Another government mechanism that relates to earthquake risk is the standards for construction or insurance required on mortgages backed by government-sponsored enterprises (GSEs) like Fannie Mae and Freddie Mac. The GSE's impose both types of standards for multifamily properties.[68] However, there are no such impositions on single family dwellings.[69] According to a 2018 report by R Street Institute, the earthquake insurance gap leaves the federal government exposed to over $200 billion in uninsured risk.[70]
-
- *Seismic Building Codes* – The foundations of building codes are the International Building Code (IBC) and the International Residential Code (IRC). IBC includes design provisions for structures to be resilient to earthquakes depending on the geographic category of risk in which the structure is placed.[71] The building codes that are in effect are adopted, modified, or amended at both the state and municipal level. Thus, IBC codes do not necessarily take effect when they are created and are instead adopted by states at their discretion. Some states have not adopted the IBC seismic standards, and others have not adopted the latest standards.[72]

4.2 RECOMMENDATIONS FOR POLICY MAKERS

This section provides recommendations as to which additional policies could be beneficial for adoption, beginning with overall recommendations, then with recommendations for individual states and polices.

<u>RECOMMENDATIONS: OVERALL</u>

Based on the foregoing assessment of earthquake risk, insurance market, and coverage gaps, the biggest opportunities to reduce financial exposure to earthquake risk appear to exist in the Western United States. California (65% of national EAL), has already adopted many policies such as forming the CEA, recording take-up rate statistics, or providing retrofit grants. Outside of California, other western states with sizeable EAL like Nevada (8.1%), Oregon (5.0%), Utah (2.5%), and Nevada (2.0%), combine for a total of 82.6% of all EAL. Because of the sizeable EAL in these states, they may benefit from adopting some of the more comprehensive programs that California has.

In Eastern regions (New Madrid and South Carolina), insurance penetration appears better in many states, and there is a smaller fraction of the population exposed. In some cases, the severity of a potential earthquake is smaller, but in others like Charleston, SC or Memphis, TN there is a material probability of a significant event. One cumbersome feature of New Madrid is that it falls directly on the intersection of several states. The risk overall is substantial, but the earthquake-exposed fraction of any given state is fairly small. Therefore, it may be unlikely that these states

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[68] Fannie Mae Multifamily Guide. *Catastrophic Risk Insurance*. Section 501.03D
https://mfguide.fanniemae.com/node/4451

[69] Federal Housing Finance Agency. *Disaster Risk for Enterprise Single-Family Mortgages*. Page 8.
https://www.fhfaoig.gov/sites/default/files/WPR-2021-004.pdf

[70] R Street Institute. *Take a Load Off Fannie: The GSEs and Uninsured Earthquake Risk.*
https://www.rstreet.org/wp-content/uploads/2018/09/No.-151.pdf

[71] FEMA. *2020 NEHRP Recommended Seismic Provisions: Seismic Design Category Maps for 2024 International Residential Code (IRC) and International Building Code (IBC)*
https://www.fema.gov/sites/default/files/documents/fema_p-2192-nehrp-provisions-seismic-design-maps-2024-irc-ibc.pdf

[72] See page 26 of United States Government Accountability Office (GAO). *EARTHQUAKES: Opportunities Exist to Further Assess Risk, Build Resilience, and Communicate Research*.
https://www.gao.gov/assets/d22105016.pdf

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would derive enough benefit from implementing more comprehensive or costly programs on their own. Instead, because earthquake risk is a problem shared among many states, there are cases where the federal government may be in the best position to act.

RECOMMENDATIONS BY STATE AND POLICY

Some of the included recommendations are for states to consider adopting policies (denoted "R" in the next table) because of the size of the state or importance of the policy. For others, the recommendation is more reserved, as the author believes that they should only be adopted depending on fact-finding or cost/benefit analyses, these are denoted "C." For other policies, states already have an approach in place, but the author's recommendation is to consider modifications, denoted "M." Recommendations appear in Table 24 and are described in the following pages.

Table 24

GOVERNMENT EARTHQUAKE PROGRAMS RECOMMENDED FOR CONSIDERATION BY TYPE AND JURISDICTION[73]

		Insurance Policies				Other Than Insurance Policies						
						Safety		Retrofitting			Real Estate	
Zone	State	Mandatory Offer/ Disclosure	Residual or Public Insurer	Consumer Guide - Insurance	Coverage Study/Data Call	Consumer Guide - Safety	Shakeout Program	Retrofit Studies	Retrofit Grant	Streamlined Permit	Lending Standards	Seismic Building Codes
California and Sierra Nevada	California	X	X	X	X	X	X	R	X	R		X
	Nevada	C		M	R		X	C	C	C		M
Cascadia Subduction	Washington	R	C	M	X	X	X	C	C	X		M
	Oregon	R		M	R	X	X	C	C	X		X
Wasatch	Utah	C		M	R	X	X	X	X	C		X
New Madrid	Missouri			M	X	X	X					M
	Illinois			M	C	X	X					M
	Kentucky			M	C	X	X					M
	Tennessee			C	C		X					M
	Arkansas			M	M	X	X					M
Middleton	South Carolina			M	C	X	X					X
	Alaska			M	C	X	X					M
	Hawaii			C	C	X	X					M
	Federal/Countrywide		C	X	R	X		C	X		M	X

"X" represents an active program.
"R" represents a program that is recommended for consideration.
"C" represents a program that could be considered, depending on an evaluation of potential benefits.
"M" represents a program for which modification is recommended for consideration.

[73] Compiled from online sources. Links provided later in this section.

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<u>RECOMMENDATIONS: INSURANCE GOVERNMENT POLICIES</u>

- *Mandatory Offer or Disclosure* – Adopting mandatory offer of or disclosure about earthquake seems like an effective way to increase the number of consumers who buy insurance. The disadvantage is that this may be an undue burden to the sales process, especially to agents, who would need to seek out relationships with earthquake insurers. Thus, this policy likely makes sense to be considered only for the two states with EAL above 5% of the national total, Oregon and Washington. For the next two, Nevada and Utah, the exposed population is smaller, so consideration would only make sense if the program benefits could be shown to be substantial enough.
- *Residual or Public Insurers* – Creating public insurance entities is a costly and complex process, so it should be reserved for problems of a commensurate scale. Also, based on the preceding examination of the private market for earthquake insurance, there is a growing number of carriers providing underwriting capacity for the risk, indicating that the coverage gap may derive from other issues than availability such as cost or awareness. With 8.1% of national EAL, Washington is likely the only state with a scale of population large enough for the formation of a public insurer to be considered. Alternatively, a federal program could be considered, as the issue of earthquake insurance is small in many individual states but may be large enough at the national level to justify the formation of a coverage-providing entity, similar to the National Flood Insurance Program (NFIP). Because of its cost and complexity, this item is not strongly recommended, but is listed as one that could be considered by the state of Washington or at the Federal level.
- *Consumer Information Guides* – Most states create these, as does the NAIC. While these guides have good intent, the author believes that they are redundant from state to state, usually containing the same information, and usually not as complete as the NAIC version. The guides contain little state-specific information, so the NAIC guide would be as useful for consumers in most cases. Additionally, while many states often provide a listing of insurers who sell earthquake insurance, this information is unlikely to be actionable to consumers who must obtain it through agents, as it is rarely sold on a direct basis. It is recommended for states to consider modifying these guides to focus on the specific features of the state, for example by informing consumers of the potential frequency and severity of earthquakes by location, so they can make an informed decision specific to their property. California provides a tool (MyHazards), which gives homeowners rich information about their specific property location.
- *Coverage Studies* – A number of states have engaged in studies to quantify their uninsured population and provide this information to the public. This seems like a useful practice to be performed every few years, so it is recommended that all states evaluate their potential benefits, and those with over 2% of national EAL without studies (Oregon, Utah, and Nevada) consider conducting them. Arkansas performs a data call but does not appear to make it available to the public, so it is recommended they consider modifying their approach by publishing the data call results.

<u>RECOMMENDATIONS: GOVERNMENT POLICIES FOR AREAS OTHER THAN INSURANCE</u>

<u>Government Retrofitting Programs</u>

- *Retrofit Studies* – Like coverage studies, understanding the extent of risk reduction that could be achieved by retrofitting is useful data that policymakers could collect at a reasonable cost. With this, they could determine the potential benefits of other retrofitting programs. Given the high degree of risk in California, it is recommended that the state, or federal government, consider endeavoring to produce these estimates. Many individual California cities have done this, but to the author’s knowledge, no study exists at the statewide level. Utah has engaged in a study, and it may make sense for the other three states with EAL above 2% of the national average (Washington, Oregon, and Nevada), to consider conducting similar studies.

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- *Retrofit Grants* – California and Utah (Salt Lake City), have retrofit grants. If Washington, Oregon, or Nevada were to do retrofit studies, depending on the results, they could consider grant programs in targeted areas.
- *Retrofit Permitting* – The streamlined retrofit permitting policies adopted by Oregen and Washington seem like efficient ways to promote retrofitting by reducing cost and hassle to consumers. Given the importance of earthquake risk in California, it is recommended the state consider adopting a similar policy. For the other states with EAL in excess of 2% of the national total - Nevada and Utah - it could also make sense to consider similar policies if the benefits can be shown to be sufficient.

Government Programs Related to Real Estate

- *Lending Standards* – Given reports of uninsured earthquake risk to GSEs, they could consider adopting insurance requirements on mortgages in high-risk areas, similar to those for flood. However, successful implementation of these standards could be difficult to achieve, as no federal insurer for earthquake insurance exists in the place of the NFIP. Therefore, if lending standards were introduced without ensuring earthquake insurance is available to all, it could be problematic. Additionally, requiring earthquake insurance would place a cost burden on many homeowners. It is recommended that the GSEs review policies for earthquake insurance requirements but to exercise a high degree of caution in making changes.
- *Seismic Building Codes* – While all states have some degree of consideration for earthquakes in their building codes, it is recommended that all states who have not already adopted the latest IBC standards consider adopting them.

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5 Appendix 1: Index of State and Federal Programs

This section lists the data that is the basis for the previous summary and provides links and references to each government program for earthquake risk. California is provided first, followed by a summary of non-California retrofit programs and non-California public awareness programs.

CALIFORNIA EARTHUAKE PROGRAMS

Table 25

CALIFORNIA EARTHQUAKE RISK - PUBLIC POLICY SUMMARY

Policy Type	Description
Insurance Regulation	California Law mandates that all insurance companies must offer earthquake coverage with the purchase of any residential policy.[74] Any policy sold without earthquake coverage must include disclosures to notify policyholders that earthquake coverage is not included. Mandatory offer has been part of California law since 1984,[75] and it was formerly typically sold as part of homeowners insurance policies. This created a market availability crisis following the 1994 Northridge Earthquake, as many insurers pulled back from the residential market out of reluctance to provide earthquake coverage. This resulted in the 1996 formation of the California Earthquake Authority (CEA), a "not-for-profit, publicly managed, privately funded entity,"[76] which is funded by the state's private insurers. Insurers may offer the coverage themselves or may offer it through CEA. The CEA has its own capacity to pay claims and purchase reinsurance. Most earthquake insurance in the state is sold through CEA.
Public Awareness and Education	The California Department of Insurance publishes consumer guides to help citizens understand and prepare for earthquake risk.[77] *MyHazards:*[78] Online tool to help citizens understand risk of wildfire, earthquake, soil liquefaction, and tsunami at their address. *The Great California Shakeout:*[79] A campaign to encourage widespread preparedness drills in workplaces, schools, and homes around the state. Drills can happen throughout the year but are encouraged on a particular day (international shakeout day).
Retrofitting Programs	Multiple Programs Available:[80] *Brace and Bolt Retrofit*: Offered through CEA and the California Residential Mitigation Program (CRMP). Intended for homes built before 1980 to bring them up to the current building code. CRMP Grants of up to $3,000 are available for homeowners in high-risk zip codes. CEA grants are for policyholders and are by invitation only. For homes with retrofit performed, CEA offers discount of up to 25% off earthquake premium. *Soft-Story Retrofit:* For houses with a living space over the garage. Intended for houses built before 2000 to bring them to current code. Grants of up to $13,000 available.

[74] California Insurance Code. Chapter 8.5, Section 10086.
[75] Palm, Risa; Hodgson, Michael. *Earthquake Insurance: Mandated Disclosure and Homeowner Response in California*. Georgia State University Department of Geosciences. 1992. https://scholarworks.gsu.edu/cgi/viewcontent.cgi?article=1011&context=geosciences_facpub
[76] California Earthquake Authority. *History of the California Earthquake Authority.* https://www.earthquakeauthority.com/About-CEA/CEA-History
[77] California Department of Insurance. *Earthquake Insurance.* https://www.insurance.ca.gov/01-consumers/105-type/95-guides/03-res/eq-ins.cfm
[78] California Governor's Office of Emergency Services. https://myhazards.caloes.ca.gov/
[79] Southern California Earthquake Center. https://www.shakeout.org/california/
[80] California Earthquake Authority. *Earthquake Retrofit Grants.* https://www.earthquakeauthority.com/Prepare-Your-House-Earthquake-Risk/Brace-and-Bolt-Grants

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<u>NON-CALIFORNIA EARTHQUAKE PROGRAMS- RETROFITTING AND RISK REDUCTION</u>

Table 26

NON-CALIFORNIA EARTHQUAKE RISK: RETROFITTING AND RISK REDUCTION PROGRAMS

Jurisdiction	Description
Federal	<u>Retrofit Grant Programs:</u> National Earthquake Hazards Reduction Program: An interagency program to study and fund seismic risk reduction throughout the United States: https://www.nehrp.gov/pdf/FY2022-29%20NEHRP%20Strategic%20Plan%20-%20Post%20Version.pdf FEMA – A History of Earthquake Mitigation Activities: A list of federal grants provided to states and municipalities for Earthquake Risk Reduction: https://www.fema.gov/emergency-managers/risk-management/earthquake/state-assistance-program-grants/history-mitigation-activities
Washington	<u>Retrofit Permitting Program:</u> Washington Association of Building Officials: Earthquake Home Retrofit Resources. Washington does not provide grants, but has a streamlined permitting process to aid efficient retrofitting: https://www.wabo.org/earthquake-home-retrofit-resource-page
Oregon	<u>Retrofit Permitting Program:</u> The state of Oregon and city of Portland provide educational resources and schematics to assist with retrofitting: Earthquake Retrofitting: https://www.oregon.gov/ccb/Documents/Earthquake%20Retrofitting.pdf Residential Seismic Strengthening: https://www.portland.gov/ppd/residential-permitting/residential-seismic-strengthening
Utah	<u>Retrofit Grant Program:</u> “Fix the Bricks” program. Pays up to 70% for seismic retrofits of unreinforced masonry homes in Salt Lake City: https://www.slc.gov/housingstability/city-housing-programs/fix-the-bricks/

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NON-CALIFORNIA EARTHQUAKE PROGRAMS- PUBLIC AWARENESS AND EDUCATION

Table 27

NON-CALIFORNIA EARTHQUAKE RISK: PUBLIC AWARENESS AND EDUCATION PROGRAMS

Jurisdiction	Description
Federal	**Consumer Guides – Insurance:** National Association of Insurance Commissioners (NAIC) – A Consumer's Guide to Earthquake Insurance: https://content.naic.org/sites/default/files/publication-equ-pp-consumer-earthquake.pdf **Consumer Guides – Safety:** Federal Emergency Management Agency (FEMA) – Earthquake Safety Checklist: https://www.fema.gov/sites/default/files/documents/fema_b-526-eq-safety-checklist.pdf Federal Emergency Management Agency (FEMA) – Earthquake Safety at Home: https://www.fema.gov/sites/default/files/2020-08/fema_earthquakes_fema-p-530-earthquake-safety-at-home-march-2020.pdf Federal Emergency Management Agency (FEMA) – Be Prepared for an Earthquake: https://www.ready.gov/sites/default/files/2021-12/ready_earthquake-information-sheet.pdf
Nevada	**Consumer Guide – Insurance:** Consumer's Guide to Earthquake Insurance: https://doi.nv.gov/uploadedFiles/doinvgov/_public-documents/News-Notes/EarthquakeInsurance_B.pdf **Shakeout Program:** The Great Nevada Shakeout: https://www.shakeout.org/nevada/
Washington	**Consumer Guide – Insurance:** Consumer Guide to Earthquake Insurance: https://www.insurance.wa.gov/earthquake-insurance Washington Consumer Guide to Homeowner Insurance: https://www.insurance.wa.gov/sites/default/files/documents/homeowner-insurance-guide_0.pdf **Coverage Study:** https://www.insurance.wa.gov/sites/default/files/2018-02/earthquake-data-call-report.pdf **Consumer Guide – Safety:** Washington State Tsunami Program: https://mil.wa.gov/tsunami **Shakeout Program:** The Great Washington Shakeout: https://www.shakeout.org/washington/
Oregon	**Consumer Guide – Insurance:** Oregon Division of Financial Regulation Guide to Earthquake Insurance: https://dfr.oregon.gov/insure/home/storm/pages/earthquake.aspx **Consumer Guide – Safety:** Oregon Health Authority. Get Prepared: Earthquakes: https://www.oregon.gov/oha/ph/preparedness/prepare/pages/prepareforearthquake.aspx Oregon Tsunami Clearinghouse: https://www.oregon.gov/dogami/tsuclearinghouse/Pages/default.aspx

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Jurisdiction	Description
	<u>Shakeout Program:</u> Great Oregon Shakeout: https://www.shakeout.org/oregon/resources/
Utah	<u>Consumer Guide – Insurance:</u> Utah Insurance Department. Earthquake Insurance in Utah: https://insurance.utah.gov/consumer/auto-home/disaster-prep/earthquake <u>Consumer Guide – Safety:</u> Utah Department of Public Safety. Be Ready Utah: https://beready.utah.gov/ <u>Shakeout Program:</u> Great Utah Shakeout: https://www.shakeout.org/utah/
Missouri	<u>Consumer Guide – Insurance:</u> Missouri Department of Insurance. Earthquake Insurance: https://insurance.mo.gov/earthquake/ Missouri Department of Insurance. Earthquake Shopping Guide: https://insurance.mo.gov/earthquake/documents/2022EarthquakeShoppingGuide.pdf <u>Coverage Study:</u> Missouri Department of Insurance. Residential Earthquake Coverage in Missouri, Statistics Section: https://insurance.mo.gov/reports/documents/OverviewofResidentialEarthquakeInsurancein2022.pdf <u>Consumer Guide – Safety:</u> Missouri Department of Public Safety. Earthquake Preparedness: https://sema.dps.mo.gov/earthquake_preparedness/ <u>Shakeout Program:</u> The Great Central U.S. Shakeout: https://www.shakeout.org/centralus/
Illinois	<u>Consumer Guide – Insurance:</u> Illinois Insurance Association. Insurance Coverage for Earthquake Damage: https://www.illinoisinsurance.org/news-updates/insurance-coverage-earthquake-damage <u>Consumer Guide – Safety:</u> Illinois Insurance Association. Prepare for Earthquake, Part 2: https://www.illinoisinsurance.org/news-updates/prepare-earthquake-part-2 <u>Shakeout Program:</u> The Great Central U.S. Shakeout: https://www.shakeout.org/centralus/
Kentucky	<u>Consumer Guide – Insurance:</u> Kentucky Department of Insurance. A Consumer's Guide to Earthquake Insurance: https://insurance.ky.gov/ppc/Documents/consguideearthquakeins071117.pdf <u>Consumer Guide – Safety:</u> Kentucky Emergency Management. KYEM Earthquake Program:

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Jurisdiction	Description
	https://kyem.ky.gov/Preparedness/Pages/Earthquake.aspx **Shakeout Program:** The Great Central U.S. Shakeout: https://www.shakeout.org/centralus/
Tennessee	**Shakeout Program:** The Great Central U.S. Shakeout: https://www.shakeout.org/centralus/
Arkansas	**Consumer Guide – Insurance:** Arkansas Insurance Department. Market Assistance Program Earthquake Resources: https://insurance.arkansas.gov/consumer-services/consumer-services/disaster-prepardness/earthquake-resources/ **Coverage Study:** Arkansas Insurance Department. Earthquake Data Call: https://rhld.insurance.arkansas.gov/EarthquakeData **Consumer Guide – Safety:** Arkansas Division of Emergency Management. Earthquake Preparedness Guide: https://www.dps.arkansas.gov/emergency-management/adem/plan-prepare/earthquake/ **Shakeout Program:** The Great Central U.S. Shakeout: https://www.shakeout.org/centralus/
South Carolina	**Consumer Guide – Insurance:** South Carolina Department of Insurance. Are You Covered for an Earthquake: https://www.doi.sc.gov/1000/Are-You-Covered-for-an-Earthquake South Carolina Department of Insurance. Earthquake Coverage Guide: https://doi.sc.gov/DocumentCenter/View/13678/Earthquake-Coverage-2022- **Consumer Guide – Safety:** South Carolina Emergency Management Division. Earthquake Preparedness Page: https://scemd.org/prepare/types-of-disasters/earthquakes/ South Carolina Emergency Management Division. Earthquake Guide: http://scemd.cdn.missc.net/media/1009/sc-earthquake-guide.pdf South Carolina Emergency Management Division. Earthquake Plan: https://scemd.org/em-professionals/plans/south-carolina-earthquake-plan/ **Shakeout Program:** The Great SouthEast Shakeout: https://www.shakeout.org/southeast/southcarolina/

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Jurisdiction	Description
Alaska	**Consumer Guide – Insurance:** Alaska Department of Commerce, Community, and Economic Development. Earthquake Insurance: https://www.commerce.alaska.gov/web/ins/Consumers/HomeInsurance/EarthquakeInsurance.aspx Alaska Insurance Division. Consumer Guide to Homeowners Insurance: https://www.commerce.alaska.gov/web/Portals/11/Pub/INS_HomeownersInsuranceGuide.pdf **Consumer Guide – Safety:** University of Alaska. Alaska Earthquake Center: https://earthquake.alaska.edu/ University of Alaska. Alaska Earthquake Center. Tsunamis in Alaska: https://earthquake.alaska.edu/about-tsunamis-alaska **Shakeout Program:** The Great Alaska Shakeout: https://www.shakeout.org/alaska/
Hawaii	**Consumer Guide – Safety:** State of Hawaii Department of Health. Earthquake Preparedness Guide: https://health.hawaii.gov/prepare/natural-disasters/earthquakes/ **Shakeout Program:** The Great Hawaii Shakeout: https://www.shakeout.org/hawaii/
Puerto Rico	**Consumer Guide – Safety:** Portal for the Government of Puerto Rico. Earthquakes Response: https://recovery.pr.gov/en/earthquakes-response **Shakeout Program:** The Great Puerto Rico Shakeout: https://www.shakeout.org/puertorico/home.html

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6 Appendix 2: U.S. Regional Profiles – Seismic and Insurance Data for Each Earthquake Region

The pages that follow contain similar statistics to those presented throughout this report for each state and seismic zone. Since the exhibits for each state are the same, descriptions and references appear here, followed by key takeaways for each state.

6.1 DESCRIPTION OF STATE AND REGION LEVEL EXHIBITS

REGION LEVEL MAP AND TABLE: EARTHQUAKES SINCE 1900

For each seismic region, there is a point map and table of the past one hundred years of seismic activity. Dot sizes and colors represent the magnitude of each event. The source for the data is the USGS "Search Earthquake Catalog", which can be found at https://earthquake.usgs.gov/earthquakes/search/. Earthquakes displayed are those above 4.5 magnitude, for period between 1/1/1900 and 10/30/2023. A table listing the top 10 earthquakes in each region, along with their date and location, also appears.

STATE LEVEL TABLE: EARTHQUAKE RISK BY AFFECTED COUNTY PERCENTILE GROUPS

For each state, a table displays earthquake risk measures for counties above the 50th, 70th, and 90th risk percentiles as identified by FEMA's National Risk Index (NRI). Building Values and Expected Losses for Earthquake and Tsunami are taken directly from NRI county-level data, which was obtained from https://hazards.fema.gov/nri/data-resources#csvDownload. Expected Economic Losses are also from the NRI, and the income data to estimate economic losses per $1,000 of income are obtained from the vendor S&P Capital IQ, which uses data from the vendor Claritas, which sources data from the American Community Survey and Decennial Census.

STATE LEVEL MAP: EXPECTED ANNUAL LOSSES BY COUNTY

For each state, Expected Annual Losses (EAL) to buildings per $1,000 of building value, sourced from the NRI.

STATE LEVEL TABLE: VULNERABILITY STATISTICS BY AFFECTED COUNTY PERCENTILE GROUPS

For each state, a table displays population vulnerability measures for counties above the 50th, 70th, and 90th risk percentiles as identified by the NRI. Social Vulnerability Score and Community Resilience Score are sourced from the NRI, and Family Poverty Rate and % Population Over 65 are sourced from Claritas via the American Community Survey and Decennial Census.

STATE LEVEL MAP: FAMILY POVERTY RATE BY COUNTY

For each state, a map of Family Poverty Rate is provided, which can be compared with the earthquake risk map to assess whether the state's most economically vulnerable populations are threatened by seismic risk. Poverty rate data is sourced from Claritas via the American Community Survey and Decennial Census.

STATE LEVEL TABLE: TOP 10 EARTHQUAKE INSURERS BY WRITTEN PREMIUM

For each state, a table names of the top 10 earthquake insurers based on 2022 written premium, the market share of each, and an indicator of whether the insurer was actively licensed during 2022. The source is the S&P Global Capital IQ platform, which aggregates data from all U.S. insurers' statutory annual statements.

STATE LEVEL TABLE AND GRAPH: EARTHQUAKE WRITTEN PREMIUM AND GROWTH SINCE 2004

For each state, a table provides the reported Earthquake written premium for each year since 2004. The accompanying graph compares the growth since 2004 with other property lines of business – Homeowners and Commercial Multiperil.

The source of the data is the S&P Global Capital IQ platform, which aggregates data from all U.S. insurers' statutory annual statements.

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6.2 TAKEAWAYS FROM STATE LEVEL DATA

CALIFORNIA AND SIERRA NEVADA FAULTS

California

As the state with the most significant share of the country's earthquake risk, California has experienced a substantial number of damaging earthquakes, and many over a 7.0 magnitude. The state's risk is concentrated along its coastline and is especially threatening in major urban centers including the San Francisco Bay Area, greater Los Angeles, and San Diego County. The populous Central Valley is comparatively lower risk, but there is a marked degree of risk in the state's inland Sierra Nevada mountains along its coast with Nevada.
Despite lower risk in a handful of inland counties, California is entirely affected by earthquake risk, with 100% of the state's building value situated in counties ranking in the NRI's 70th percentile of risk or above, and 93% of building value positioned in the 90th percentile of risk or above. Overall expectation of loss is much higher than the national average, with expected EAL per $1,000 of building value around five to six times the national average, and economic losses per $1,000 of income five times the national average.

Although earthquake risk throughout the state is quite substantial, California ranks well in its vulnerability metrics, a result of its affluence. Counties with the highest poverty rates lie in inland areas, away from the most hazardous seismic areas. The state has an elderly population slightly lower than the national average, a social vulnerability score lower than the national average and a community resilience score significantly higher than average. The metrics suggest that California's population is in a better position to withstand a damaging earthquake than other states if they were to experience a similar event.

The state's insurance market is dominated by the California Earthquake Authority, a partnership between homeowners insurers and state authority to minimize coverage gaps in risky areas, but also features significant writings from a mix of admitted and non-admitted insurers. While earthquake premiums have grown significantly since 2016, they have not outpaced the growth in homeowners and commercial multiperil lines.

Nevada

The majority of Nevada's earthquake risk lies along the border with California, near the Sierra Nevada Mountain range. The entirety of the state is exposed to significant risk compared to the national average, with 100% of building value situated in counties of NRI's 70th percentile and above, but only a fraction (23%) in the 90th percentile and above. Las Vegas, the state's largest population center, is not significantly exposed; but the second largest, Reno, is situated in the high-risk area near the California coast.

Overall, the state's risk metrics are more benign than California's, with statewide EAL and expected economic losses only around two times the national average. However, for the counties in the 90th percentile and above, the risk is similar to California, at around five times the national average for EAL and five to six times the national average for economic losses.

In general, the state appears at risk based on population vulnerability metrics, with an above average rate of poverty and elderly population, but a social vulnerability score higher than, and a community resilience score lower than, the national average. These metrics are markedly better in the state's most exposed counties, but still significantly worse than the national average.

The earthquake insurance industry is populated with private insurers, and most of the top writers hold active licenses. Written premiums have increased significantly since 2019, vastly outpacing other property lines in terms of growth, which suggests that the earthquake coverage gap may be closing.

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CASCADIA SUBDUCTION ZONE

Washington

Although historical earthquakes have not been as significant as those in California, the state is one of the most hazardous from a tsunami perspective, as subduction faults are usually associated with this risk. Given its high population and coastal position, Washington contains the second largest share of earthquake risk in the country.

Washington does not appear particularly at-risk in terms of population vulnerability metrics, with a low poverty rate, a small elderly population, and social vulnerability and community resilience scores significantly better than national averages.

The state's earthquake insurance industry is dominated by admitted carriers, the most prominent being State Farm, suggesting that a large share of earthquake premiums are being written on residential properties. As with other states, earthquake premium growth has outpaced other property lines, suggesting that coverage may be improving.

Oregon

While less populous than Washington, Oregon's risk profile appears similar. The riskiest areas are positioned along the coast, but risk is significant throughout the state. Tsunami risk is prominent in coastal areas, given the state's proximity to the Cascadia Subduction Fault. EAL and expected economic losses are both significant, at around three to five times the national average.

Oregon appears more exposed in terms of population vulnerability metrics. Although the state's poverty rate is low, some of the counties with significant poverty are also those with elevated earthquake risk, in the southwest corner of the state. The elderly population is above the national average. The social vulnerability score is slightly below the national average, and the community resilience score is higher, but the difference is not as large as in more affluent states like California and Washington.

The state's earthquake insurance industry is dominated by admitted, residential carriers. Like other states, growth in earthquake premiums has outpaced other property lines.

WASATCH FAULT

Utah

Utah's earthquake history is fairly sparse, with only two events exceeding 6.0 on the Richter scale since 1900. Nevertheless, the state's earthquake risk is considered significant, with 77% of the state's building value situated in counties considered in the 90th percentile of risk or above. EAL and economic risk are high, at around three to four times the national average.

The state's population does not appear to be vulnerable. Utah has a low poverty rate, small elderly population, low social vulnerability score, and high community resilience score. The state's most impoverished counties are not those with the most significant earthquake exposure.

Utah's earthquake insurance industry is populated with admitted carriers, focused on residential business. The state has experienced significant recent growth in earthquake premiums, rapidly outpacing growth in other property lines of business.

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NEW MADRID FAULT
While there is potential for a major earthquake in the New Madrid area, historical earthquake activity has been benign, with no events exceeding a magnitude of 6.0 since 1900.

Missouri
The risk in most of Missouri is above average, with 68% of the state's building value in counties classified by NRI in the 70th percentile of risk or above. However, little of the state faces extreme risk, with only 5% of building value in the 90th percentile and above, concentrated in the southeast corner of the state. While the EAL in these counties is not notably high (three to four times the national average), the potential economic loss is significant since some of the state's most exposed counties are also some of its lowest income.

Statewide, population vulnerability metrics are similar to the national average. However, the state's most exposed counties are vulnerable, with prevalent poverty, a large elderly population, and social vulnerability and community resilience scores worse than the national average.

The state's earthquake insurance industry is almost entirely populated with admitted carriers. While growth in the state's earthquake premiums has not kept pace with homeowners, this may not be cause for alarm, as the premium relative to risk is the highest among all states considered (see section 1).

Illinois
Only a small fraction of Illinois is considered high risk, with 22% of building value in counties above the NRI 70th percentile, and only 7% above the 90th percentile. The risk is concentrated in the state's southern tip, near the New Madrid fault.

The riskiest counties face some exposure from a population vulnerability perspective, with a prevalent poverty rate and a higher-than-average elderly population. However, these areas appear strong based on their community resilience and social vulnerability scores.

The state's earthquake insurance industry features a mix of admitted and non-admitted carriers, and has experienced rapid growth in recent years, which has contributed to one of the smallest gaps between expected risk and premiums among all states (see section 1).

Kentucky
While the extreme risk in Kentucky is limited to the westernmost part of the state, the majority of the state is exposed to meaningful risk, with 72% of building value in counties of NRI risk 70th percentile and above. However, in terms of EAL or economic risk, only those in the 90th percentile and above exceed the national average.

Kentucky is more exposed than other states in terms of population vulnerability, with a high rate of poverty and low community resilience in the most exposed counties.

The insurance industry is populated with admitted residential carriers. However, growth has not kept pace with the homeowners line, and premiums fell in 2022.

Tennessee
Earthquake exposure is significant throughout Tennessee, as the New Madrid system in the west is not the only fault in the state, so 98% of all building value lies in counties of NRI 70th percentile and above, and a significant 23% of

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building value lies in counties in the 90th percentile and above, where EAL and economic risk are roughly two to four times the national average.

Population vulnerability is fairly high, with high rates of poverty and social vulnerability, especially in the most exposed counties.

The earthquake insurance industry is populated with admitted, residential carriers. While premium growth has been significant, it is roughly similar to the homeowners line.

Arkansas

Like Tennessee, earthquake risk affects most of Arkansas with 81% of building value in the NRI category of 70th percentile and above. A significant share of the state is more exposed, with 19% of value in the 90th percentile and above, with EAL and economic risk at significant multiples of the national average in these counties.

Population vulnerability is high, as the state's most impoverished counties are also those most exposed to earthquakes, in the East and Northeast portions of the state. These most exposed counties feature high poverty, high social vulnerability, and low community resilience.

The earthquake insurance industry is populated with mostly admitted carriers, and given fairly rapid recent growth, features an expected coverage gap smaller than the national average.

MIDDLETON PLATE

South Carolina

Earthquake activity in South Carolina has been minimal for the past century, with only one occurrence in excess of 4.5 magnitude. Prior to this period, the state did experience one exceptionally large event, the Charleston earthquake of 1886, suggesting that the threat can be substantial, even if events are sparse.

Most of the state is in an elevated risk area, with 93% of building value in counties of NRI 70th percentile and above, and a material 16% in counties of 90th percentile and above, mostly in the southeast of the state around the Charleston area.

While the state's population exposure suggests high vulnerability, the population in the most exposed counties may be better positioned for an extreme event, as poverty and community resilience are better in these areas.

Earthquake premiums are written mostly by admitted residential carriers. Premium growth has kept pace with the homeowners line of business.

ALASKA

With some of the most extreme seismic activity in the country, Alaska is the only state which regularly experiences earthquakes in excess of 7.0 magnitude, and 12 such events have occurred since 1900. However, given the state's sparse population density, these events have usually occurred in unpopulated areas, and have not been as damaging as those in California. Most of the state is at risk, with 93% of building value in NRI counties 70th percentile and above, and 70% in counties of 90th percentile and above. EAL and economic risk in these counties is three to four times the national average.

Population vulnerability appears fairly low, as the state has a low poverty rate, which is even lower in the most exposed counties. One area of concern is the state's low community resilience score, which can be attributed to the state's sparse density, which could create difficulty for recovery or safety programs to operate effectively.

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The state's earthquake premiums are mostly written by admitted carriers and has experienced rapid growth in recent years. The state's coverage gap is smaller than the national average (see section 1).

HAWAII

Earthquake risk is substantial throughout Hawaii, which has experienced several historical events above 6.0 magnitude. Given the state's oceanic environment, tsunami risk also presents a substantial threat. Ninety-four percent of Hawaii's building value is situated in counties with NRI 70th percentile and above, and 29% of building value is in counties of NRI 90th percentile and above.

Hawaii's population has above average rates of vulnerability, as its poverty rate and elderly population are larger than average in the state's most exposed counties.

Hawaii's earthquake insurance industry is populated with a larger than average share of non-admitted carriers. The state's premium has experienced rapid growth in recent years, but it still has a coverage gap (see section 1) well in excess of the national average, indicating that more growth would be necessary for the bulk of the state's risk to be insured.

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6.3 CALIFORNIA AND SIERRA NEVADA FAULTS

Figure 15

MAP OF EARTHQUAKES SINCE 1900 - CALIFORNIA AND SIERRA NEVADA FAULTS

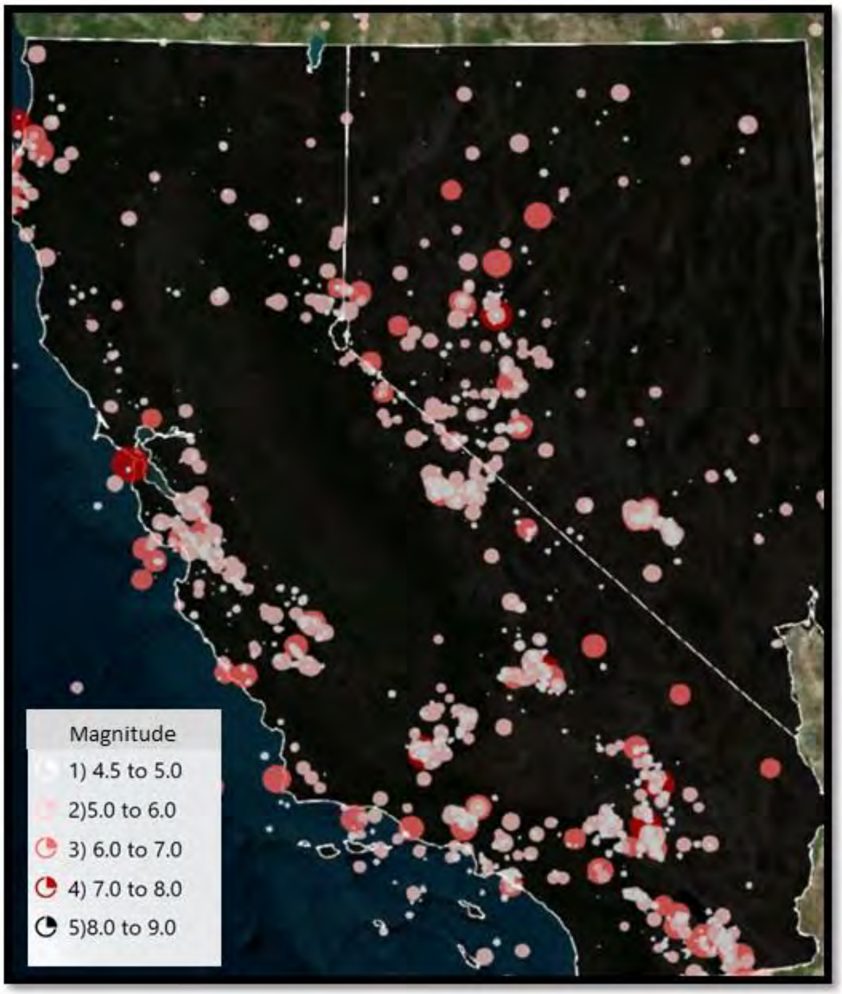

Table 28

EARTHQUAKES SINCE 1900 - CALIFORNIA AND SIERRA NEVADA FAULTS

Magnitude	Counties in Top 50th Percentile	Counties in Top 70th Percentile	Counties in Top 90th Percentile	Total
1) 4.5 to 5.0	1,136	1,136	934	1,136
2) 5.0 to 6.0	583	583	404	583
3) 6.0 to 7.0	73	73	59	73
4) 7.0 to 8.0	7	7	7	7
5) 8.0 to 9.0	-	-	-	-
6) 9.0 and above	-	-	-	-

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Table 29

TOP 10 EARTHQUAKES IN PAST 100 YEARS: CALIFORNIA AND SIERRA NEVADA FAULTS

Rank	Date	Magnitude	Location
1	1906-04-18	7.9	The 1906 San Francisco Earthquake
2	1952-07-21	7.5	6 km WNW of Grapevine, CA
3	1992-06-28	7.3	The 1992 Landers Earthquake, California
4	1954-12-16	7.3	The 1954 Fairview Peak Earthquake, Nevada
5	1992-04-25	7.2	19 km SSW of Scotia, California
6	2019-07-06	7.1	Ridgecrest Earthquake Sequence
7	1999-10-16	7.1	Hector Mine, CA Earthquake
8	1954-12-16	6.9	The 1954 Dixie Valley Earthquake, Nevada
9	1989-10-18	6.9	Loma Prieta, California Earthquake
10	1940-05-19	6.9	4 km N of Holtville, CA

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California – Risk Statistics

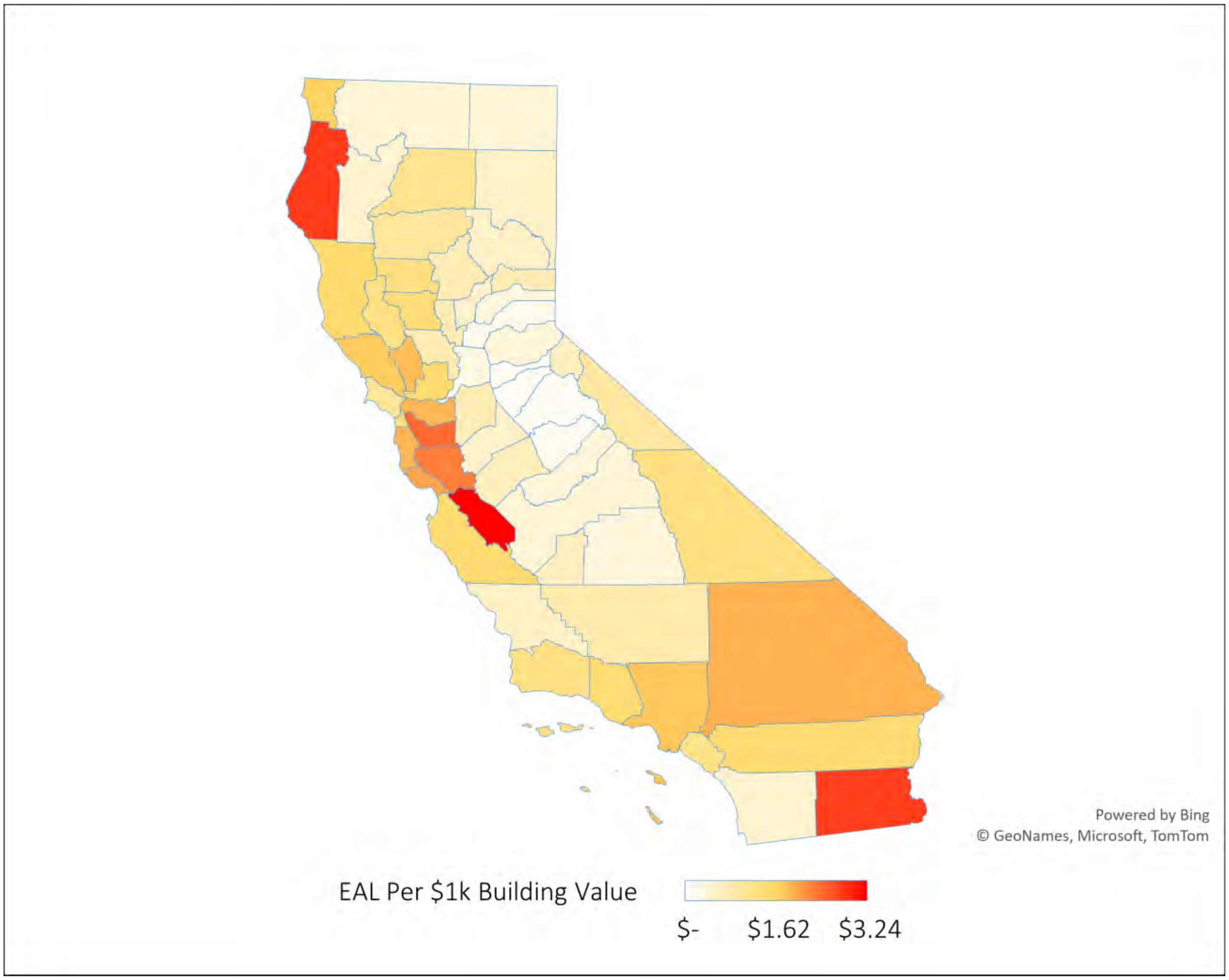
Table 30

CALIFORNIA EARTHQUAKE RISK BY AFFECTED COUNTY PERCENTILE GROUPS

Share of State	Building Stock		Expected Annual Losses		Risk Metrics	
Affected Counties	Building Value ($ Billions)	% of Value	Earthquake ($ Millions)	Tsunami ($ Millions)	EAL Per $1k Building Val	Economic Losses Per $1k Income
California Total	6,898	100%	9,615	0.58	$1.39	$7.40
> 50th %-ile Counties	6,898	100%	9,615	0.58	$1.39	$7.40
> 70th %-ile Counties	6,898	100%	9,615	0.58	$1.39	$7.40
> 90th %-ile Counties	6,404	93%	9,471	0.58	$1.48	$7.79
				National Average	**$0.24**	**$1.50**

Figure 16

CALIFORNIA EXPECTED ANNUAL LOSSES BY COUNTY



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California – Vulnerability Statistics

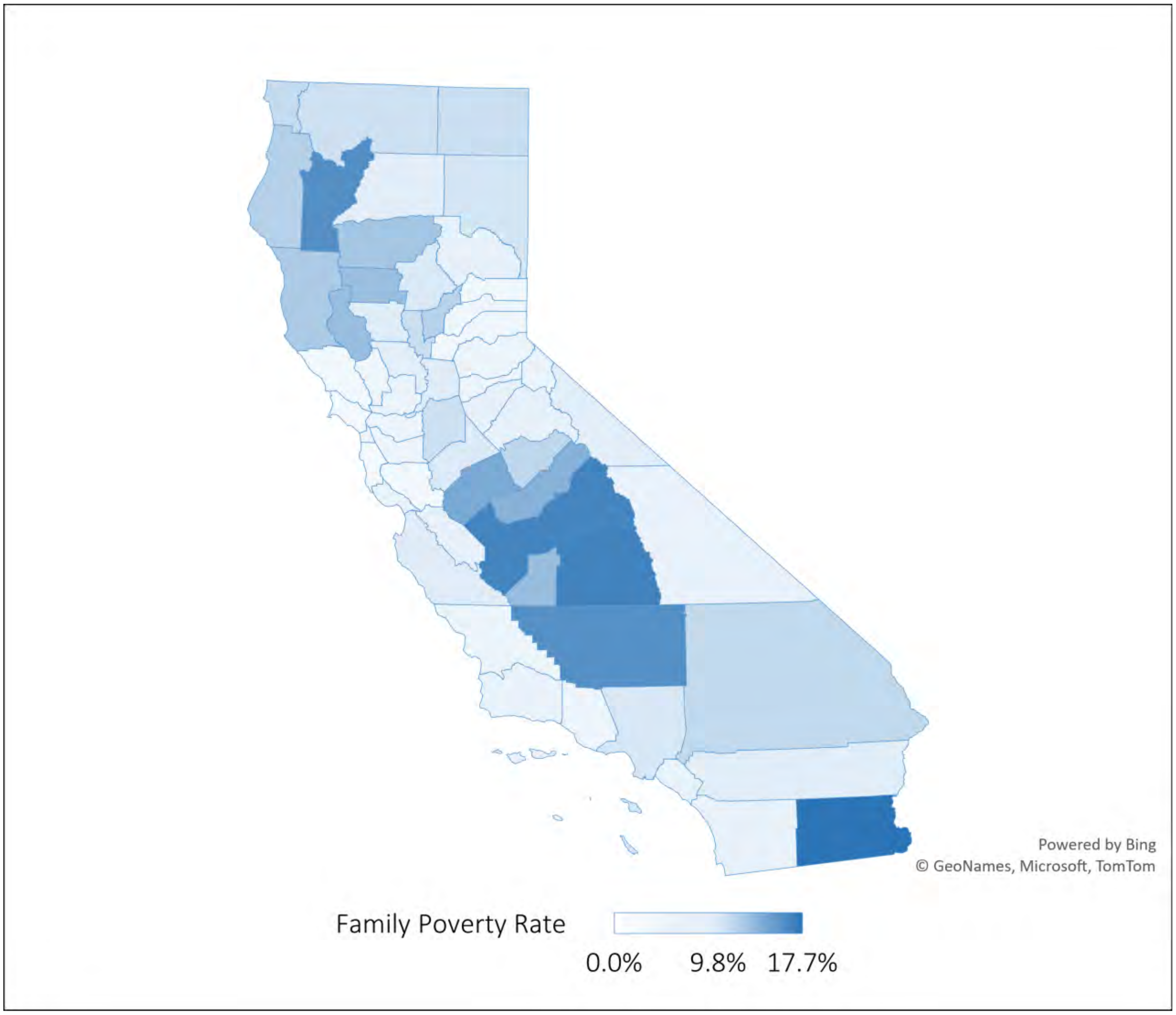
Table 31

CALIFORNIA VULNERABILITY STATISTICS BY AFFECTED COUNTY PERCENTILE GROUPS

Affected Counties	Family Poverty Rate	% Population over 65	Social Vulnerability Score	Community Resilience Score
California Total	8.6%	16%	72	40
> 50th %-ile Counties	8.6%	16%	72	40
> 70th %-ile Counties	8.6%	16%	72	40
> 90th %-ile Counties	8.5%	16%	72	39
National Average	8.8%	18%	58	57

Figure 17

CALIFORNIA FAMILY POVERTY RATE BY COUNTY



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California – Insurance Statistics

Table 32

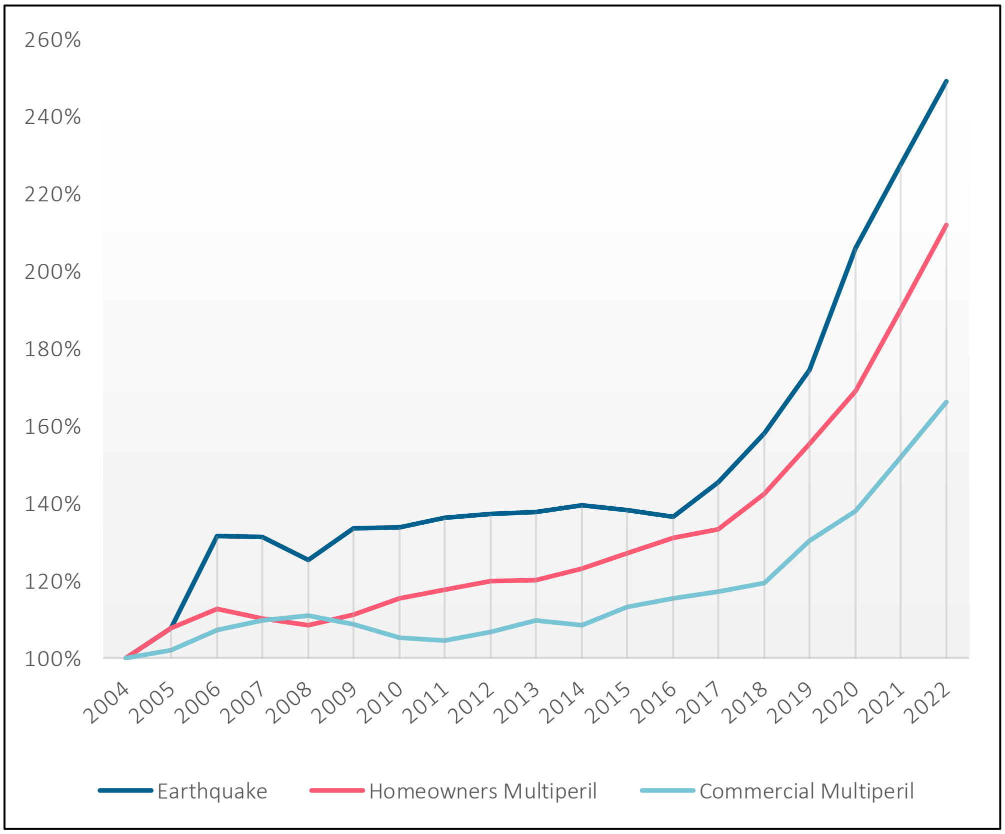
TOP 10 CALIFORNIA EARTHQUAKE INSURERS BY WRITTEN PREMIUM FOR 2022

Rank	Insurer	Written Premium	Market Share	Active License
1	California Earthquake Authority	$956,388	32%	
2	Factory Mutual Insurance Company	$240,414	8%	X
3	Palomar Specialty Insurance Company	$169,075	6%	X
4	Palomar Excess and Surplus Insurance Company	$125,288	4%	
5	Steadfast Insurance Company	$110,768	4%	
6	Zurich American Insurance Company	$104,961	4%	X
7	Everest Indemnity Insurance Company	$82,554	3%	
8	Golden Bear Insurance Company	$69,348	2%	X
9	GeoVera Insurance Company	$68,336	2%	X
10	National Fire & Marine Insurance Company	$63,343	2%	
	Industry Total	$2,959,391		

Figure 18

CALIFORNIA EARTHQUAKE WRITTEN PREMIUM AND GROWTH SINCE 2004 COMPARED TO OTHER PROPERTY LINES

Year	Written Premium
2004	1,187,816
2005	1,279,730
2006	1,563,440
2007	1,559,878
2008	1,487,924
2009	1,584,897
2010	1,590,392
2011	1,620,137
2012	1,629,422
2013	1,636,448
2014	1,656,283
2015	1,643,302
2016	1,621,988
2017	1,729,209
2018	1,878,488
2019	2,072,849
2020	2,446,565
2021	2,702,509
2022	2,959,391



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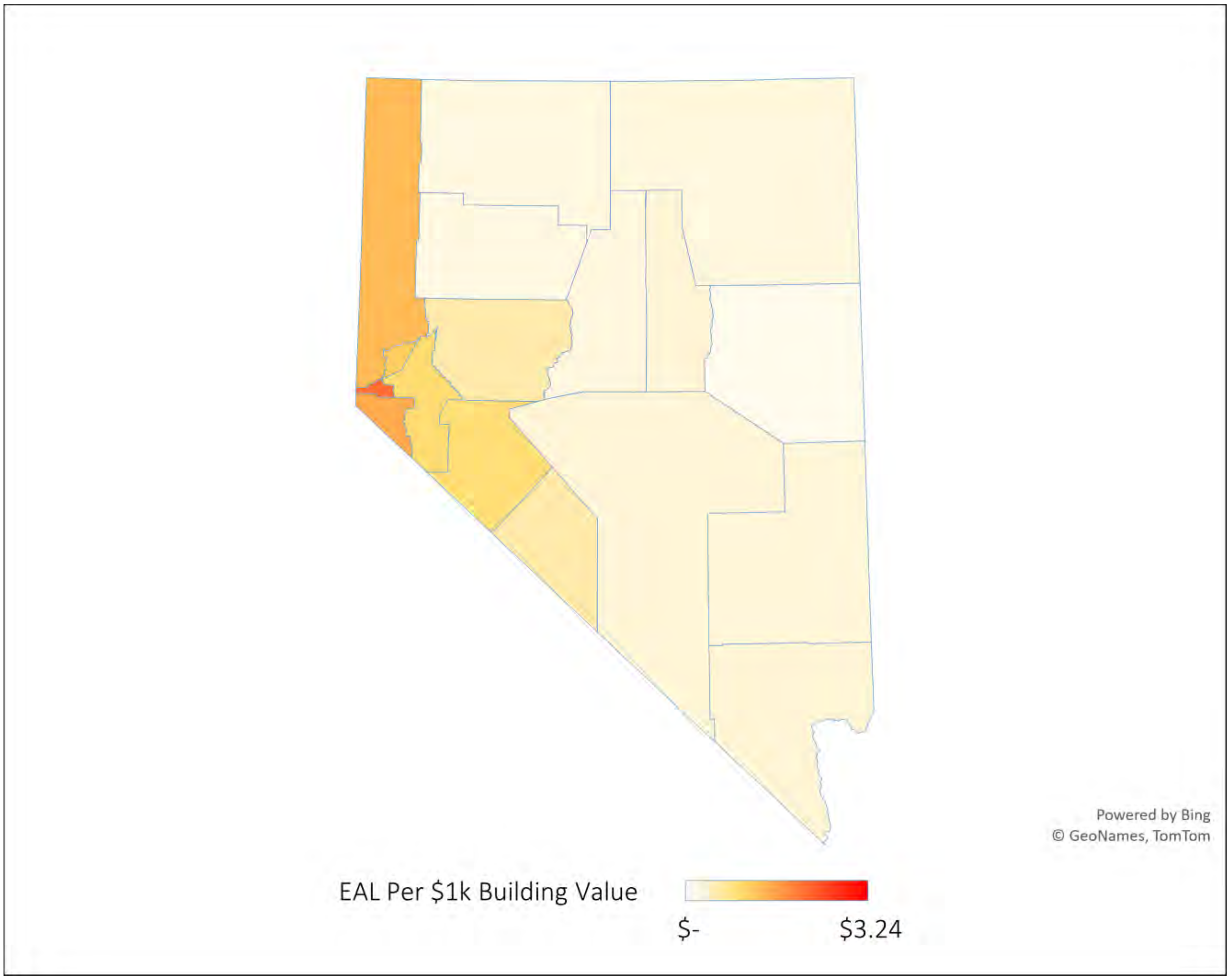
Nevada – Risk Statistics
Table 33
NEVADA EARTHQUAKE RISK BY AFFECTED COUNTY PERCENTILE GROUPS

Share of State	Building Stock		Expected Annual Losses		Risk Metrics	
Affected Counties	Building Value ($ Billions)	% of Value	Earthquake ($ Millions)	Tsunami ($ Millions)	EAL Per $1k Building Val	Economic Losses Per $1k Income
Nevada Total	560	100%	297	-	$0.53	$3.52
> 50th %-ile Counties	560	100%	297	-	$0.53	$3.52
> 70th %-ile Counties	560	100%	297	-	$0.53	$3.52
> 90th %-ile Counties	131	23%	177	-	$1.36	$8.27
			National Average		**$0.24**	**$1.50**

Figure 19
NEVADA EXPECTED ANNUAL LOSSES BY COUNTY



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Nevada – Vulnerability Statistics

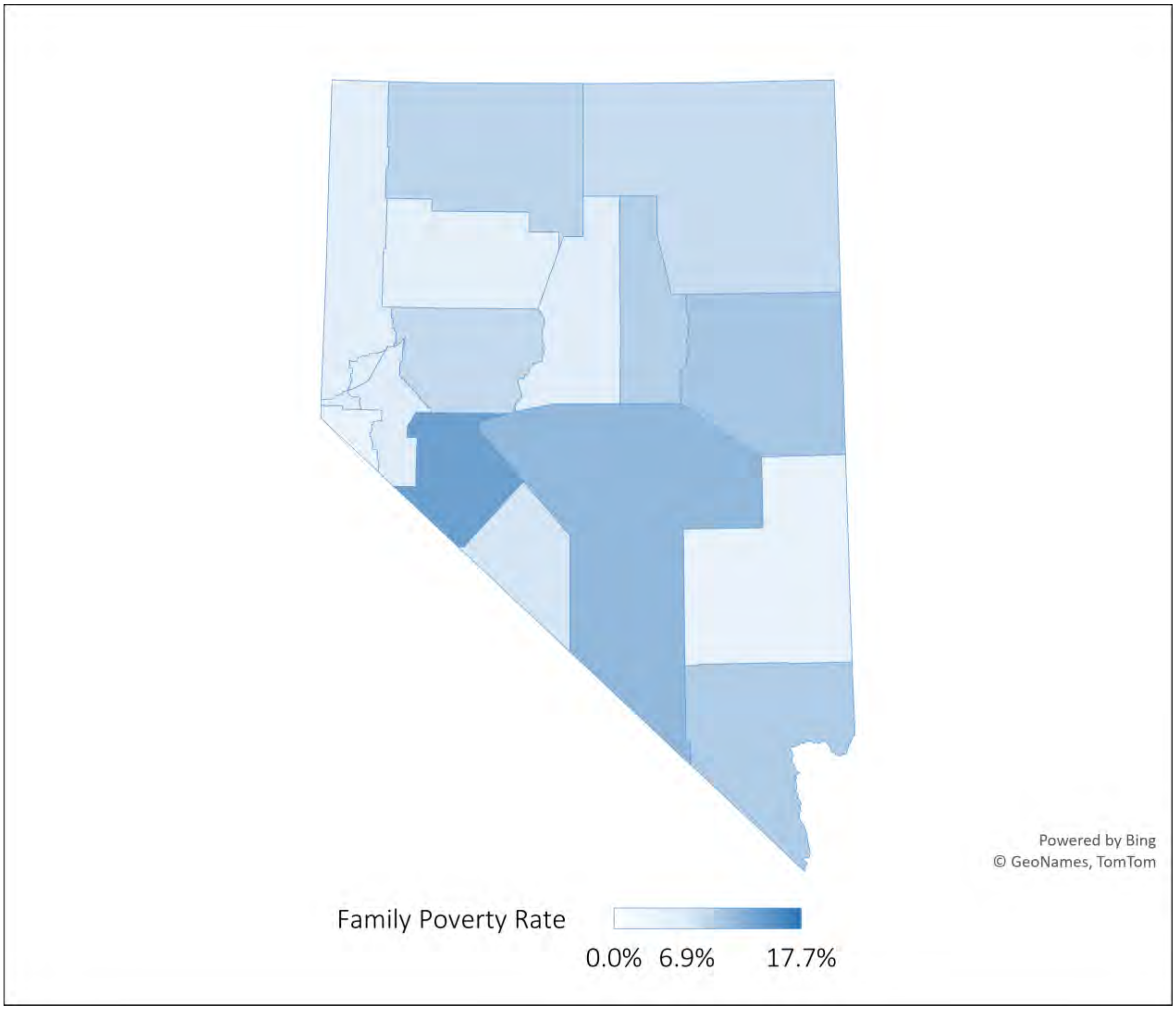
Table 34

NEVADA VULNERABILITY STATISTICS BY AFFECTED COUNTY PERCENTILE GROUPS

Affected Counties	Family Poverty Rate	% Population over 65	Social Vulnerability Score	Community Resilience Score
Nevada Total	8.8%	18%	80	18
> 50th %-ile Counties	8.8%	18%	80	18
> 70th %-ile Counties	8.8%	18%	80	18
> 90th %-ile Counties	6.0%	20%	64	44
National Average	8.8%	18%	58	57

Figure 20

NEVADA FAMILY POVERTY RATE BY COUNTY



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Nevada – Insurance Statistics

Table 35

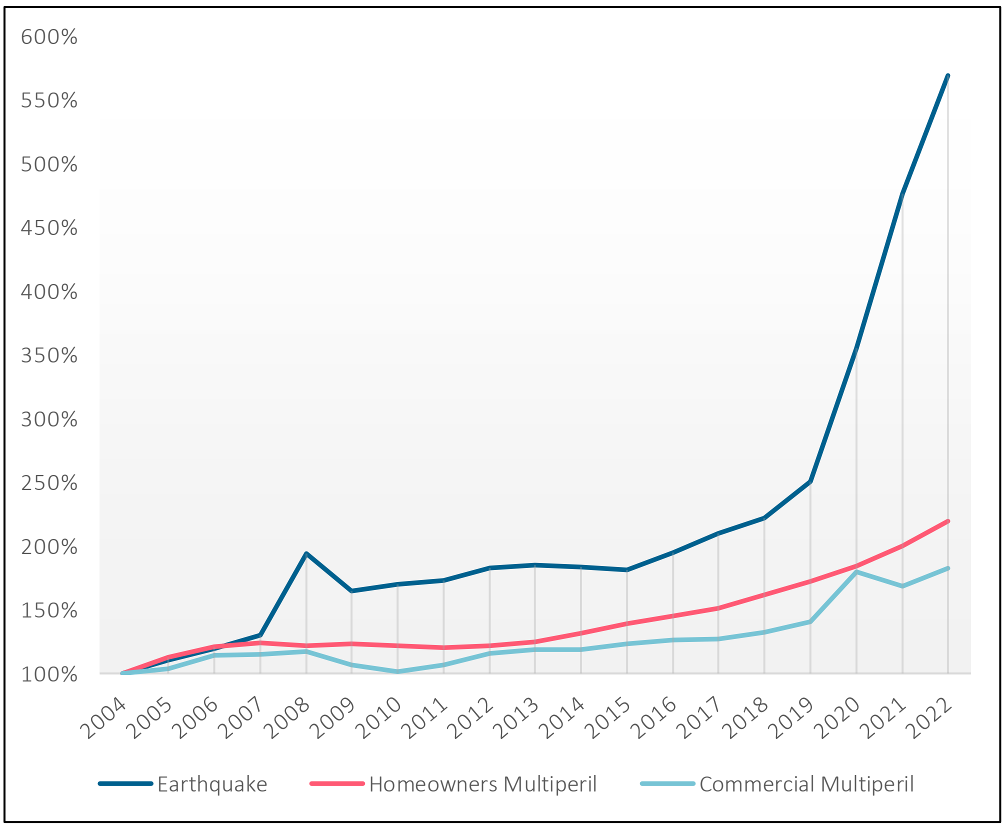
TOP 10 NEVADA EARTHQUAKE INSURERS BY WRITTEN PREMIUM FOR 2022

Rank	Insurer	Written Premium	Market Share	Active License
1	Factory Mutual Insurance Company	$14,880	24%	X
2	The Travelers Indemnity Company	$4,303	7%	X
3	State Farm Fire and Casualty Company	$3,922	6%	X
4	Zurich American Insurance Company	$3,706	6%	X
5	Affiliated FM Insurance Company	$2,318	4%	X
6	Travelers Property Casualty Company of America	$2,261	4%	X
7	National Fire & Marine Insurance Company	$1,859	3%	
8	Employers Insurance Company of Wausau	$1,803	3%	X
9	Swiss Re Corporate Solutions Elite Insurance Corp	$1,778	3%	X
10	Endurance American Specialty Insurance Company	$1,688	3%	
	Industry Total	$61,117		

Figure 21

NEVADA EARTHQUAKE WRITTEN PREMIUM AND GROWTH SINCE 2004 COMPARED TO OTHER PROPERTY LINES

Year	Written Premium
2004	10,736
2005	11,882
2006	12,855
2007	13,958
2008	20,854
2009	17,708
2010	18,272
2011	18,553
2012	19,641
2013	19,898
2014	19,694
2015	19,481
2016	20,884
2017	22,551
2018	23,851
2019	26,931
2020	38,148
2021	51,172
2022	61,117



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6.4 CASCADIA SUBDUCTION ZONE

Figure 22

MAP OF EARTHQUAKES SINCE 1900 - CASCADIA SUBDUCTION ZONE

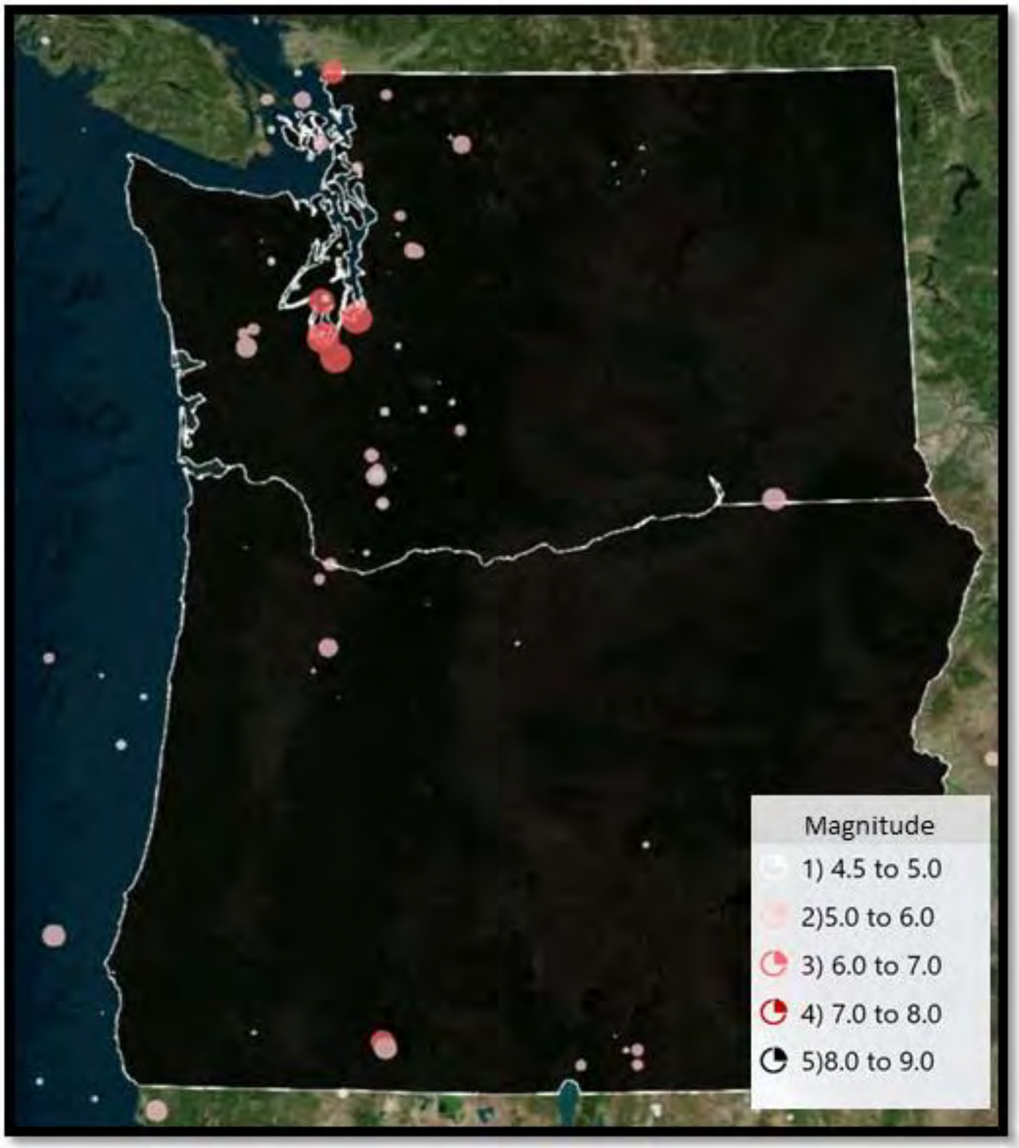

Table 36

EARTHQUAKES SINCE 1900 - CASCADIA SUBDUCTION ZONE

Magnitude	Counties in Top 50th Percentile	Counties in Top 70th Percentile	Counties in Top 90th Percentile	Total
1) 4.5 to 5.0	112	112	102	112
2) 5.0 to 6.0	38	38	34	38
3) 6.0 to 7.0	6	6	6	6
4) 7.0 to 8.0	-	-	-	-
5) 8.0 to 9.0	-	-	-	-
6) 9.0 and above	-	-	-	-

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Table 37

TOP 10 EARTHQUAKES IN PAST 100 YEARS: CASCADIA SUBDUCTION ZONE

Rank	Date	Magnitude	Location
1	2001-02-28	6.8	7 km SSE of Longbranch, Washington
2	1965-04-29	6.7	3 km ESE of Browns Point, Washington
3	1949-04-13	6.7	4 km WNW of Roy, Washington
4	1939-11-13	6.1	Puget Sound region, Washington
5	1993-09-21	6.0	27 km WNW of Klamath Falls, Oregon
6	1909-01-11	6.0	3 km ENE of Blaine, Washington
7	1936-07-16	6.0	3 km SW of Garrett, Washington
8	1993-09-21	5.9	22 km WNW of Klamath Falls, Oregon
9	1999-07-03	5.8	8 km N of Satsop, Washington
10	1980-05-18	5.7	38 km NNE of Amboy, Washington

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Washington– Risk Statistics

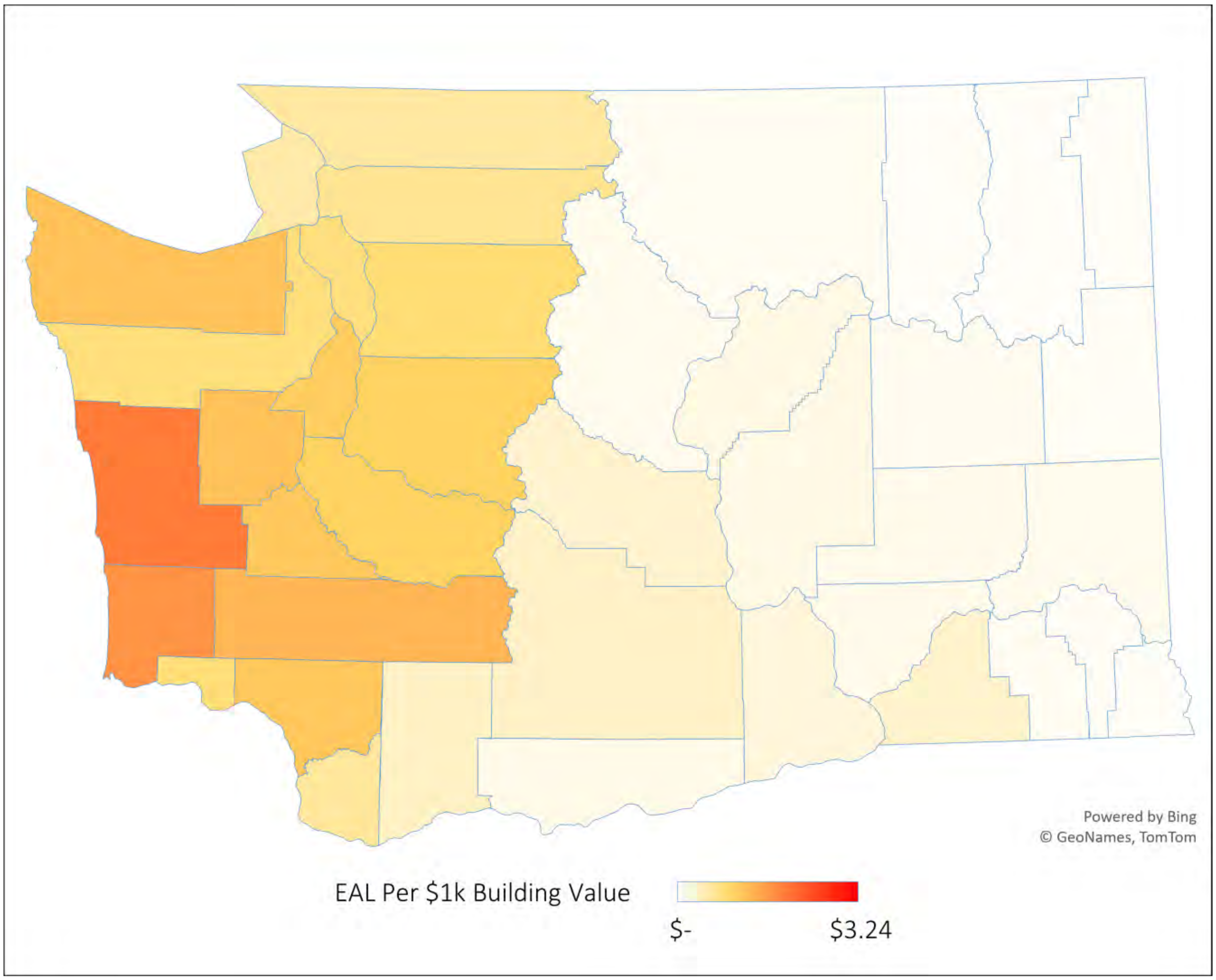
Table 38

WASHINGTON EARTHQUAKE RISK BY AFFECTED COUNTY PERCENTILE GROUPS

Share of State	Building Stock		Expected Annual Losses		Risk Metrics	
Affected Counties	Building Value ($ Billions)	% of Value	Earthquake ($ Millions)	Tsunami ($ Millions)	EAL Per $1k Building Val	Economic Losses Per $1k Income
Washington Total	1,466	100%	1,192	0.39	$0.81	$4.39
> 50th %-ile Counties	1,466	100%	1,192	0.39	$0.81	$4.39
> 70th %-ile Counties	1,458	99%	1,191	0.39	$0.82	$4.41
> 90th %-ile Counties	1,207	82%	1,158	0.39	$0.96	$4.96
			National Average		**$0.24**	**$1.50**

Figure 23

WASHINGTON EXPECTED ANNUAL LOSSES BY COUNTY



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Washington – Vulnerability Statistics

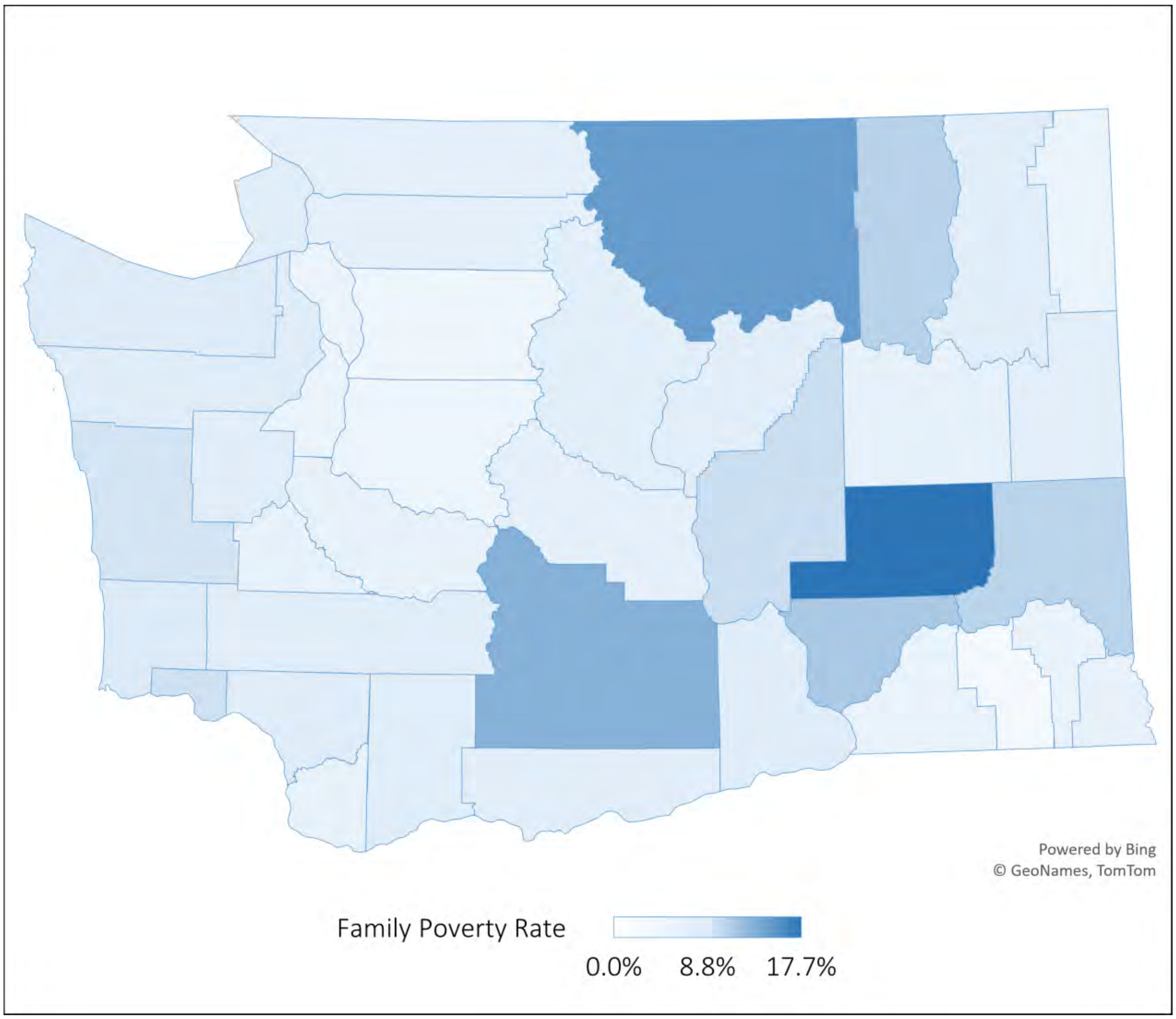
Table 39

WASHINGTON VULNERABILITY STATISTICS BY AFFECTED COUNTY PERCENTILE GROUPS

Affected Counties	Family Poverty Rate	% Population over 65	Social Vulnerability Score	Community Resilience Score
Washington Total	6.4%	17%	48	68
> 50th %-ile Counties	6.4%	17%	48	68
> 70th %-ile Counties	6.4%	17%	48	68
> 90th %-ile Counties	5.9%	17%	45	70
National Average	8.8%	18%	58	57

Figure 24

WASHINGTON FAMILY POVERTY RATE BY COUNTY



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Washington – Insurance Statistics

Table 40

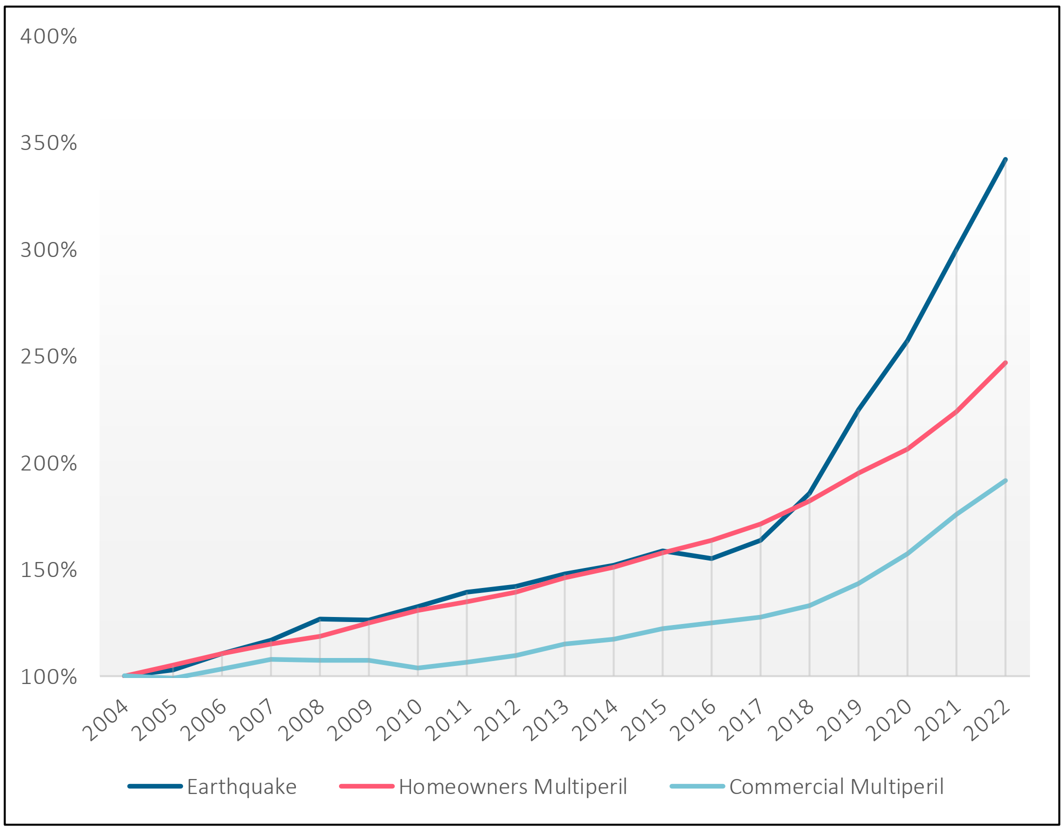
TOP 10 WASHINGTON EARTHQUAKE INSURERS BY WRITTEN PREMIUM FOR 2022

Rank	Insurer	Written Premium	Market Share	Active License
1	State Farm Fire and Casualty Company	$54,939	15%	X
2	Factory Mutual Insurance Company	$24,965	7%	X
3	Palomar Specialty Insurance Company	$23,703	6%	X
4	GeoVera Insurance Company	$21,347	6%	X
5	Affiliated FM Insurance Company	$16,232	4%	X
6	National Fire & Marine Insurance Company	$14,989	4%	
7	Everest Indemnity Insurance Company	$10,961	3%	
8	Zurich American Insurance Company	$10,600	3%	X
9	Golden Bear Insurance Company	$8,782	2%	
10	Palomar Excess and Surplus Insurance Company	$8,586	2%	
	Industry Total	$365,265		

Figure 25

WASHINGTON EARTHQUAKE WRITTEN PREMIUM AND GROWTH SINCE 2004 COMPARED TO OTHER PROPERTY LINES

Year	Written Premium
2004	106,751
2005	109,656
2006	117,912
2007	124,869
2008	135,285
2009	134,970
2010	141,611
2011	148,559
2012	151,438
2013	157,949
2014	162,245
2015	169,354
2016	165,309
2017	174,645
2018	198,413
2019	239,773
2020	274,418
2021	320,039
2022	365,264



Oregon – Risk Statistics

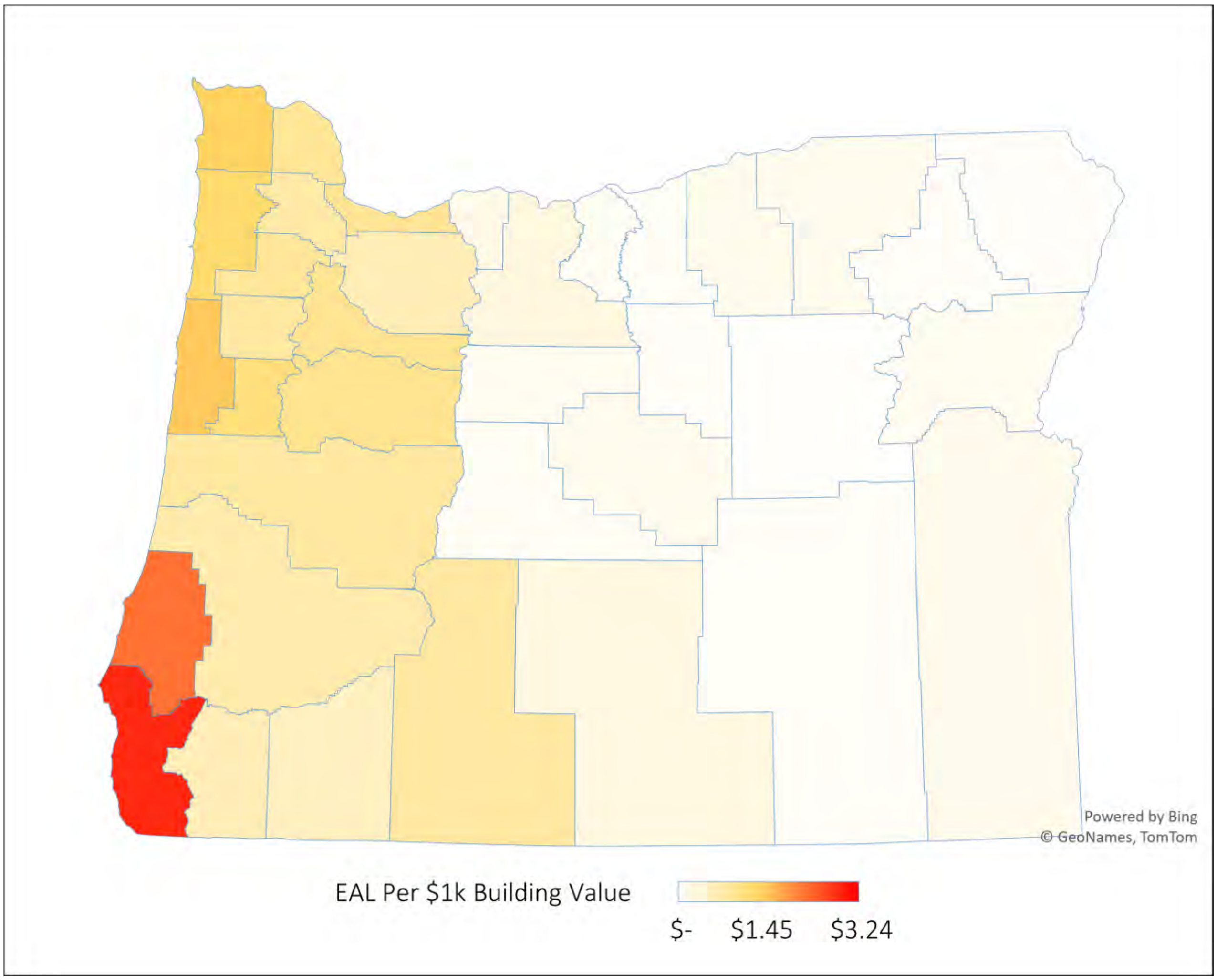
Table 41

OREGON EARTHQUAKE RISK BY AFFECTED COUNTY PERCENTILE GROUPS

Share of State	Building Stock		Expected Annual Losses		Risk Metrics	
Affected Counties	Building Value ($ Billions)	% of Value	Earthquake ($ Millions)	Tsunami ($ Millions)	EAL Per $1k Building Val	Economic Losses Per $1k Income
Oregon Total	900	100%	745	0.33	$0.83	$6.49
> 50th %-ile Counties	900	100%	745	0.33	$0.83	$6.49
> 70th %-ile Counties	898	100%	745	0.33	$0.83	$6.49
> 90th %-ile Counties	773	86%	728	0.33	$0.94	$7.16
			National Average		**$0.24**	**$1.50**

Figure 26

OREGON EXPECTED ANNUAL LOSSES BY COUNTY



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Oregon – Vulnerability Statistics

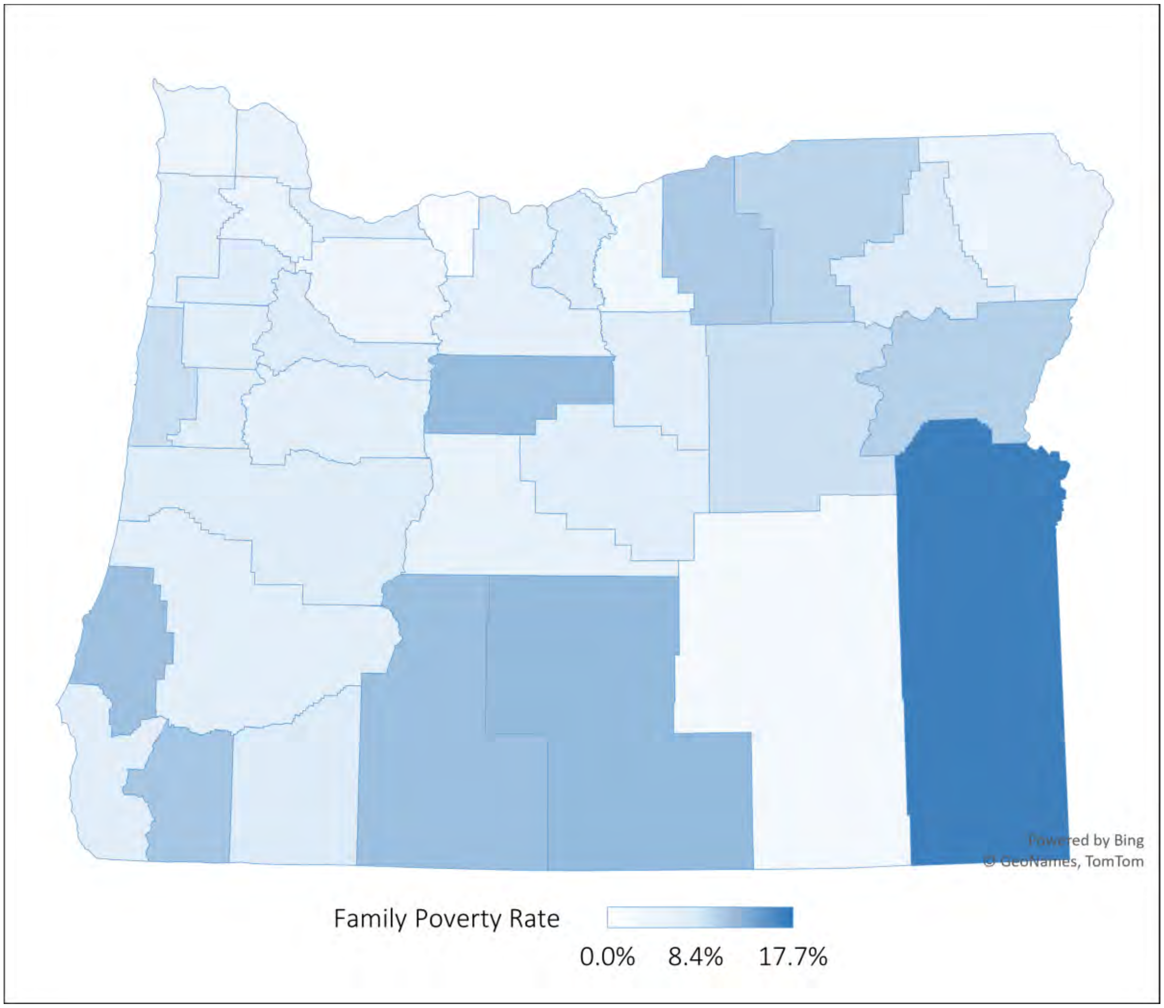
Table 42

OREGON VULNERABILITY STATISTICS BY AFFECTED COUNTY PERCENTILE GROUPS

Affected Counties	Family Poverty Rate	% Population over 65	Social Vulnerability Score	Community Resilience Score
Oregon Total	7.2%	20%	57	64
> 50th %-ile Counties	7.2%	20%	57	64
> 70th %-ile Counties	7.2%	20%	57	64
> 90th %-ile Counties	7.1%	19%	57	66
National Average	8.8%	18%	58	57

Figure 27

OREGON FAMILY POVERTY RATE BY COUNTY



Oregon – Insurance Statistics

Table 43

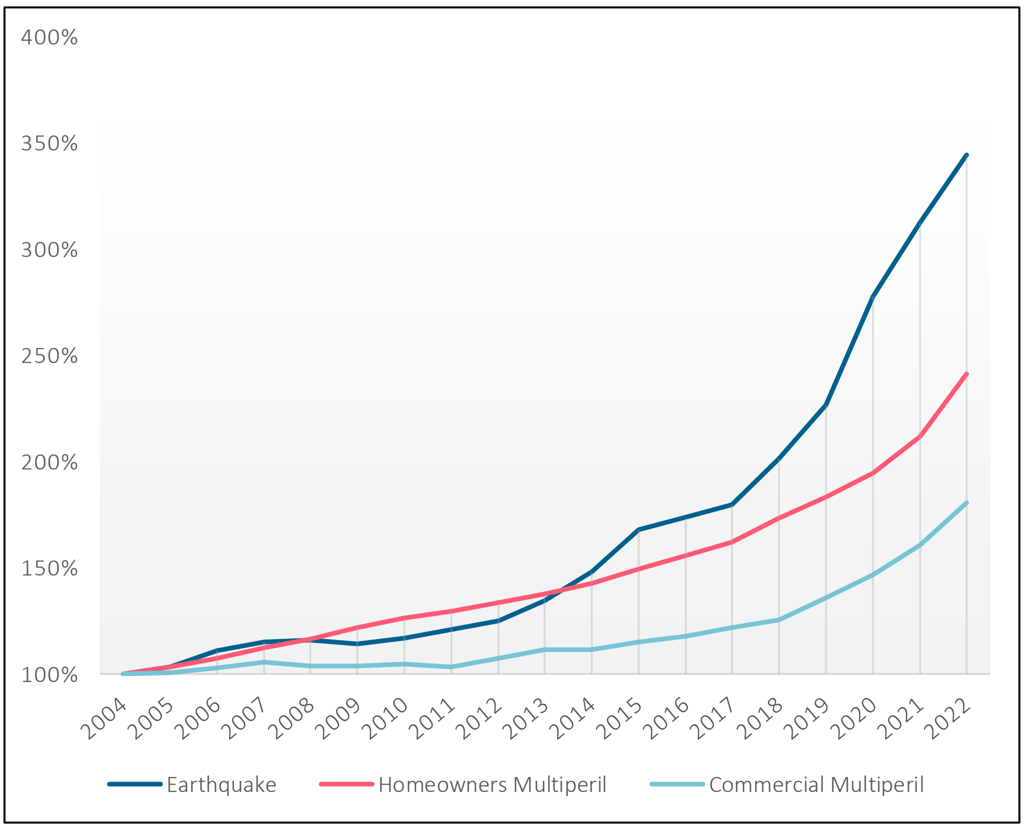
TOP 10 OREGON EARTHQUAKE INSURERS BY WRITTEN PREMIUM FOR 2022

Rank	Insurer	Written Premium	Market Share	Active License
1	State Farm Fire and Casualty Company	$31,945	20%	X
2	Factory Mutual Insurance Company	$14,857	9%	X
3	Palomar Specialty Insurance Company	$11,583	7%	X
4	Affiliated FM Insurance Company	$6,754	4%	X
5	GeoVera Insurance Company	$5,654	3%	X
6	Zurich American Insurance Company	$5,105	3%	X
7	Palomar Excess and Surplus Insurance Company	$3,919	2%	
8	Safeco Insurance Company of Illinois	$3,808	2%	X
9	Farmers Insurance Company of Oregon	$3,606	2%	X
10	Travelers Property Casualty Company of America	$3,503	2%	X
	Industry Total	$162,088		

Figure 28

OREGON EARTHQUAKE WRITTEN PREMIUM AND GROWTH SINCE 2004 COMPARED TO OTHER PROPERTY LINES

Year	Written Premium
2004	47,066
2005	48,715
2006	52,176
2007	54,206
2008	54,478
2009	53,777
2010	54,941
2011	56,846
2012	58,738
2013	63,239
2014	69,684
2015	79,096
2016	81,900
2017	84,658
2018	94,868
2019	106,635
2020	130,712
2021	147,066
2022	162,088



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6.5 WASATCH FAULT

Figure 29

MAP OF EARTHQUAKES SINCE 1900 - WASATCH FAULT

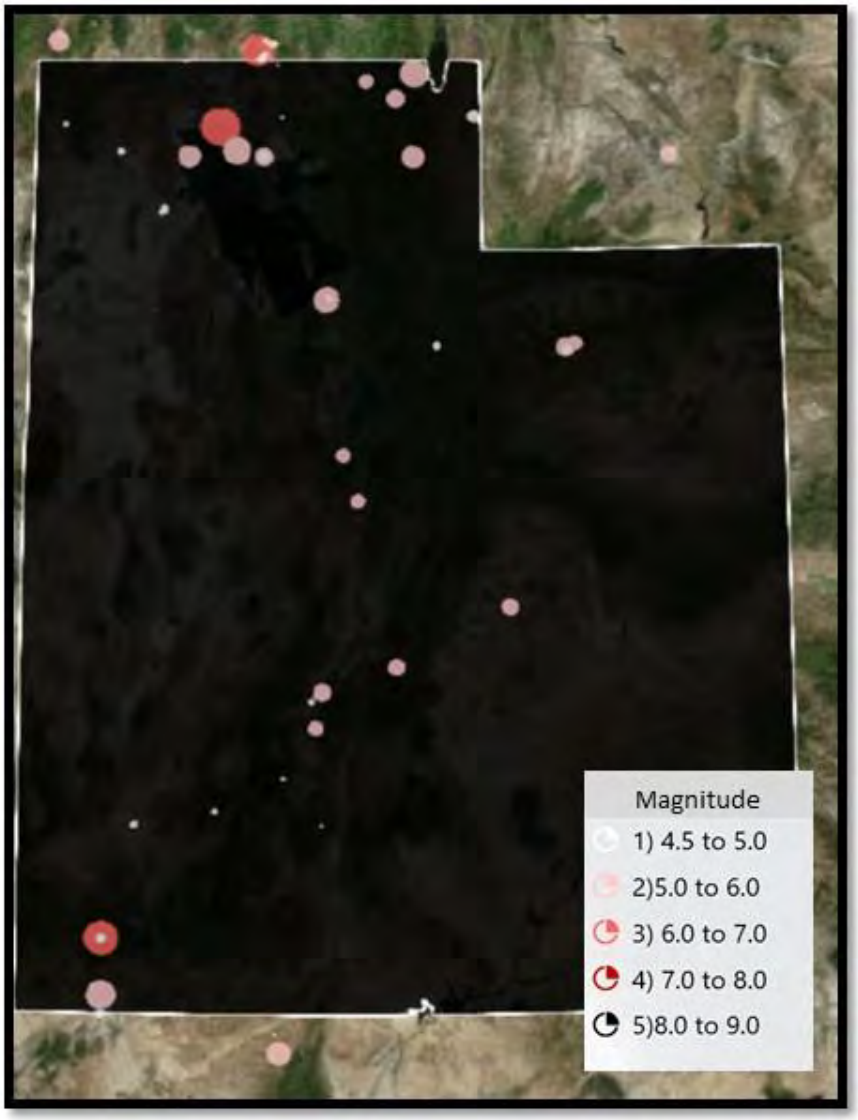

Table 44

EARTHQUAKES SINCE 1900– WASATCH FAULT

Magnitude	Counties in Top 50th Percentile	Counties in Top 70th Percentile	Counties in Top 90th Percentile	Total
1) 4.5 to 5.0	19	18	10	19
2) 5.0 to 6.0	20	17	13	20
3) 6.0 to 7.0	2	2	1	2
4) 7.0 to 8.0	-	-	-	-
5) 8.0 to 9.0	-	-	-	-
6) 9.0 and above	-	-	-	-

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Table 45

TOP 10 EARTHQUAKES IN PAST 100 YEARS: WASATCH FAULT

Rank	Date	Magnitude	Location
1	1934-03-12	6.6	The 1934 Hansel Valley Earthquake, Utah
2	1902-11-17	6.3	Near Pine Valley, Utah
3	1992-09-02	5.9	3 km SSE of Washington, Utah
4	1934-03-12	5.9	35 km SSW of Howell, Utah
5	1962-08-30	5.8	8 km W of Garden City, Utah
6	2020-03-18	5.7	5 km NNE of Magna, Utah
7	1934-05-06	5.5	56 km SW of Howell, Utah
8	1934-04-07	5.5	26 km E of Avon, Utah
9	1950-01-18	5.3	23 km NW of Altamont, Utah
10	1934-04-14	5.3	27 km SW of Thatcher, Utah

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Utah – Risk Statistics

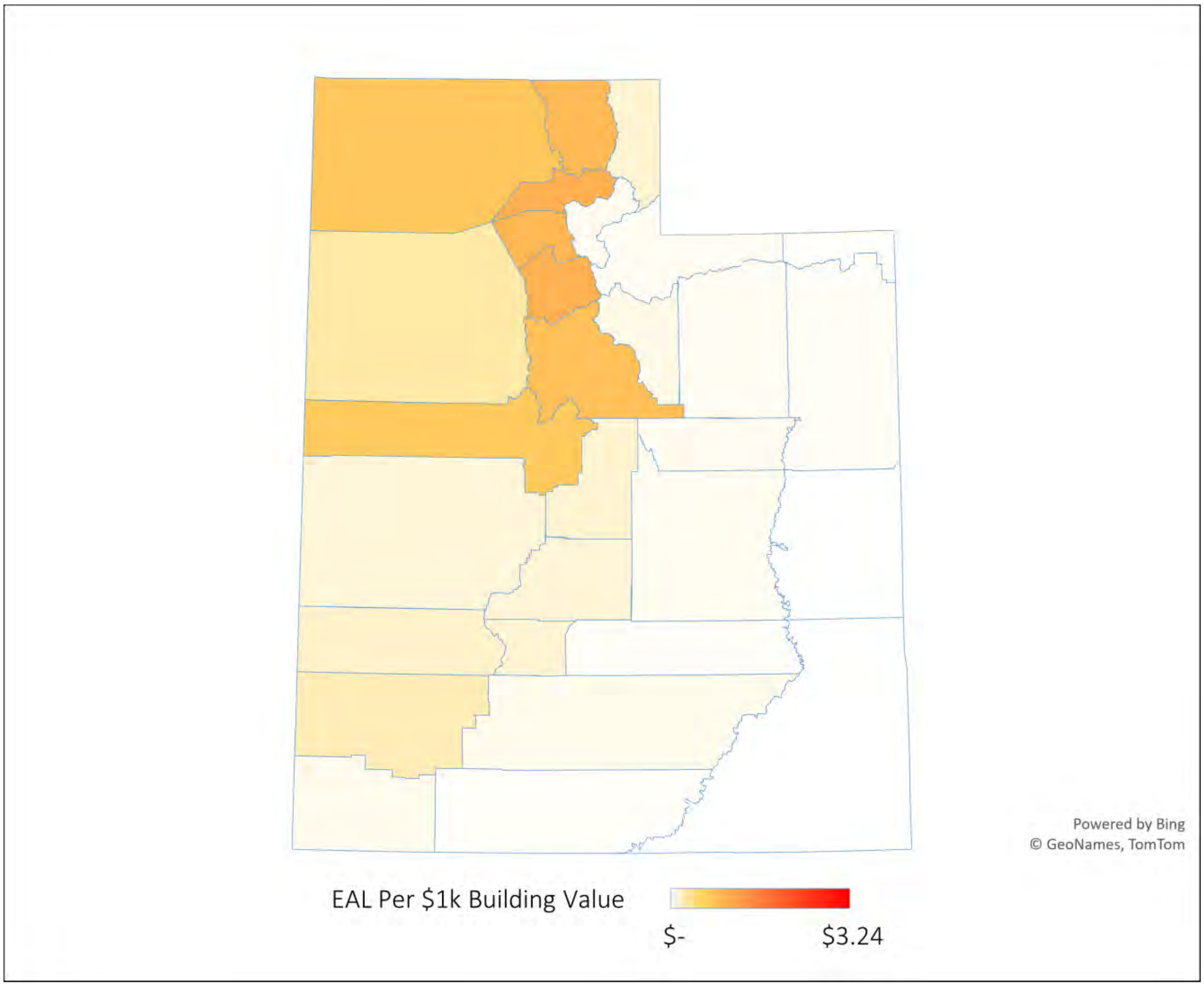
Table 46

UTAH EARTHQUAKE RISK BY AFFECTED COUNTY PERCENTILE GROUPS

Share of State	Building Stock		Expected Annual Losses		Risk Metrics	
Affected Counties	Building Value ($ Billions)	% of Value	Earthquake ($ Millions)	Tsunami ($ Millions)	EAL Per $1k Building Val	Economic Losses Per $1k Income
Utah Total	500	100%	367	-	$0.73	$4.57
> 50th %-ile Counties	493	99%	367	-	$0.74	$4.59
> 70th %-ile Counties	463	93%	366	-	$0.79	$4.80
> 90th %-ile Counties	383	77%	355	-	$0.93	$5.39
			National Average		**$0.24**	**$1.50**

Figure 30

UTAH EXPECTED ANNUAL LOSSES BY COUNTY



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Utah – Vulnerability Statistics

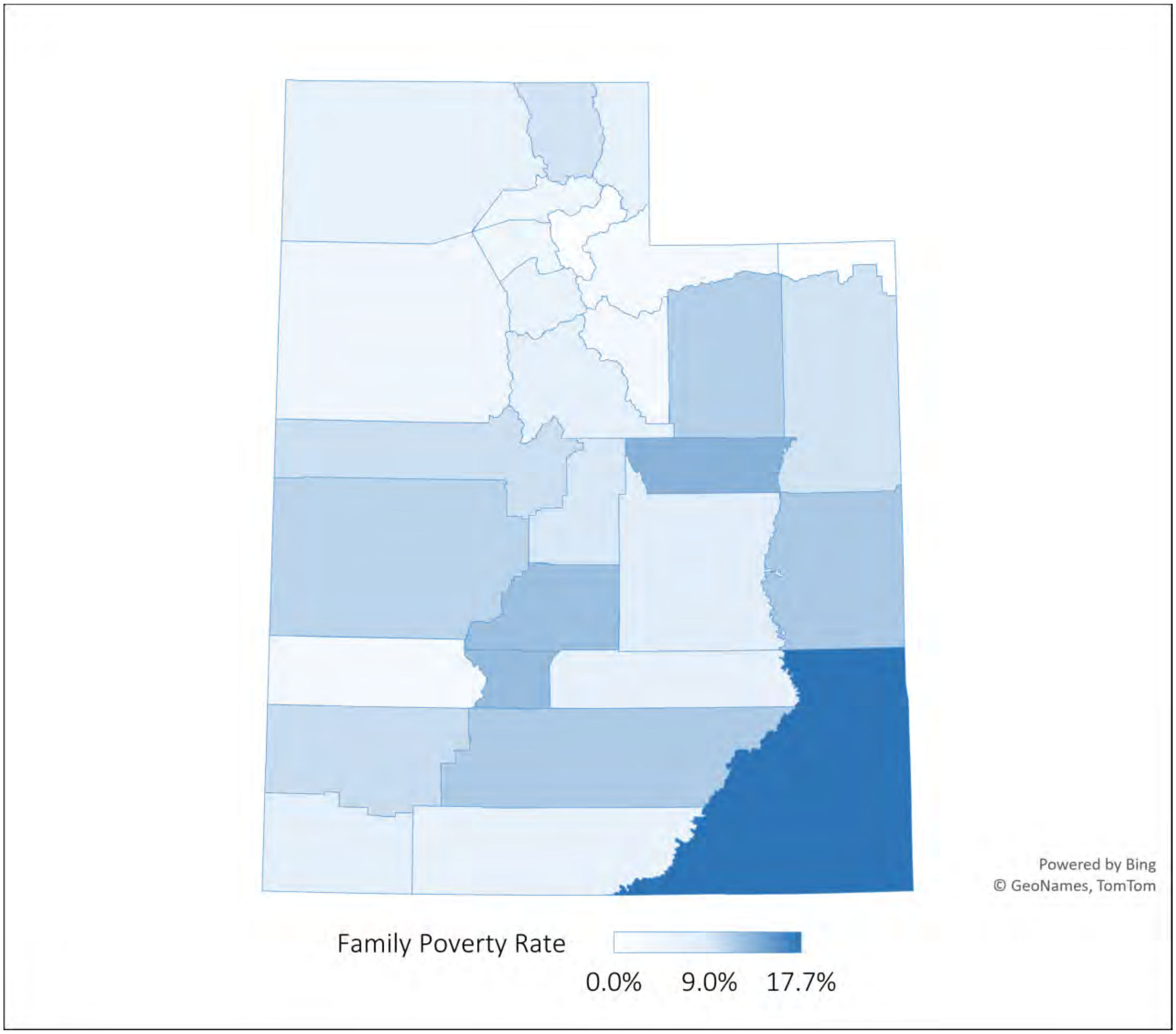
Table 47

UTAH VULNERABILITY STATISTICS BY AFFECTED COUNTY PERCENTILE GROUPS

Affected Counties	Family Poverty Rate	% Population over 65	Social Vulnerability Score	Community Resilience Score
Utah Total	6.2%	12%	34	79
> 50th %-ile Counties	6.1%	12%	34	80
> 70th %-ile Counties	6.0%	12%	33	81
> 90th %-ile Counties	5.8%	11%	33	84
National Average	8.8%	18%	58	57

Figure 31

UTAH FAMILY POVERTY RATE BY COUNTY



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Utah – Insurance Statistics

Table 48

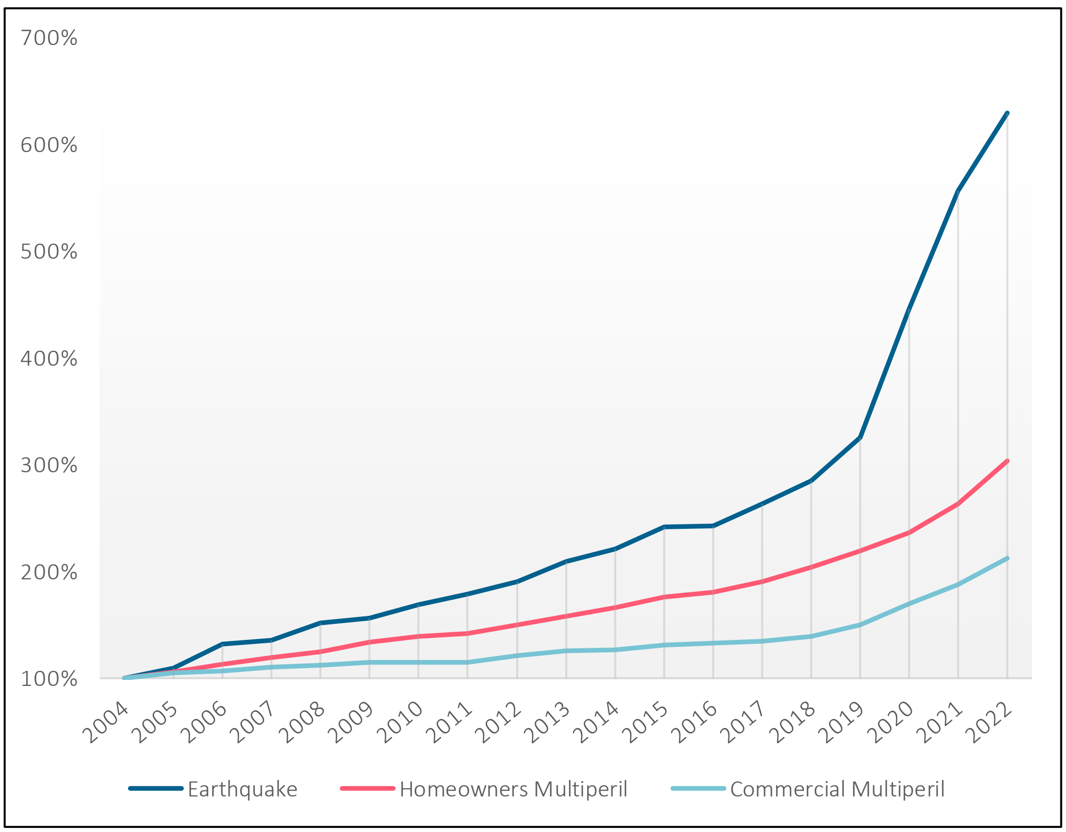
TOP 10 UTAH EARTHQUAKE INSURERS BY WRITTEN PREMIUM FOR 2022

Rank	Insurer	Written Premium	Market Share	Active License
1	State Farm Fire and Casualty Company	$16,781	14%	X
2	Affiliated FM Insurance Company	$11,143	10%	X
3	Factory Mutual Insurance Company	$10,638	9%	X
4	Farmers Insurance Exchange	$7,068	6%	X
5	Golden Bear Insurance Company	$5,472	5%	
6	Palomar Specialty Insurance Company	$4,656	4%	X
7	United Services Automobile Association	$3,605	3%	X
8	Employers Insurance Company of Wausau	$3,506	3%	X
9	Travelers Property Casualty Company of America	$3,104	3%	X
10	Fire Insurance Exchange	$2,986	3%	X
	Industry Total	$162,088		

Figure 32

UTAH EARTHQUAKE WRITTEN PREMIUM AND GROWTH SINCE 2004 COMPARED TO OTHER PROPERTY LINES

Year	Written Premium
2004	18,634
2005	20,309
2006	24,562
2007	25,224
2008	28,241
2009	29,121
2010	31,378
2011	33,312
2012	35,426
2013	38,977
2014	41,122
2015	44,999
2016	45,219
2017	49,083
2018	53,149
2019	60,615
2020	83,048
2021	103,740
2022	117,289



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6.6 NEW MADRID FAULT

Figure 33

MAP OF EARTHQUAKES SINCE 1900 - NEW MADRID FAULT

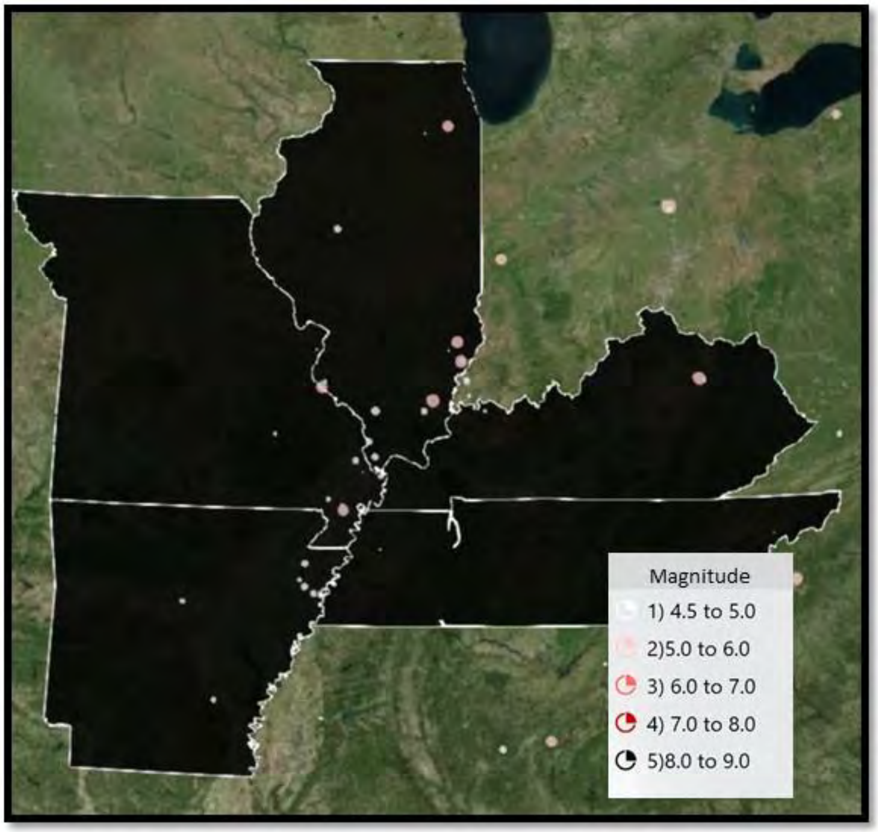

Table 49

EARTHQUAKES SINCE 1900– NEW MADRID FAULT

Magnitude	Counties in Top 50th Percentile	Counties in Top 70th Percentile	Counties in Top 90th Percentile	Total
1) 4.5 to 5.0	31	29	21	31
2) 5.0 to 6.0	8	5	4	8
3) 6.0 to 7.0	-	-	-	-
4) 7.0 to 8.0	-	-	-	-
5) 8.0 to 9.0	-	-	-	-
6) 9.0 and above	-	-	-	-

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Table 50
TOP 10 EARTHQUAKES IN PAST 100 YEARS: NEW MADRID FAULT

Rank	Date	Magnitude	Location
1	1968-11-09	5.3	5 km SSW of Norris City, Illinois
2	2008-04-18	5.2	7 km NNE of Bellmont, Illinois
3	1987-06-10	5.2	2 km ESE of Claremont, Illinois
4	1980-07-27	5.2	3 km SSE of Sharpsburg, Kentucky
5	1917-04-09	5.1	7 km S of Fults, Illinois
6	1909-05-26	5.1	3 km WNW of Lockport, Illinois
7	1903-11-04	5.1	1 km ESE of Tallapoosa, Missouri
8	1980-07-27	5.0	2 km SW of Sharpsburg, Kentucky
9	1903-02-09	4.9	3 km E of Harrison, Illinois
10	1990-09-26	4.8	4 km SE of Chaffee, Missouri

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Missouri – Risk Statistics

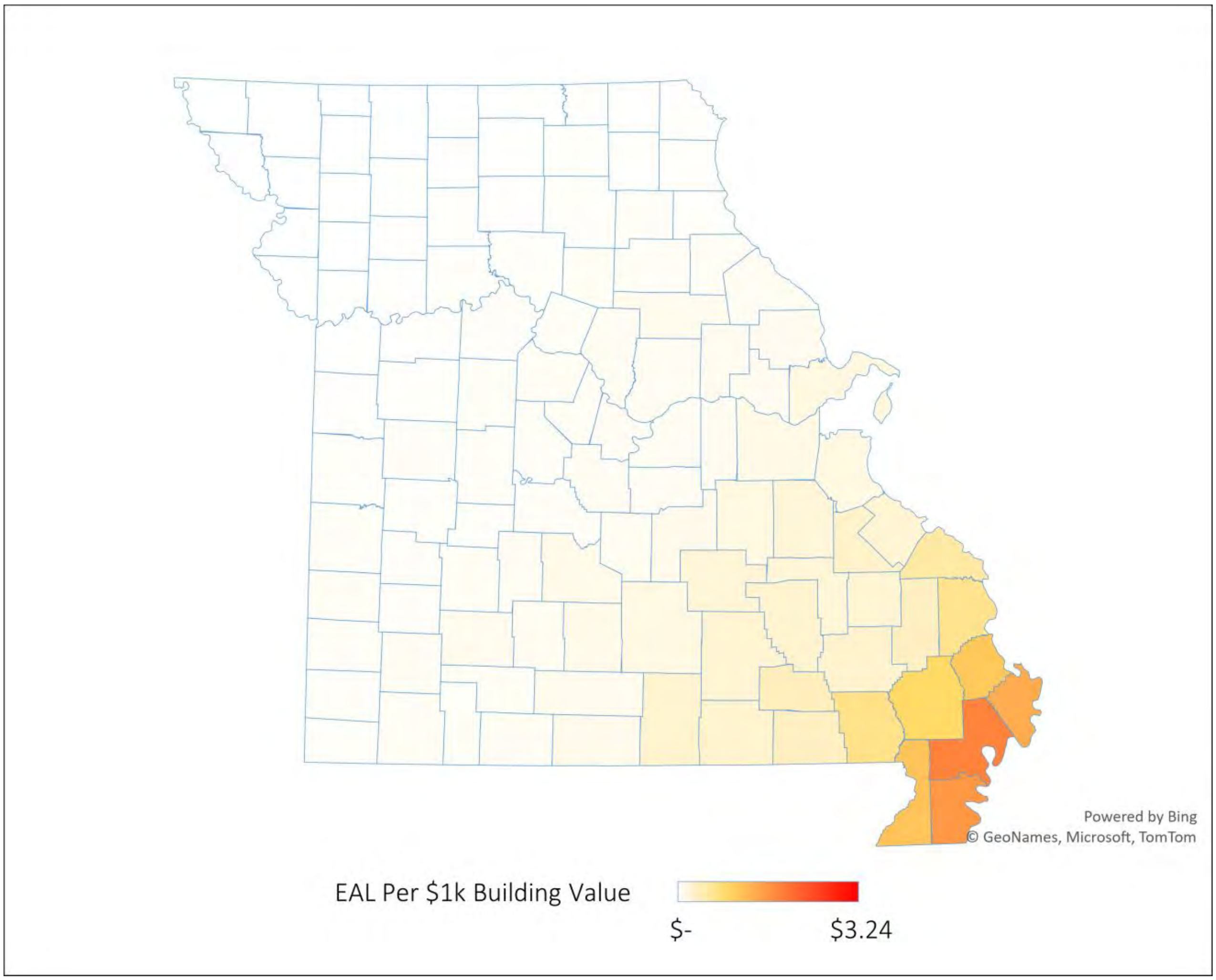
Table 51

MISSOURI EARTHQUAKE RISK BY AFFECTED COUNTY PERCENTILE GROUPS

Share of State	Building Stock		Expected Annual Losses		Risk Metrics	
Affected Counties	Building Value ($ Billions)	% of Value	Earthquake ($ Millions)	Tsunami ($ Millions)	EAL Per $1k Building Val	Economic Losses Per $1k Income
Missouri Total	1,316	100%	188	-	$0.14	$1.21
> 50th %-ile Counties	1,044	79%	186	-	$0.18	$1.51
> 70th %-ile Counties	890	68%	181	-	$0.20	$1.69
> 90th %-ile Counties	65	5%	57	-	$0.87	$10.03
			National Average		**$0.24**	**$1.50**

Figure 34

MISSOURI EXPECTED ANNUAL LOSSES BY COUNTY



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Missouri – Vulnerability Statistics

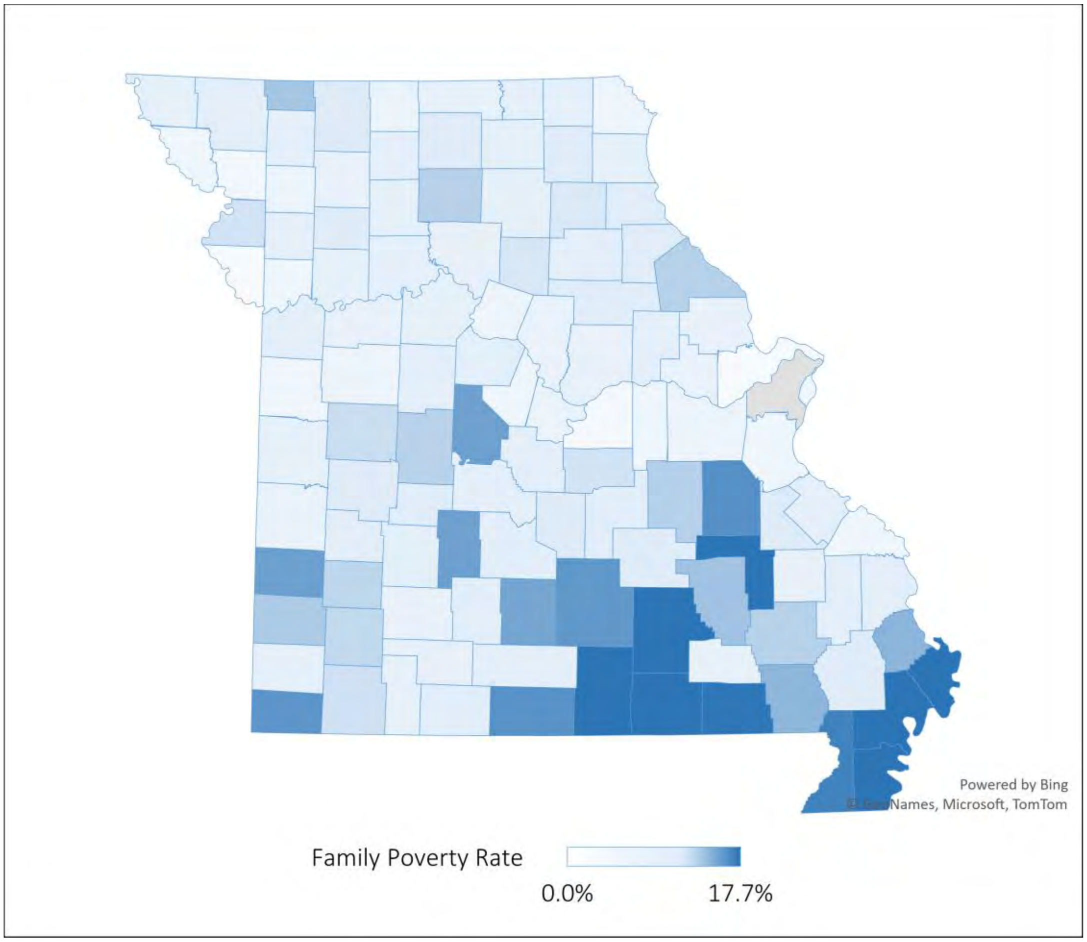
Table 52

MISSOURI VULNERABILITY STATISTICS BY AFFECTED COUNTY PERCENTILE GROUPS

Affected Counties	Family Poverty Rate	% Population over 65	Social Vulnerability Score	Community Resilience Score
Missouri Total	8.8%	19%	44	66
> 50th %-ile Counties	8.9%	19%	42	65
> 70th %-ile Counties	8.7%	19%	41	66
> 90th %-ile Counties	13.5%	20%	63	45
National Average	8.8%	18%	58	57

Figure 35

MISSOURI FAMILY POVERTY RATE BY COUNTY



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Missouri – Insurance Statistics

Table 53

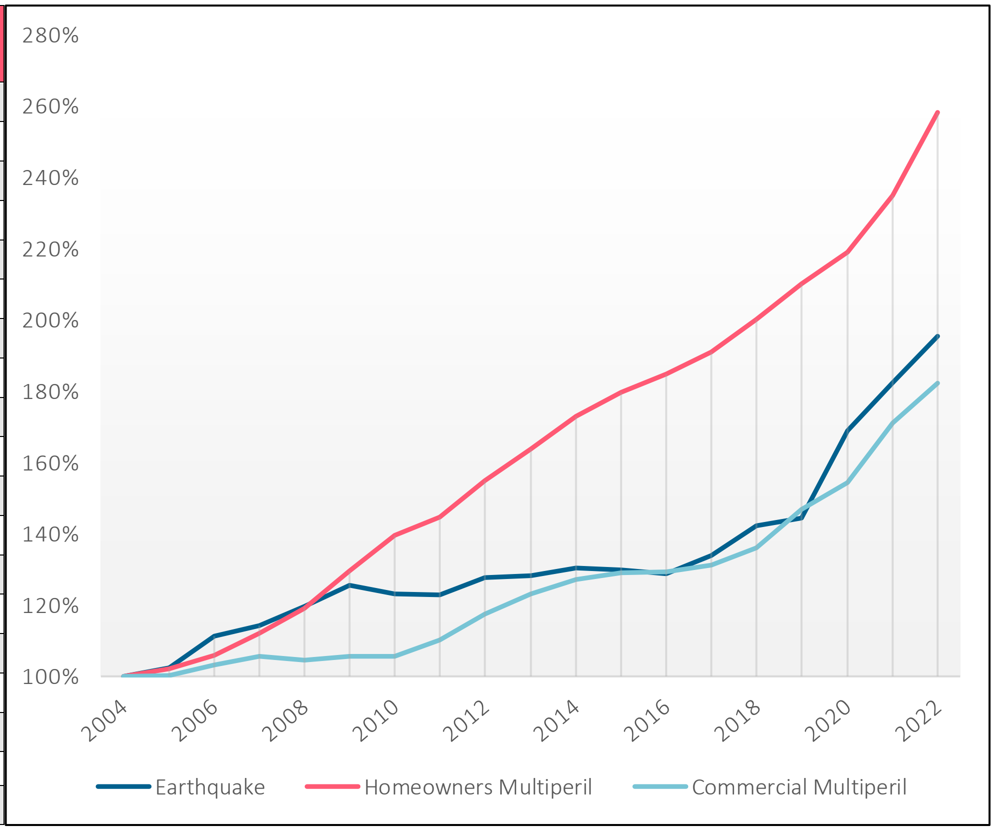
TOP 10 MISSOURI EARTHQUAKE INSURERS BY WRITTEN PREMIUM FOR 2022

Rank	Insurer	Written Premium	Market Share	Active License
1	State Farm Fire and Casualty Company	$37,232	27%	X
2	Factory Mutual Insurance Company	$10,212	7%	X
3	American Family Mutual Insurance Company, S.I.	$7,726	6%	X
4	Palomar Specialty Insurance Company	$5,191	4%	X
5	Shelter Mutual Insurance Company	$4,103	3%	X
6	Affiliated FM Insurance Company	$3,908	3%	X
7	Safeco Insurance Company of America	$3,644	3%	X
8	Farmers Insurance Exchange	$3,579	3%	X
9	American Family Insurance Company	$3,339	2%	X
10	American Economy Insurance Company	$3,026	2%	X
	Industry Total	$137,690		

Figure 36

MISSOURI EARTHQUAKE WRITTEN PREMIUM AND GROWTH SINCE 2004 COMPARED TO OTHER PROPERTY LINES

Year	Written Premium
2004	70,447
2005	72,113
2006	78,431
2007	80,539
2008	84,351
2009	88,542
2010	86,658
2011	86,511
2012	89,924
2013	90,310
2014	91,893
2015	91,411
2016	90,652
2017	94,412
2018	100,302
2019	101,823
2020	118,916
2021	128,488
2022	137,690



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Illinois – Risk Statistics

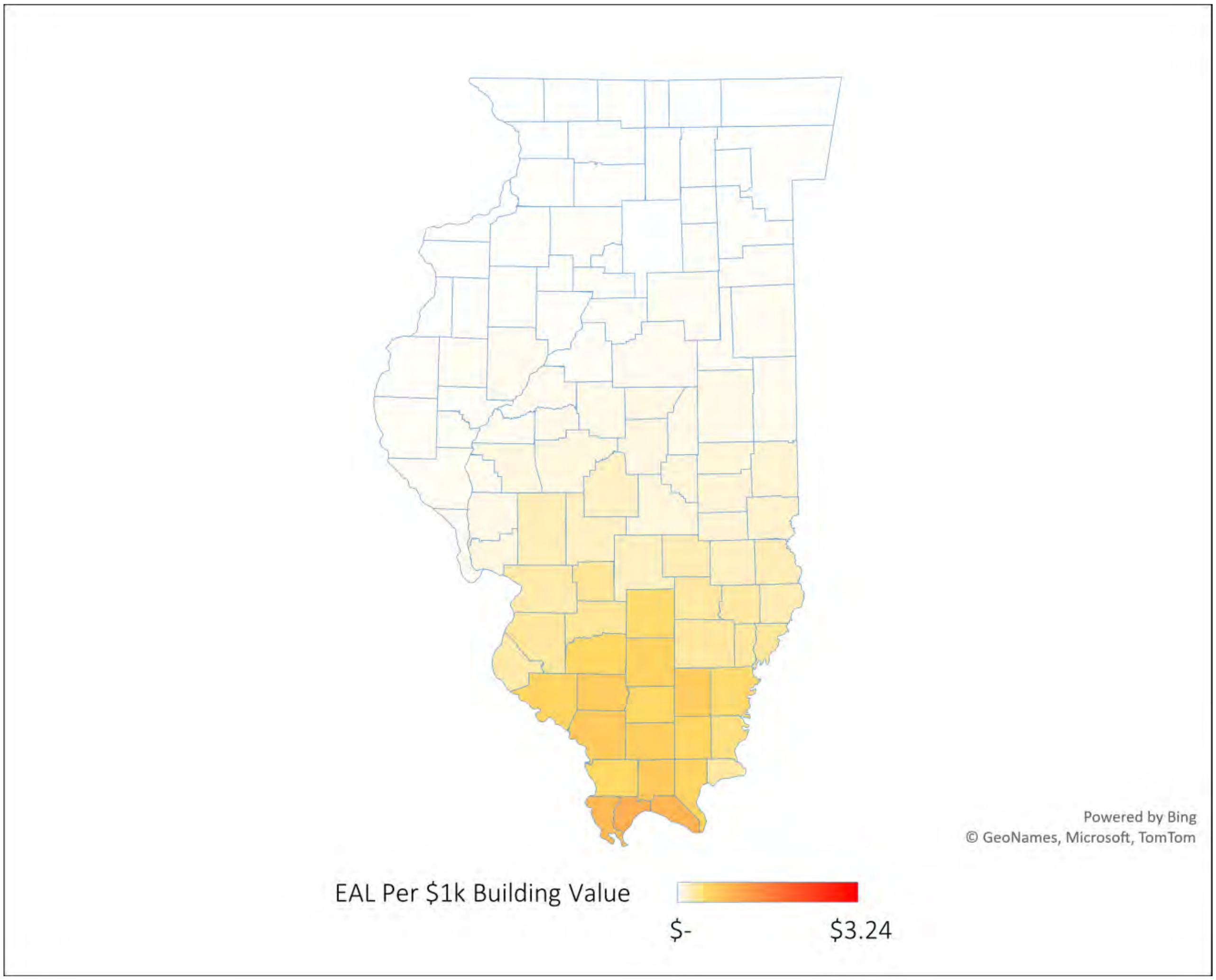
Table 54

ILLINOIS EARTHQUAKE RISK BY AFFECTED COUNTY PERCENTILE GROUPS

Share of State	Building Stock		Expected Annual Losses		Risk Metrics	
Affected Counties	Building Value ($ Billions)	% of Value	Earthquake ($ Millions)	Tsunami ($ Millions)	EAL Per $1k Building Val	Economic Losses Per $1k Income
Illinois Total	2,684	100%	179	-	$0.07	$0.48
> 50th %-ile Counties	2,179	81%	174	-	$0.08	$0.57
> 70th %-ile Counties	586	22%	148	-	$0.25	$2.48
> 90th %-ile Counties	195	7%	94	-	$0.48	$5.50
			National Average		**$0.24**	**$1.50**

Figure 37

ILLINOIS EXPECTED ANNUAL LOSSES BY COUNTY



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Illinois – Vulnerability Statistics

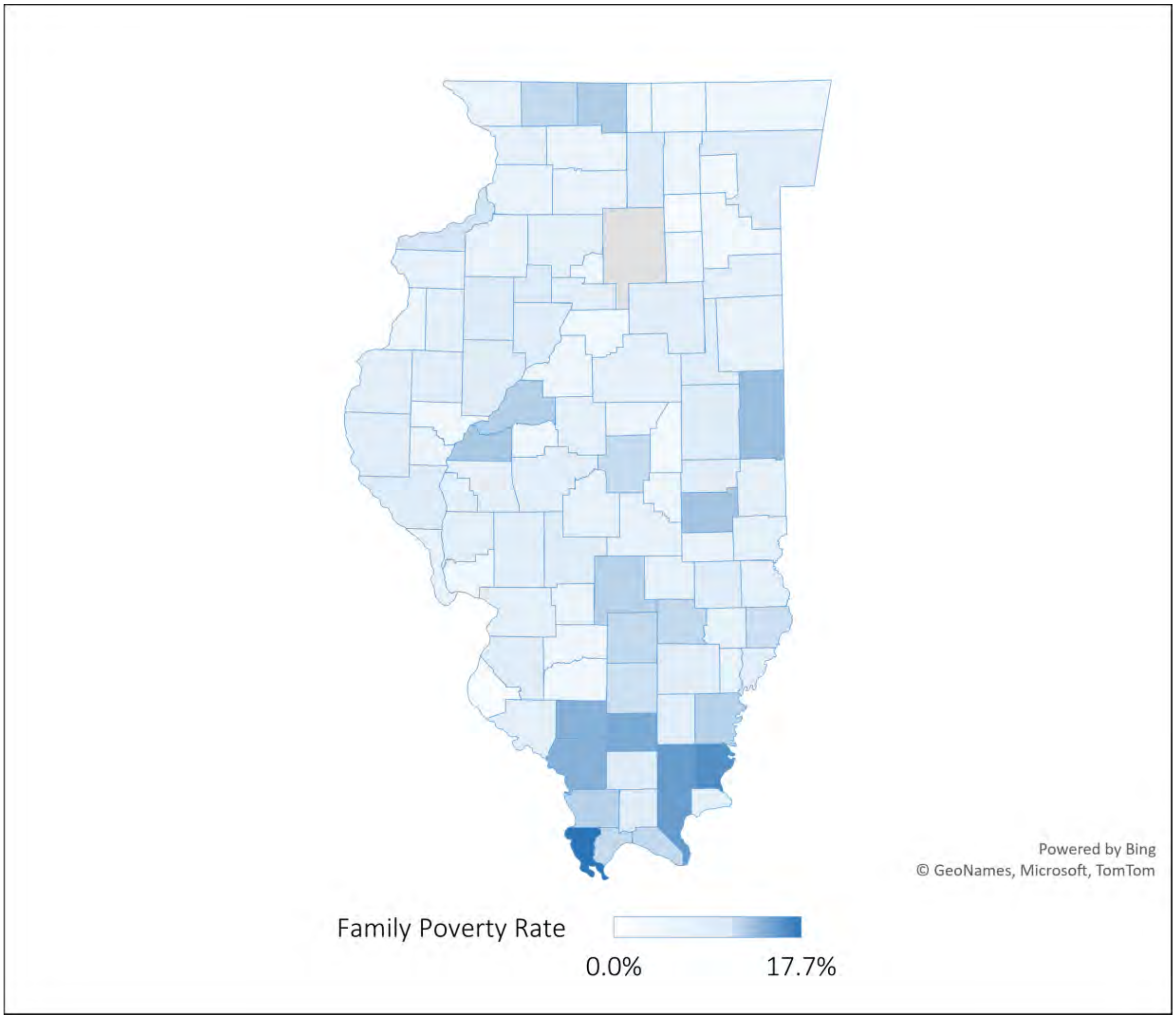
Table 55

ILLINOIS VULNERABILITY STATISTICS BY AFFECTED COUNTY PERCENTILE GROUPS

Affected Counties	Family Poverty Rate	% Population over 65	Social Vulnerability Score	Community Resilience Score
Illinois Total	8.2%	18%	55	79
> 50th %-ile Counties	8.5%	18%	57	79
> 70th %-ile Counties	9.5%	20%	40	81
> 90th %-ile Counties	10.6%	20%	51	72
National Average	8.8%	18%	58	57

Figure 38

ILLINOIS FAMILY POVERTY RATE BY COUNTY



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Illinois – Insurance Statistics

Table 56

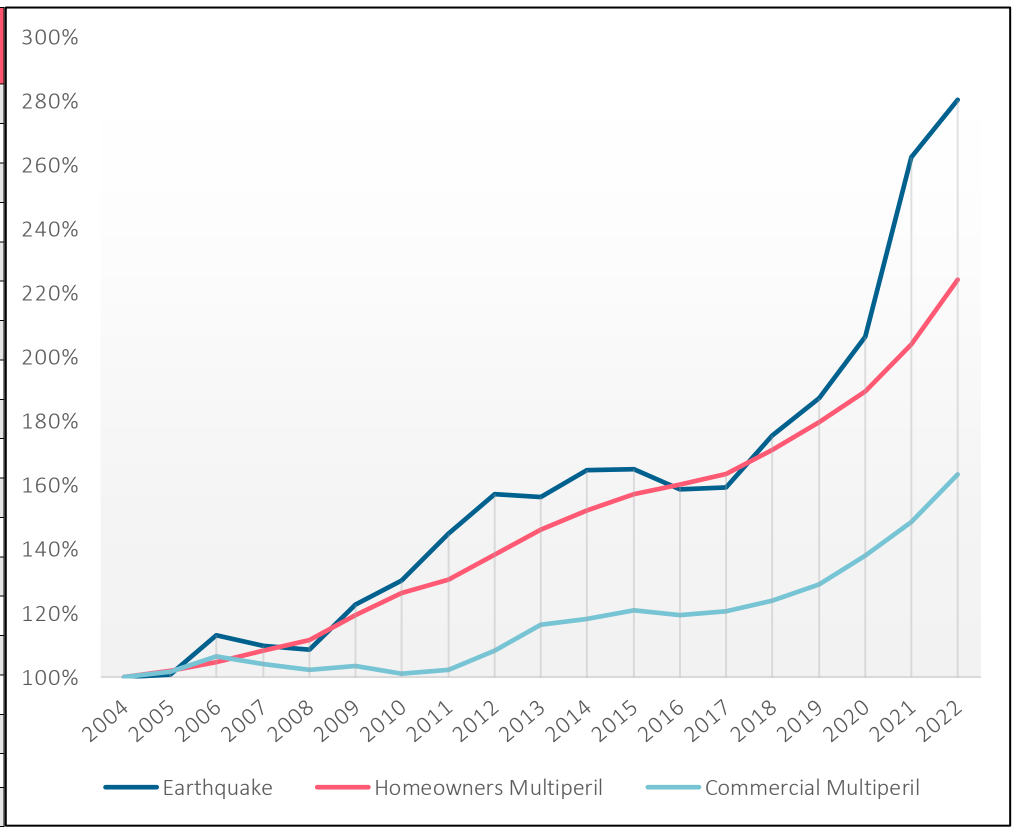
TOP 10 ILLINOIS EARTHQUAKE INSURERS BY WRITTEN PREMIUM FOR 2022

Rank	Insurer	Written Premium	Market Share	Active License
1	State Farm Fire and Casualty Company	$37,232	26%	X
2	National Fire & Marine Insurance Company	$10,212	13%	
3	Endurance American Specialty Insurance Company	$7,726	11%	
4	The Travelers Indemnity Company	$5,191	3%	X
5	Factory Mutual Insurance Company	$4,103	3%	X
6	Auto-Owners Insurance Company	$3,908	2%	X
7	Grinnell Mutual Reinsurance Company	$3,644	2%	X
8	Houston Casualty Company	$3,579	2%	
9	Liberty Mutual Fire Insurance Company	$3,339	1%	X
10	Allianz Global Risks US Insurance Company	$3,026	1%	X
	Industry Total	$114,174		

Figure 39

ILLINOIS EARTHQUAKE WRITTEN PREMIUM AND GROWTH SINCE 2004 COMPARED TO OTHER PROPERTY LINES

Year	Written Premium
2004	40,727
2005	41,067
2006	46,052
2007	44,740
2008	44,159
2009	49,999
2010	53,016
2011	58,950
2012	64,022
2013	63,616
2014	67,095
2015	67,210
2016	64,575
2017	64,832
2018	71,402
2019	76,216
2020	84,023
2021	106,857
2022	114,174



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Kentucky– Risk Statistics

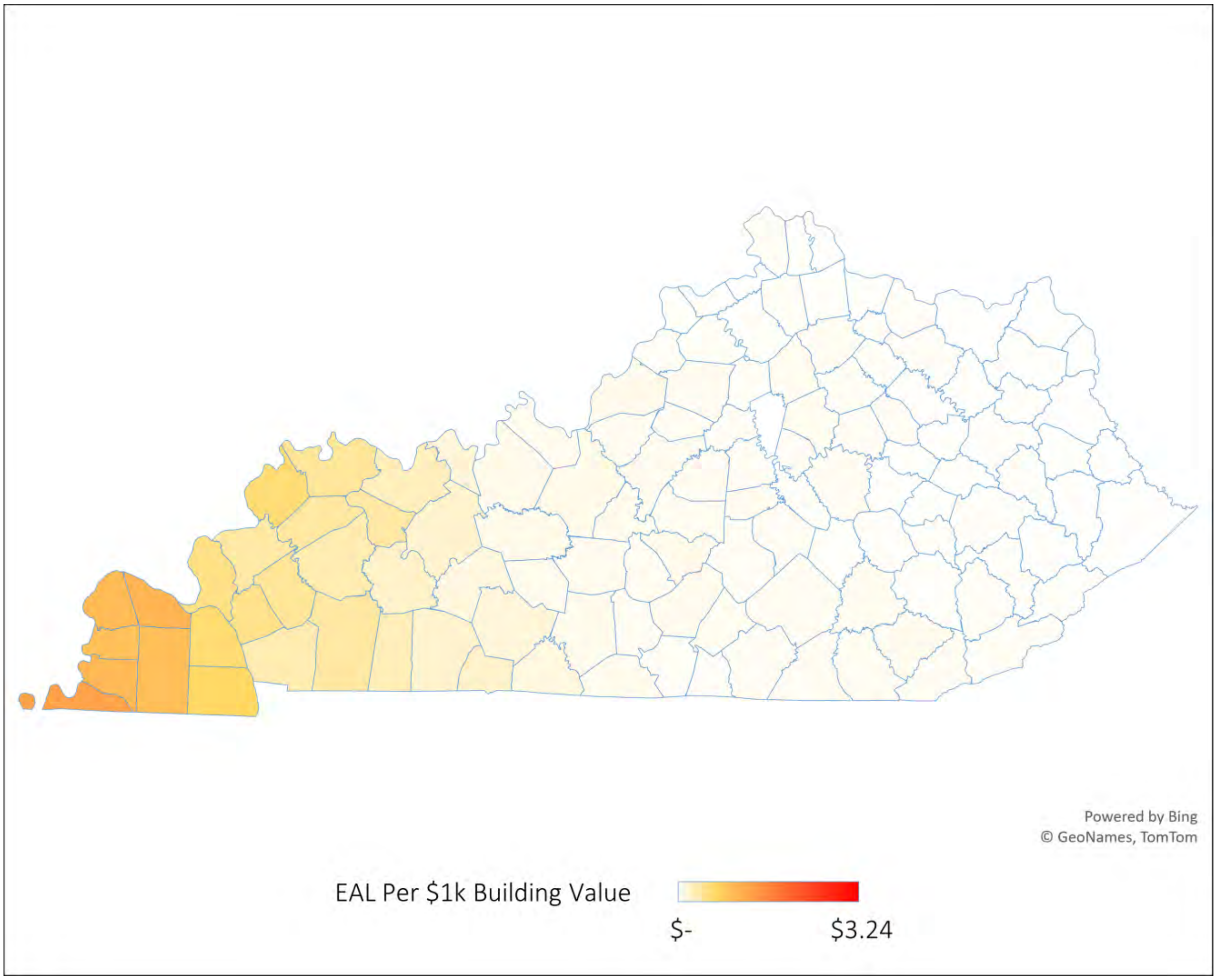
Table 57

KENTUCKY EARTHQUAKE RISK BY AFFECTED COUNTY PERCENTILE GROUPS

Share of State	Building Stock		Expected Annual Losses		Risk Metrics	
Affected Counties	Building Value ($ Billions)	% of Value	Earthquake ($ Millions)	Tsunami ($ Millions)	EAL Per $1k Building Val	Economic Losses Per $1k Income
Kentucky Total	845	100%	111	-	$0.13	$1.06
> 50th %-ile Counties	813	96%	110	-	$0.14	$1.09
> 70th %-ile Counties	606	72%	104	-	$0.17	$1.41
> 90th %-ile Counties	93	11%	59	-	$0.63	$6.55
			National Average		**$0.24**	**$1.50**

Figure 40

KENTUCKY EXPECTED ANNUAL LOSSES BY COUNTY



Kentucky – Vulnerability Statistics

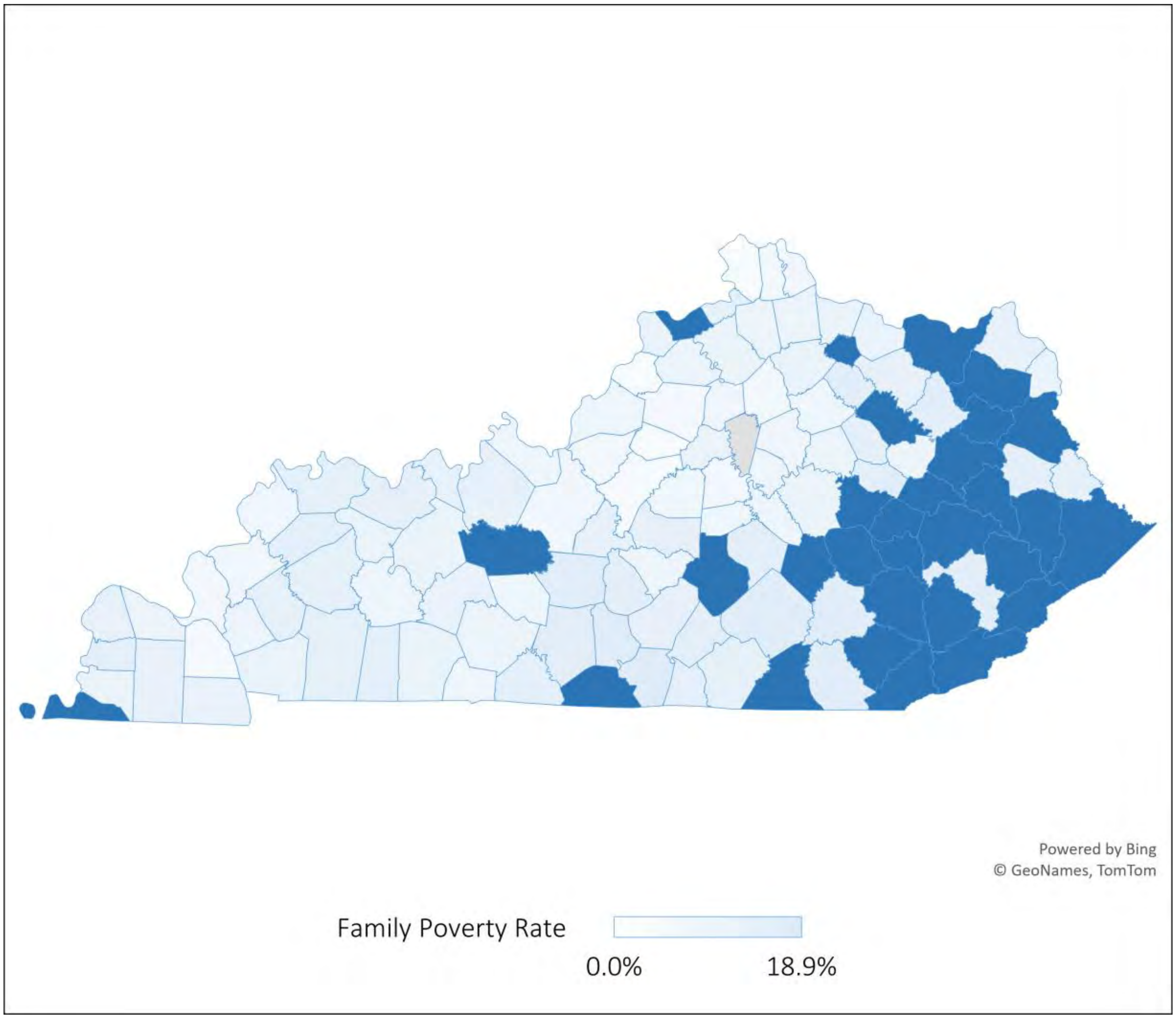
Table 58

KENTUCKY VULNERABILITY STATISTICS BY AFFECTED COUNTY PERCENTILE GROUPS

Affected Counties	Family Poverty Rate	% Population over 65	Social Vulnerability Score	Community Resilience Score
Kentucky Total	12.1%	18%	52	58
> 50th %-ile Counties	11.8%	18%	52	60
> 70th %-ile Counties	11.3%	18%	54	63
> 90th %-ile Counties	12.2%	20%	58	50
National Average	8.8%	18%	58	57

Figure 41

KENTUCKY FAMILY POVERTY RATE BY COUNTY



Kentucky – Insurance Statistics

Table 59

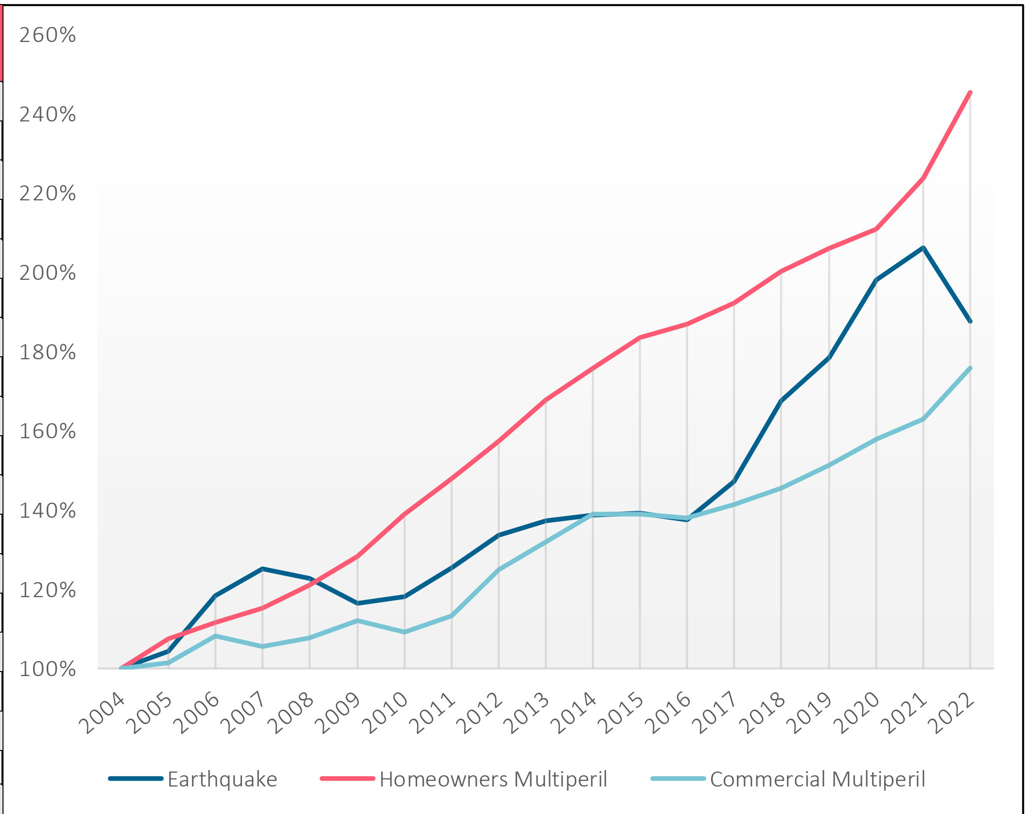
TOP 10 KENTUCKY EARTHQUAKE INSURERS BY WRITTEN PREMIUM FOR 2022

Rank	Insurer	Written Premium	Market Share	Active License
1	State Farm Fire and Casualty Company	$14,956	27%	X
2	Factory Mutual Insurance Company	$4,676	8%	X
3	Liberty Mutual Fire Insurance Company	$2,638	5%	X
4	Auto-Owners Insurance Company	$2,273	4%	X
5	The Cincinnati Insurance Company	$1,991	4%	X
6	Safeco Insurance Company of America	$1,771	3%	X
7	American Economy Insurance Company	$947	2%	X
8	National Fire & Marine Insurance Company	$879	2%	
9	United Services Automobile Association	$797	1%	X
10	Farmers Property and Casualty Insurance Company	$793	1%	X
	Industry Total	$56,176		

Figure 42

KENTUCKY EARTHQUAKE WRITTEN PREMIUM AND GROWTH SINCE 2004 COMPARED TO OTHER PROPERTY LINES

Year	Written Premium
2004	30,164
2005	31,494
2006	35,719
2007	37,759
2008	37,053
2009	35,141
2010	35,647
2011	37,830
2012	40,294
2013	41,366
2014	41,818
2015	41,992
2016	41,443
2017	44,414
2018	50,532
2019	53,831
2020	59,745
2021	62,189
2022	56,610



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Tennessee – Risk Statistics

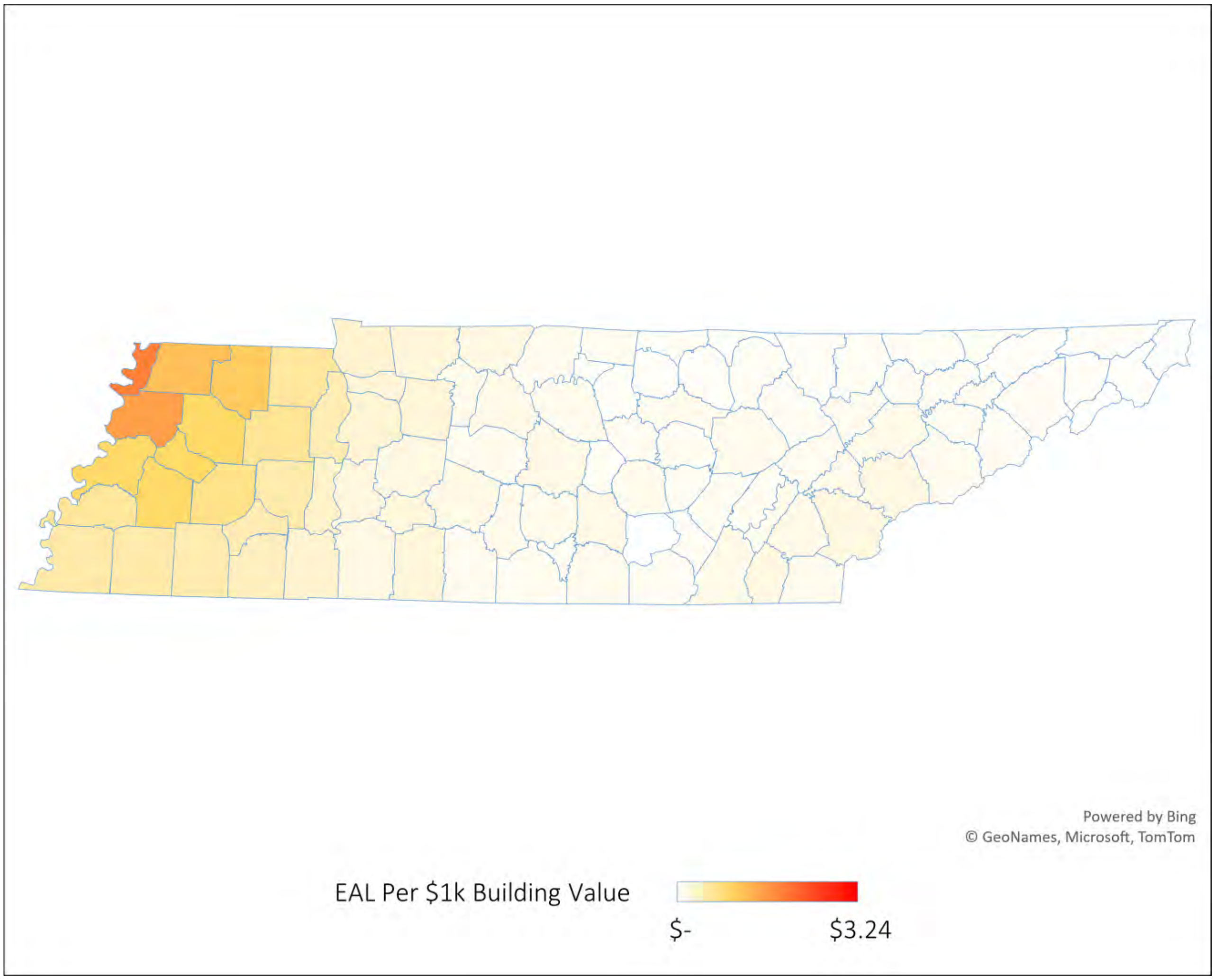
Table 60

TENNESSEE EARTHQUAKE RISK BY AFFECTED COUNTY PERCENTILE GROUPS

Share of State	Building Stock		Expected Annual Losses		Risk Metrics	
Affected Counties	Building Value ($ Billions)	% of Value	Earthquake ($ Millions)	Tsunami ($ Millions)	EAL Per $1k Building Val	Economic Losses Per $1k Income
Tennessee Total	1,209	100%	284	-	$0.24	$1.66
> 50th %-ile Counties	1,209	100%	284	-	$0.24	$1.66
> 70th %-ile Counties	1,187	98%	283	-	$0.24	$1.69
> 90th %-ile Counties	282	23%	171	-	$0.61	$5.15
			National Average		**$0.24**	**$1.50**

Figure 43

TENNESSEE EXPECTED ANNUAL LOSSES BY COUNTY



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Tennessee – Vulnerability Statistics

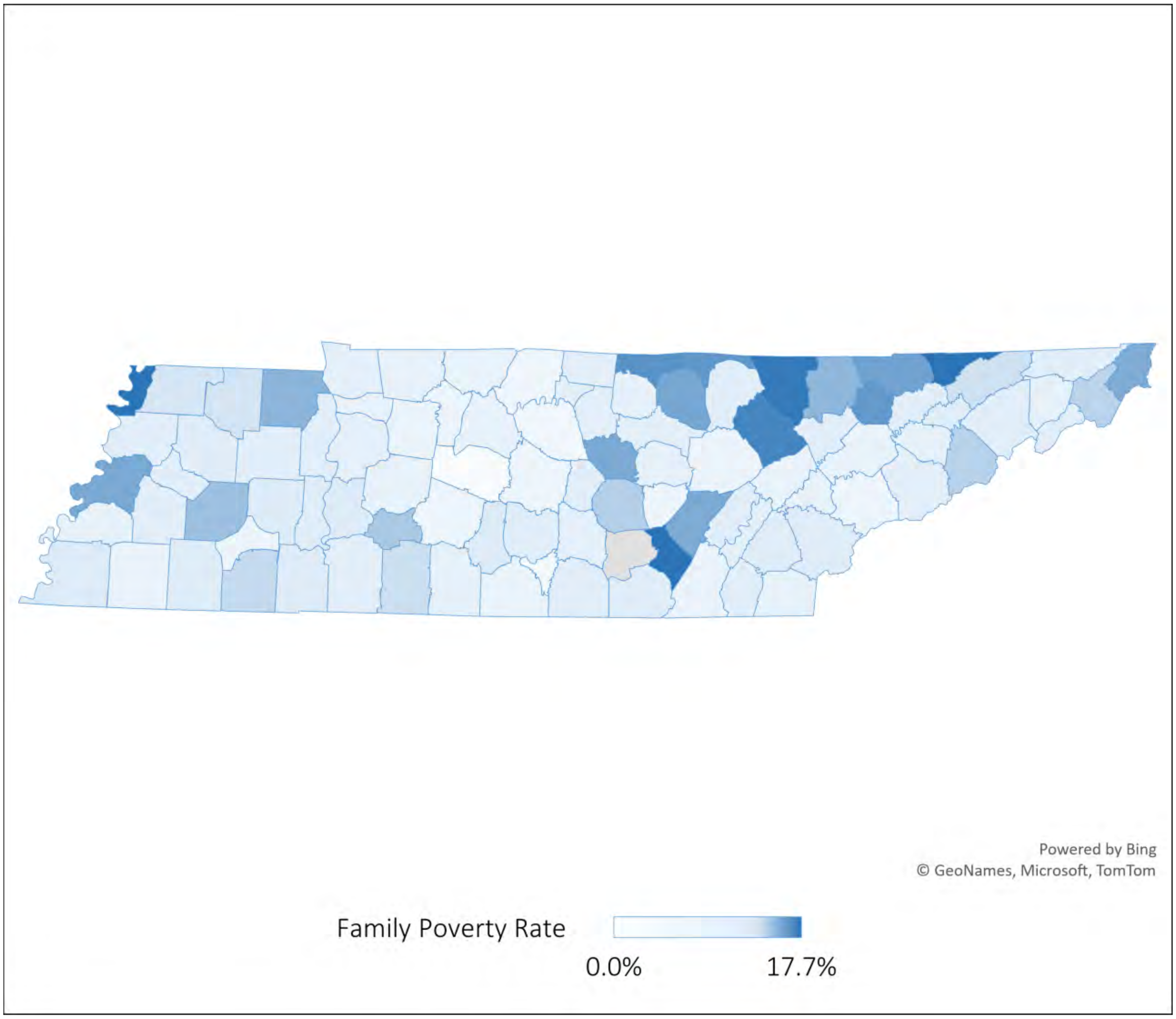
Table 61

TENNESSEE VULNERABILITY STATISTICS BY AFFECTED COUNTY PERCENTILE GROUPS

Affected Counties	Family Poverty Rate	% Population over 65	Social Vulnerability Score	Community Resilience Score
Tennessee Total	10.3%	18%	56	52
> 50th %-ile Counties	10.3%	18%	56	52
> 70th %-ile Counties	10.2%	18%	56	53
> 90th %-ile Counties	13.0%	17%	80	54
National Average	8.8%	18%	58	57

Figure 44

TENNESSEE FAMILY POVERTY RATE BY COUNTY



Tennessee – Insurance Statistics

Table 62

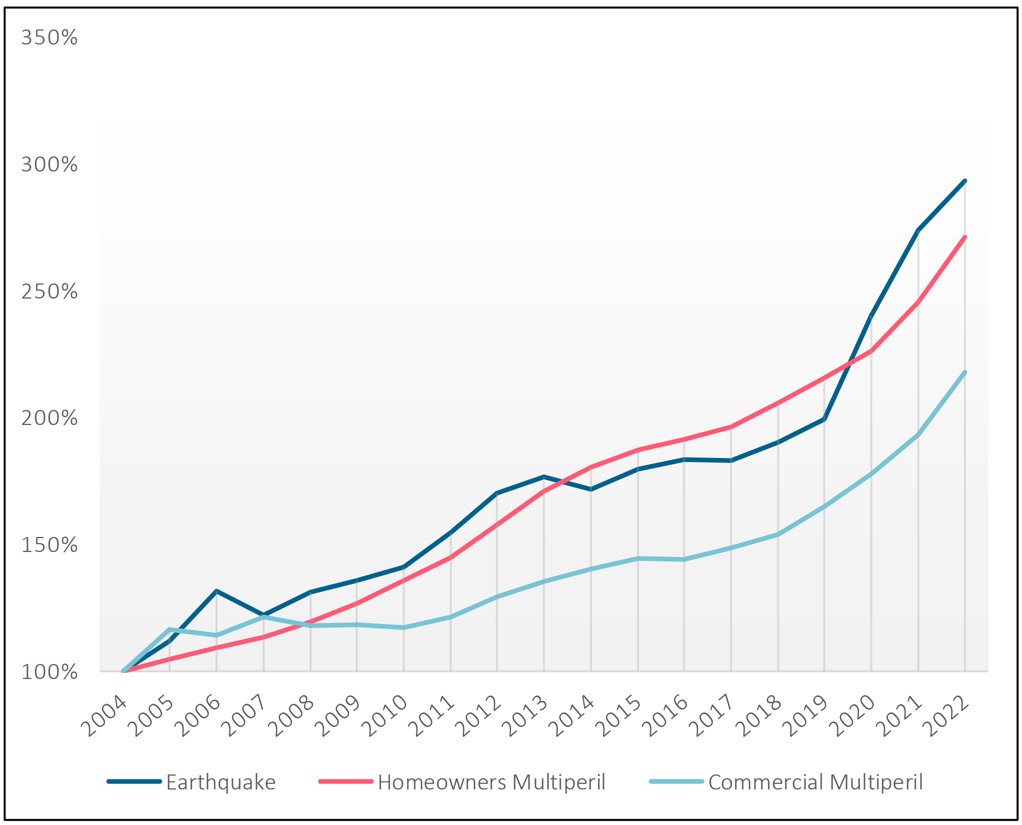
TOP 10 TENNESSEE EARTHQUAKE INSURERS BY WRITTEN PREMIUM FOR 2022

Rank	Insurer	Written Premium	Market Share	Active License
1	State Farm Fire and Casualty Company	$32,392	25%	X
2	Factory Mutual Insurance Company	$21,522	17%	X
3	Employers Insurance Company of Wausau	$5,621	4%	X
4	Swiss Re Corporate Solutions Elite Insurance Corp	$3,800	3%	X
5	Zurich American Insurance Company	$3,628	3%	X
6	Travelers Excess and Surplus Lines Company	$3,589	3%	
7	United Services Automobile Association	$3,583	3%	X
8	National Fire & Marine Insurance Company	$3,165	2%	
9	Affiliated FM Insurance Company	$2,716	2%	X
10	Liberty Mutual Fire Insurance Company	$2,530	2%	X
	Industry Total	$128,052		

Figure 45

TENNESSEE EARTHQUAKE WRITTEN PREMIUM AND GROWTH SINCE 2004 COMPARED TO OTHER PROPERTY LINES

Year	Written Premium
2004	43,937
2005	49,174
2006	57,818
2007	53,726
2008	57,631
2009	59,612
2010	61,980
2011	67,986
2012	74,710
2013	77,636
2014	75,402
2015	78,908
2016	80,555
2017	80,437
2018	83,559
2019	87,637
2020	105,486
2021	120,359
2022	128,858



Arkansas – Risk Statistics

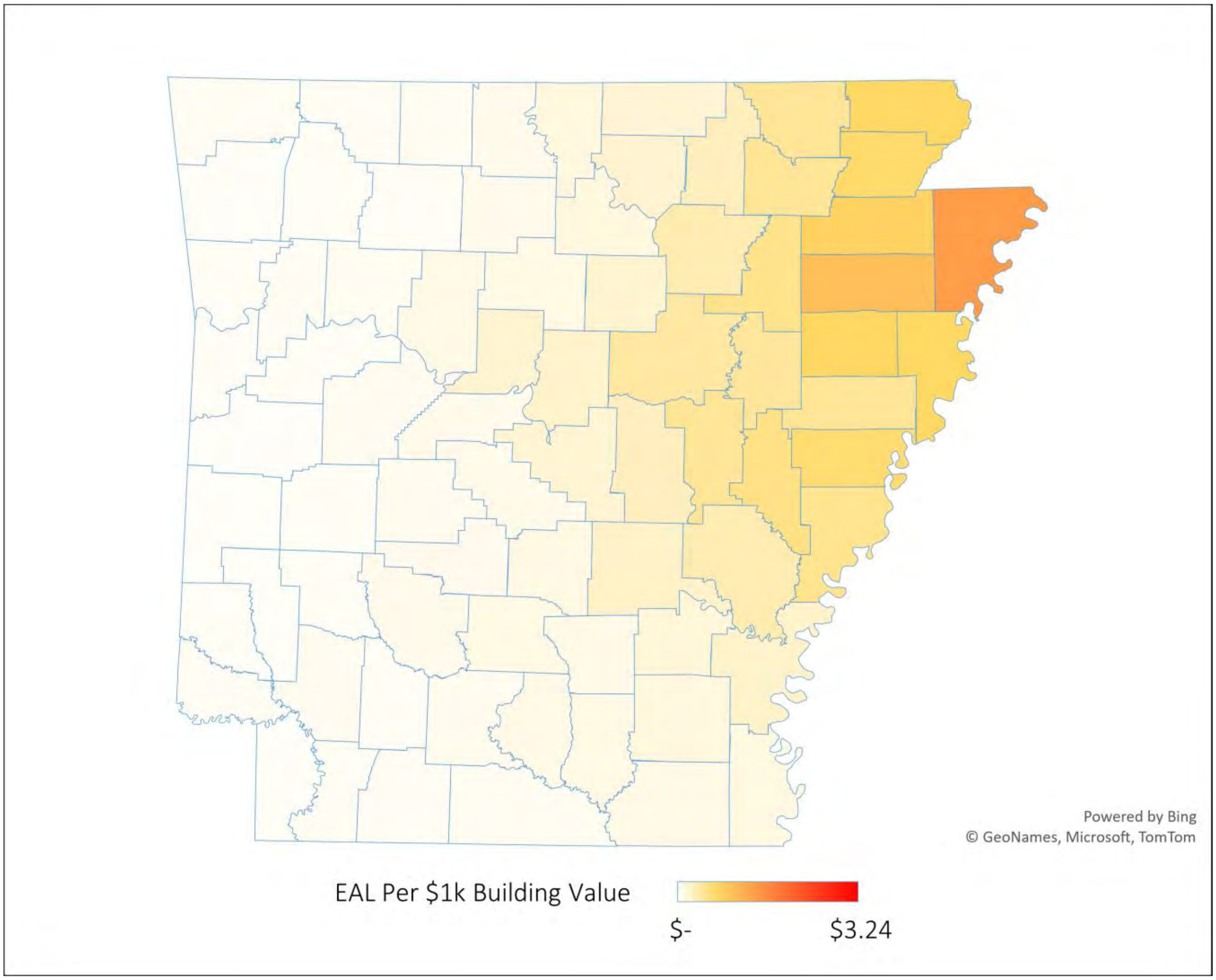
Table 63

ARKANSAS EARTHQUAKE RISK BY AFFECTED COUNTY PERCENTILE GROUPS

Share of State	Building Stock		Expected Annual Losses		Risk Metrics	
Affected Counties	Building Value ($ Billions)	% of Value	Earthquake ($ Millions)	Tsunami ($ Millions)	EAL Per $1k Building Val	Economic Losses Per $1k Income
Tennessee Total	532	100%	116	-	$0.22	$1.83
> 50th %-ile Counties	532	100%	116	-	$0.22	$1.83
> 70th %-ile Counties	430	81%	112	-	$0.26	$2.17
> 90th %-ile Counties	100	19%	68	-	$0.68	$6.81
			National Average		**$0.24**	**$1.50**

Figure 46

ARKANSAS EXPECTED ANNUAL LOSSES BY COUNTY



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Arkansas – Vulnerability Statistics

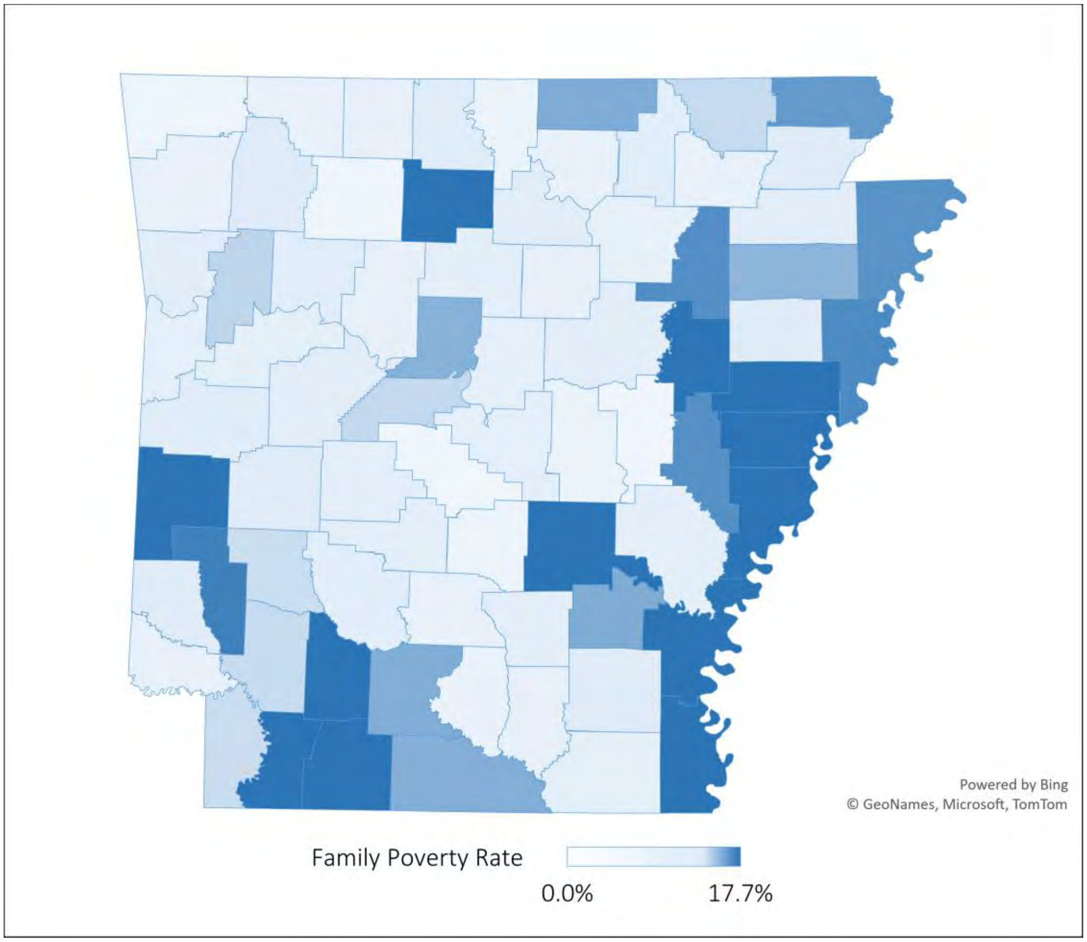
Table 64

ARKANSAS VULNERABILITY STATISTICS BY AFFECTED COUNTY PERCENTILE GROUPS

Affected Counties	Family Poverty Rate	% Population over 65	Social Vulnerability Score	Community Resilience Score
Tennessee Total	11.8%	19%	66	40
> 50th %-ile Counties	11.8%	19%	66	40
> 70th %-ile Counties	11.8%	19%	63	42
> 90th %-ile Counties	14.5%	18%	78	34
National Average	8.8%	18%	58	57

Figure 47

ARKANSAS FAMILY POVERTY RATE BY COUNTY

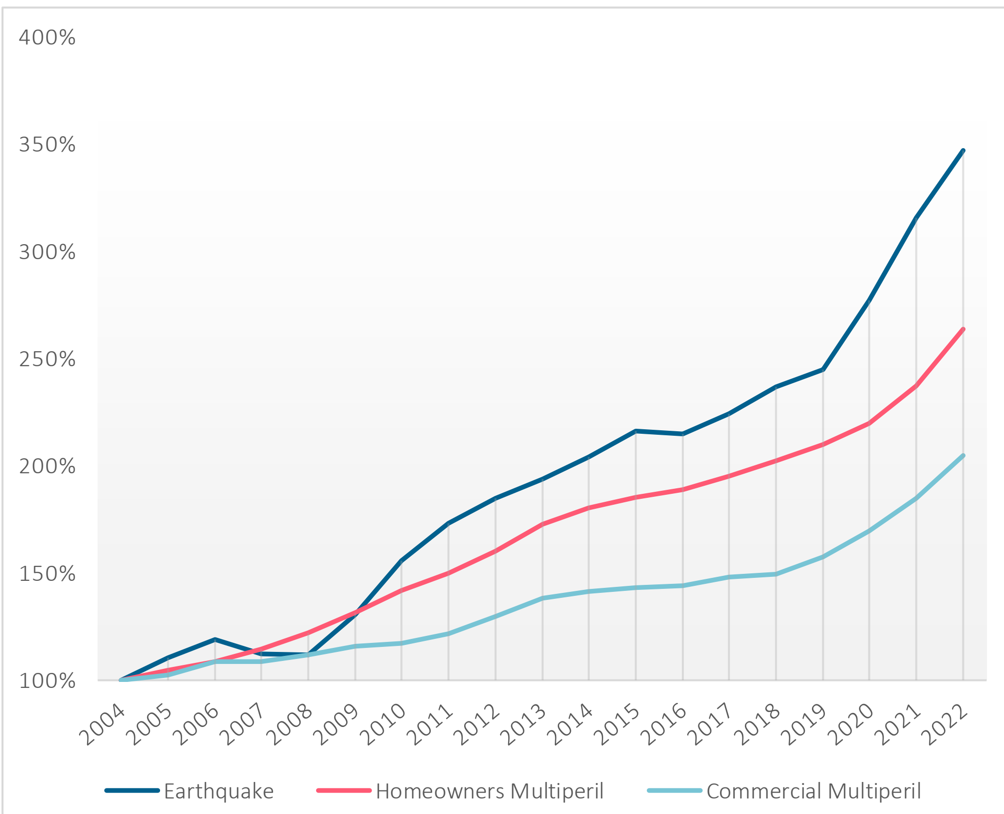


Arkansas – Insurance Statistics
Table 65
TOP 10 ARKANSAS EARTHQUAKE INSURERS BY WRITTEN PREMIUM FOR 2022

Rank	Insurer	Written Premium	Market Share	Active License
1	State Farm Fire and Casualty Company	$17,601	35%	X
2	Factory Mutual Insurance Company	$4,678	9%	X
3	United Services Automobile Association	$2,946	6%	X
4	The Travelers Indemnity Company	$1,771	4%	X
5	Shelter Mutual Insurance Company	$1,667	3%	
6	USAA Casualty Insurance Company	$1,464	3%	X
7	Zurich American Insurance Company	$1,009	2%	X
8	Affiliated FM Insurance Company	$981	2%	X
9	Mt. Hawley Insurance Company	$962	2%	
10	USAA General Indemnity Company	$901	2%	X
	Industry Total	$50,241		

Figure 48
ARKANSAS EARTHQUAKE WRITTEN PREMIUM AND GROWTH SINCE 2004 COMPARED TO OTHER PROPERTY LINES

Year	Written Premium
2004	14,612
2005	16,124
2006	17,400
2007	16,398
2008	16,364
2009	19,113
2010	22,743
2011	25,298
2012	27,038
2013	28,330
2014	29,855
2015	31,615
2016	31,365
2017	32,767
2018	34,596
2019	35,813
2020	40,467
2021	46,122
2022	50,713



6.7 MIDDLETON PLATE

Figure 49

MAP OF EARTHQUAKES SINCE 1900 - MIDDLETON FAULT

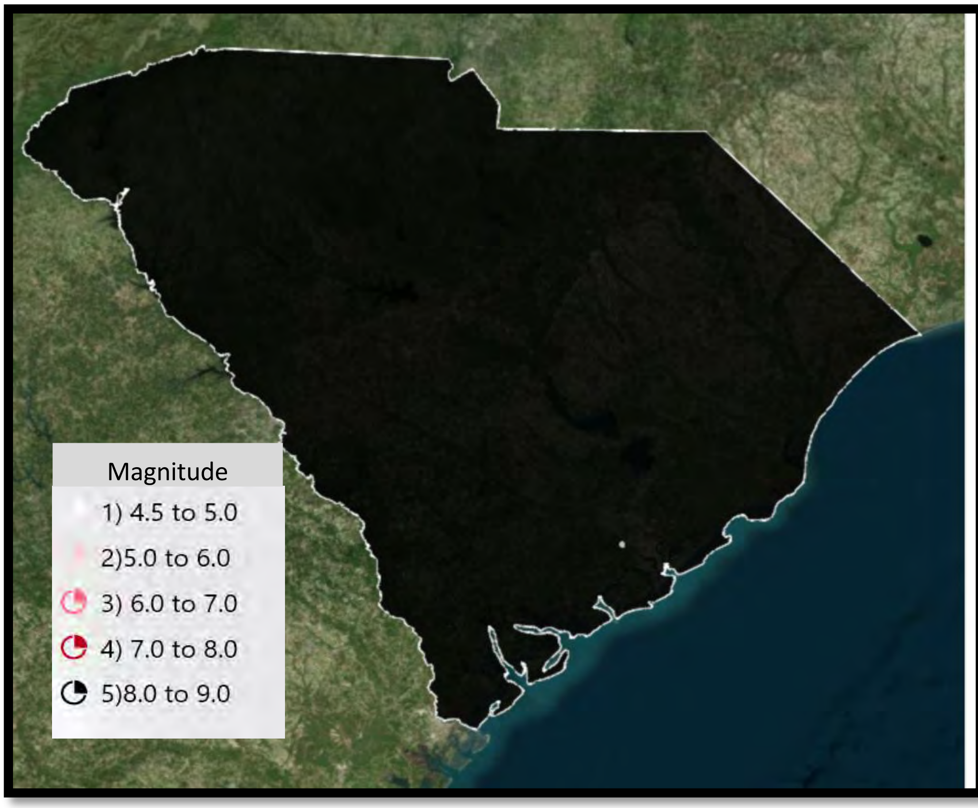


Table 66

EARTHQUAKES SINCE 1900– MIDDLETON FAULT

Magnitude	Counties in Top 50th Percentile	Counties in Top 70th Percentile	Counties in Top 90th Percentile	Total
1) 4.5 to 5.0	1	1	1	1
2) 5.0 to 6.0	-	-	-	-
3) 6.0 to 7.0	-	-	-	-
4) 7.0 to 8.0	-	-	-	-
5) 8.0 to 9.0	-	-	-	-
6) 9.0 and above	-	-	-	-

Table 67

TOP 10 EARTHQUAKES IN PAST 100 YEARS: MIDDLETON FAULT

Rank	Date	Magnitude	Location
1	1974-11-22	4.7	10 km SSW of Ladson, South Carolina

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South Carolina – Risk Statistics

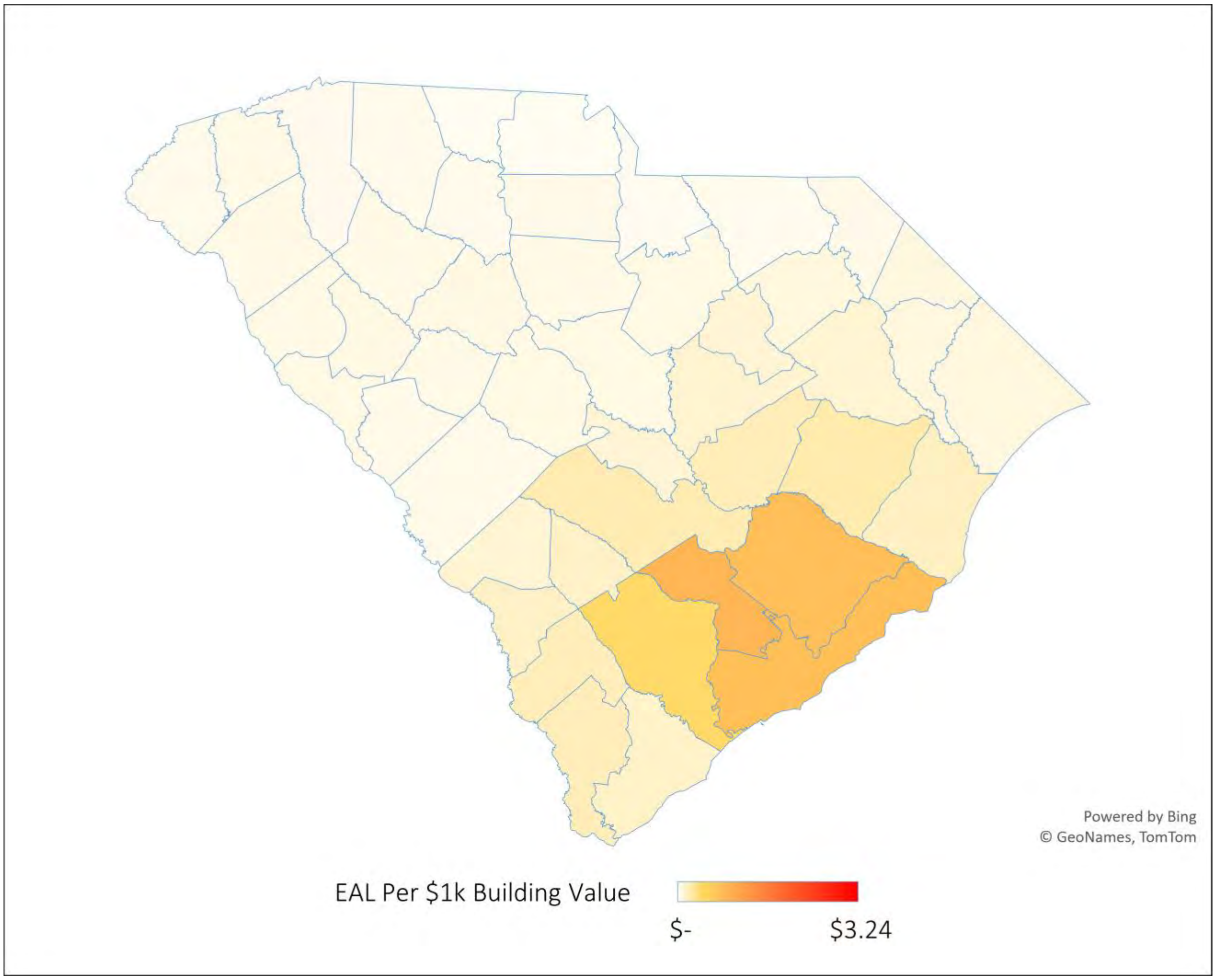
Table 68

SOUTH CAROLINA EARTHQUAKE RISK BY AFFECTED COUNTY PERCENTILE GROUPS

Share of State	Building Stock		Expected Annual Losses		Risk Metrics	
Affected Counties	Building Value ($ Billions)	% of Value	Earthquake ($ Millions)	Tsunami ($ Millions)	EAL Per $1k Building Val	Economic Losses Per $1k Income
South Carolina Total	1,013	100%	194	-	$0.19	$1.53
> 50th %-ile Counties	1,013	100%	194	-	$0.19	$1.53
> 70th %-ile Counties	940	93%	191	-	$0.20	$1.62
> 90th %-ile Counties	157	16%	123	-	$0.78	$5.31
				National Average	**$0.24**	**$1.50**

Figure 50

SOUTH CAROLINA EXPECTED ANNUAL LOSSES BY COUNTY



South Carolina – Vulnerability Statistics

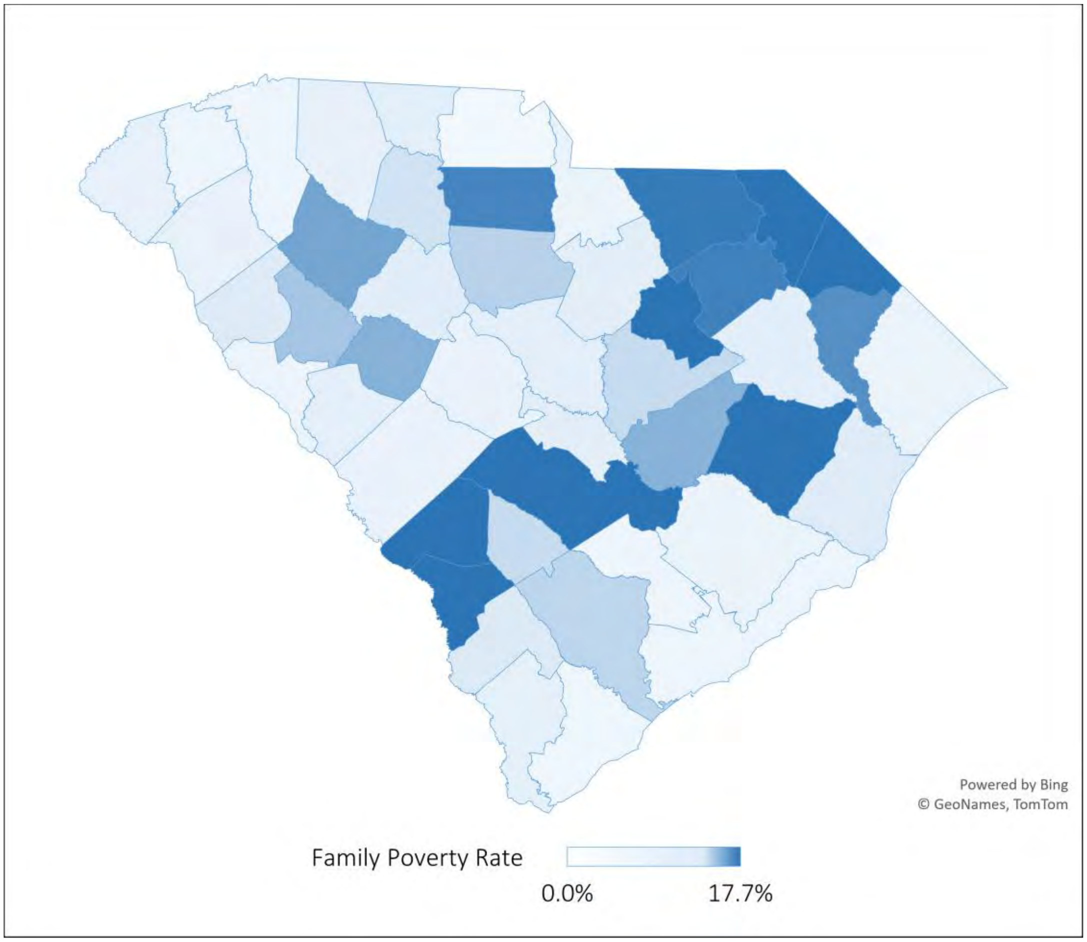
Table 69

SOUTH CAROLINA VULNERABILITY STATISTICS BY AFFECTED COUNTY PERCENTILE GROUPS

Affected Counties	Family Poverty Rate	% Population over 65	Social Vulnerability Score	Community Resilience Score
Arkansas Total	10.1%	20%	67	59
> 50th %-ile Counties	10.1%	20%	67	59
> 70th %-ile Counties	10.4%	20%	69	59
> 90th %-ile Counties	8.3%	18%	56	77
National Average	8.8%	18%	58	57

Figure 51

SOUTH CAROLINA FAMILY POVERTY RATE BY COUNTY



South Carolina – Insurance Statistics

Table 70

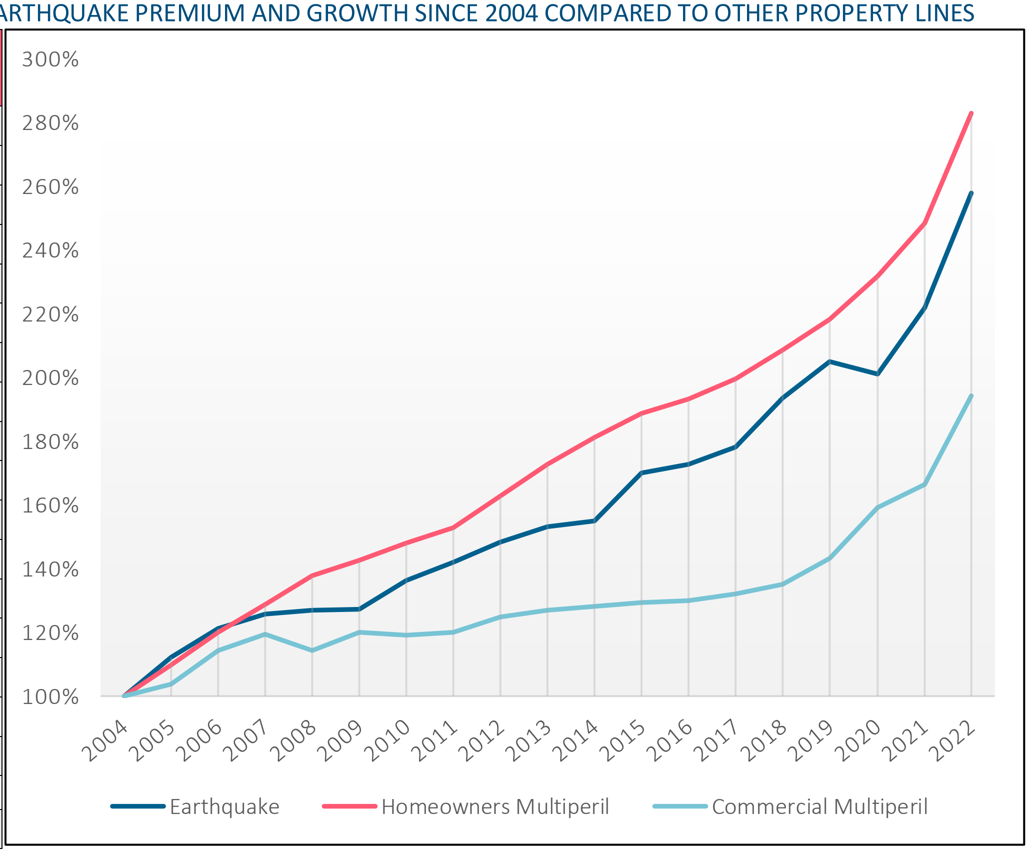
TOP 10 SOUTH CAROLINA EARTHQUAKE INSURERS BY WRITTEN PREMIUM FOR 2022

Rank	Insurer	Written Premium	Market Share	Active License
1	State Farm Fire and Casualty Company	$14,983	25%	X
2	United Services Automobile Association	$3,326	5%	X
3	Zurich American Insurance Company	$2,673	4%	X
4	Lexington Insurance Company	$2,462	4%	
5	AIG Property Casualty Company	$2,071	3%	X
6	QBE Specialty Insurance Company	$1,962	3%	
7	Swiss Re Corporate Solutions Elite Insurance Corp	$1,854	3%	X
8	The Travelers Indemnity Company	$1,835	3%	X
9	USAA Casualty Insurance Company	$1,356	2%	X
10	Employers Insurance Company of Wausau	$1,214	2%	X
	Industry Total	$61,057		

Figure 52

SOUTH CAROLINA EARTHQUAKE PREMIUM AND GROWTH SINCE 2004 COMPARED TO OTHER PROPERTY LINES

Year	Written Premium
2004	23,977
2005	26,935
2006	29,069
2007	30,158
2008	30,461
2009	30,515
2010	32,661
2011	34,068
2012	35,533
2013	36,702
2014	37,147
2015	40,740
2016	41,437
2017	42,737
2018	46,369
2019	49,127
2020	48,212
2021	53,211
2022	61,840



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6.8 ALASKA

Figure 53

MAP OF EARTHQUAKES SINCE 1900 - ALASKA

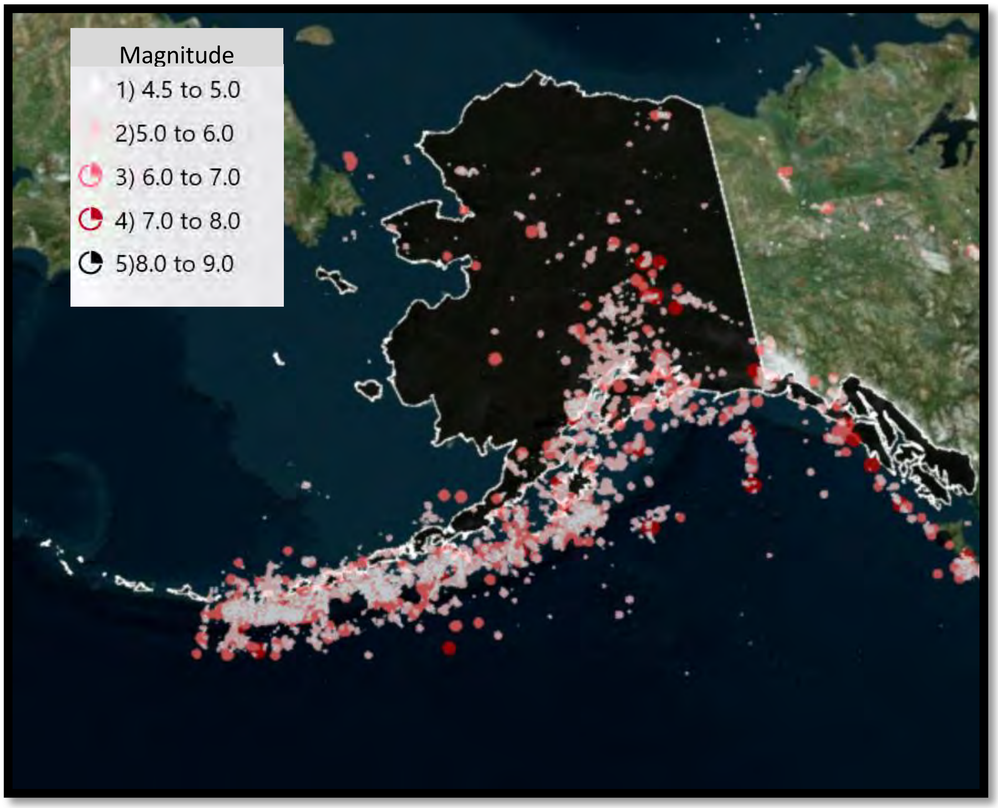

Table 71

EARTHQUAKES SINCE 1900 - ALASKA

Magnitude	Counties in Top 50th Percentile	Counties in Top 70th Percentile	Counties in Top 90th Percentile	Total
1) 4.5 to 5.0	881	881	691	912
2) 5.0 to 6.0	409	409	316	419
3) 6.0 to 7.0	76	76	59	79
4) 7.0 to 8.0	12	12	10	12
5) 8.0 to 9.0	-	-	-	-
6) 9.0 and above	-	-	-	-

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Table 72

TOP 10 EARTHQUAKES IN PAST 100 YEARS: ALASKA

Rank	Date	Magnitude	Location
1	2002-11-03	7.9	75 km E of Cantwell, Alaska
2	1958-07-10	7.8	22 km W of Elfin Cove, Alaska
3	1917-05-31	7.4	54 km SE of Sand Point, Alaska
4	1906-12-23	7.3	19 km ESE of Akhiok, Alaska
5	1904-08-27	7.3	21 km S of Ester, Alaska
6	1912-07-07	7.3	46 km ESE of Denali Park, Alaska
7	1937-07-22	7.1	Central Alaska
8	2018-11-30	7.1	1 km SE of Point MacKenzie, Alaska
9	2016-01-24	7.1	47 km ESE of Pedro Bay, Alaska
10	1912-11-07	7.1	4 km ENE of Karluk, Alaska

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Alaska – Risk Statistics

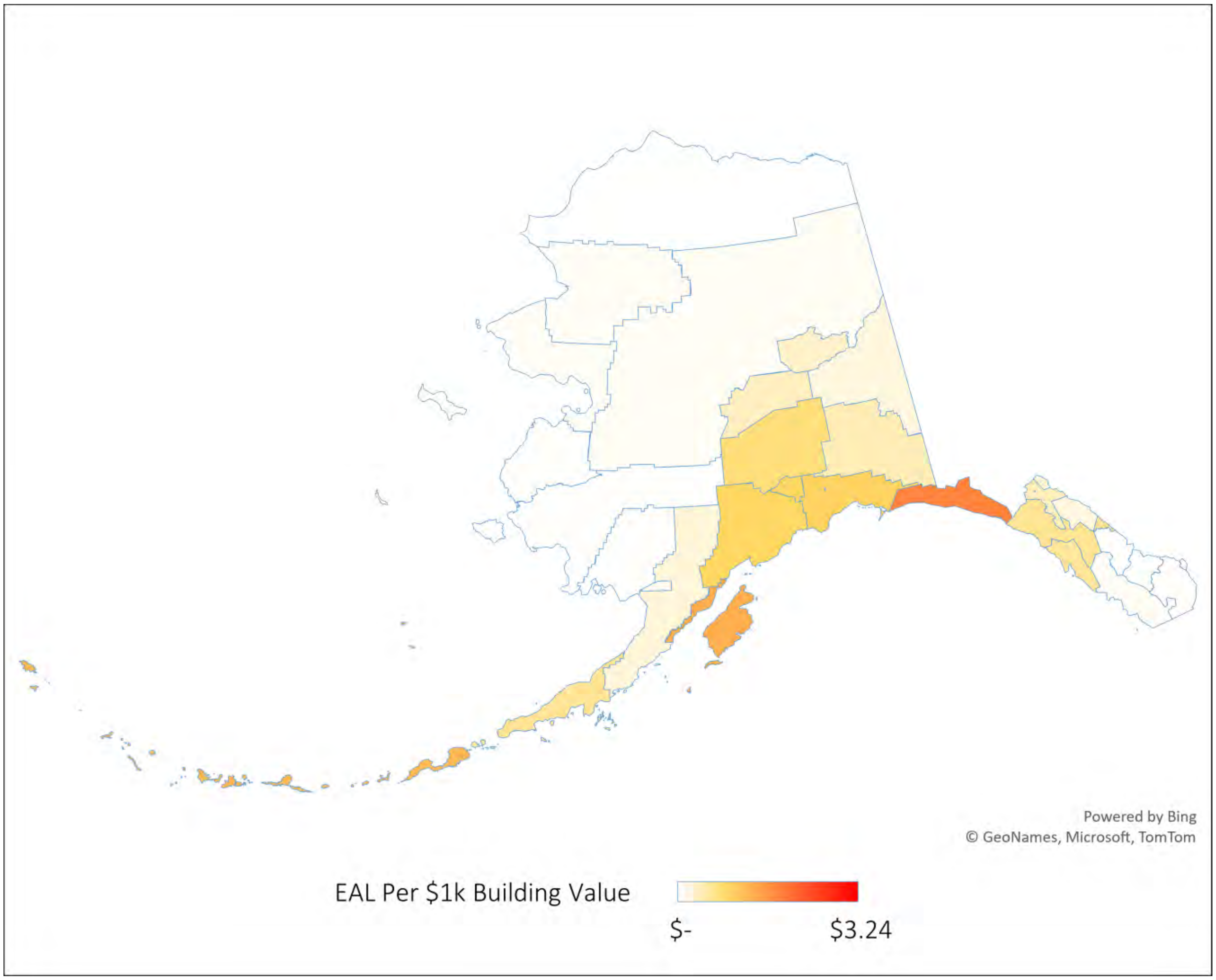
Table 73

ALASKA EARTHQUAKE RISK BY AFFECTED COUNTY PERCENTILE GROUPS

Share of State	Building Stock		Expected Annual Losses		Risk Metrics	
Affected Counties	Building Value ($ Billions)	% of Value	Earthquake ($ Millions)	Tsunami ($ Millions)	EAL Per $1k Building Val	Economic Losses Per $1k Income
Alaska Total	179	100%	121	0.52	$0.68	$4.77
> 50th %-ile Counties	174	97%	121	0.52	$0.70	$4.90
> 70th %-ile Counties	167	93%	121	0.52	$0.72	$5.05
> 90th %-ile Counties	125	70%	111	0.50	$0.89	$6.23
			National Average		**$0.24**	**$1.50**

Figure 54

ALASKA EXPECTED ANNUAL LOSSES BY COUNTY



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Alaska – Vulnerability Statistics

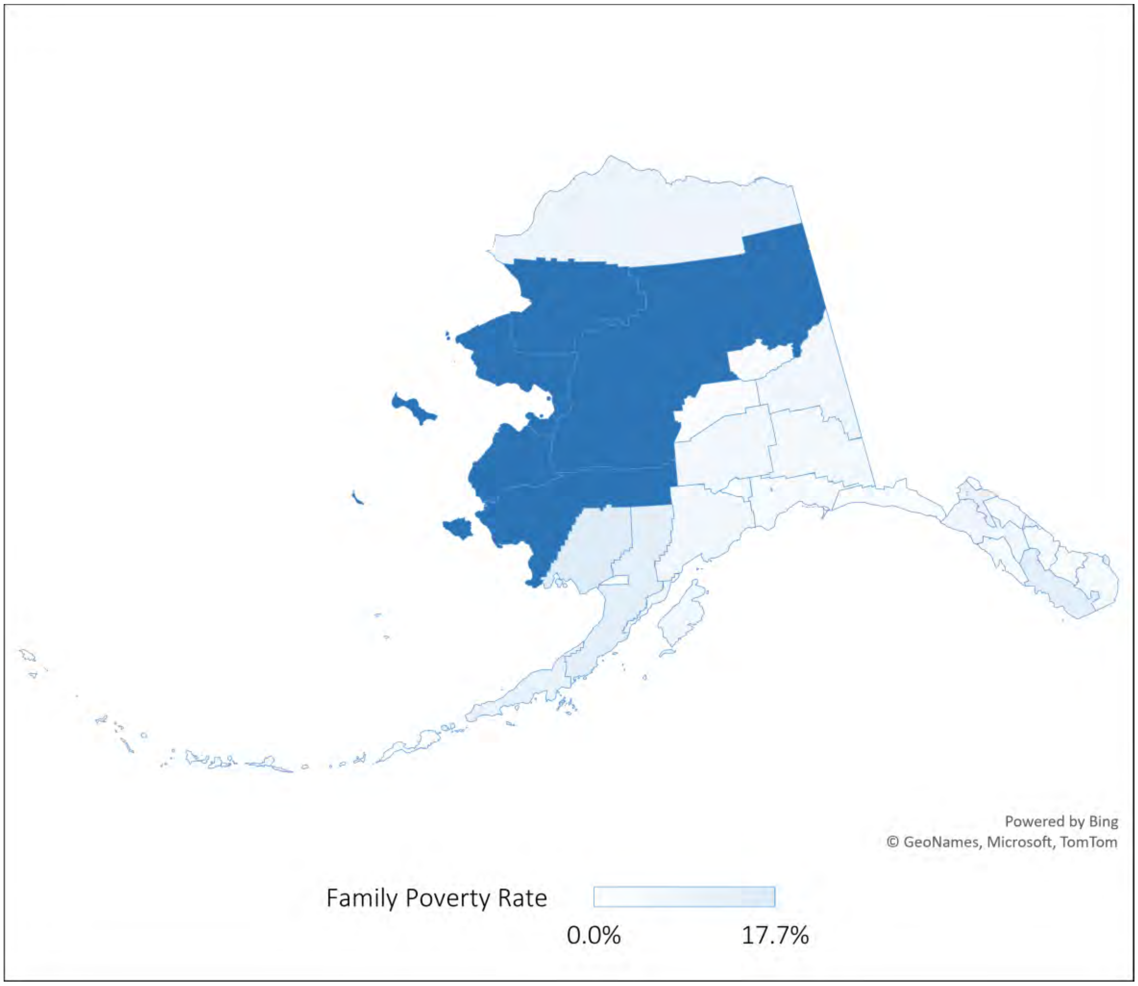
Table 74

ALASKA VULNERABILITY STATISTICS BY AFFECTED COUNTY PERCENTILE GROUPS

Affected Counties	Family Poverty Rate	% Population over 65	Social Vulnerability Score	Community Resilience Score
Alaska Total	6.8%	14%	58	39
> 50th %ile Counties	6.4%	15%	56	39
> 70th %-ile Counties	6.1%	15%	55	39
> 90th %-ile Counties	6.1%	15%	55	36
National Average	8.8%	18%	58	57

Figure 55

ALASKA FAMILY POVERTY RATE BY COUNTY

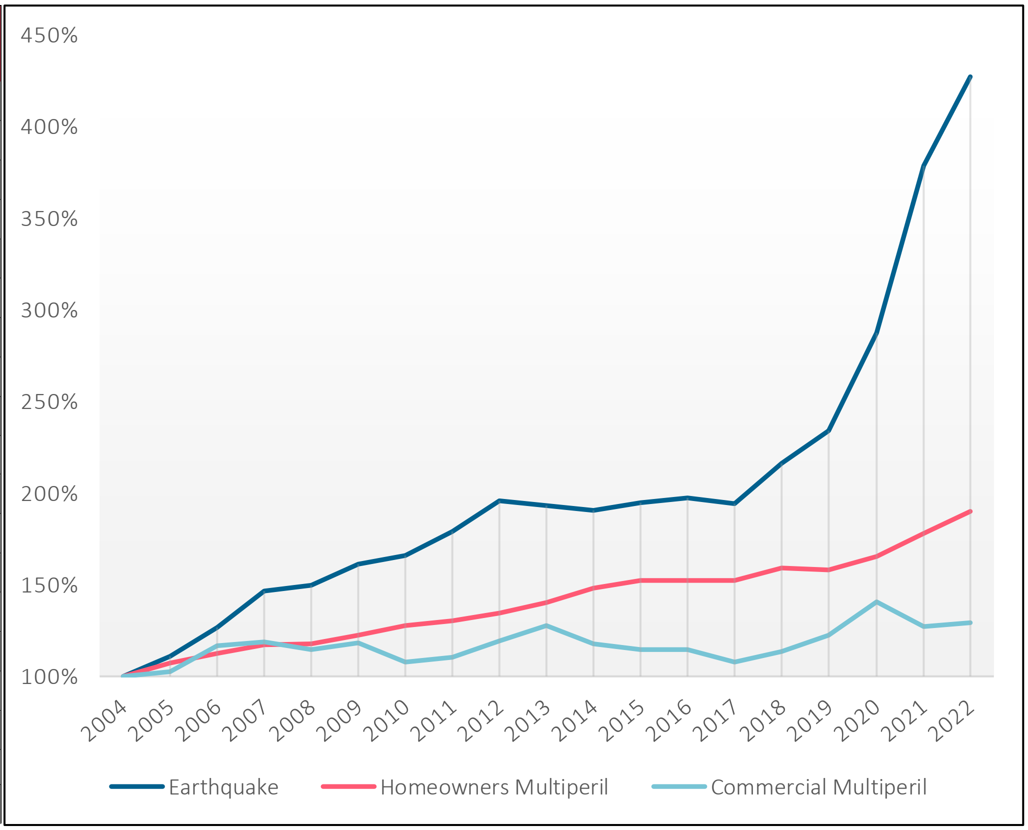


Alaska – Insurance Statistics
Table 75
TOP 10 ALASKA EARTHQUAKE INSURERS BY WRITTEN PREMIUM FOR 2022

Rank	Insurer	Written Premium	Market Share	Active License
1	Factory Mutual Insurance Company	$10,639	19%	X
2	State Farm Fire and Casualty Company	$8,951	16%	X
3	Affiliated FM Insurance Company	$4,950	9%	X
4	Swiss Re Corporate Solutions Elite Insurance Corp	$4,020	7%	X
5	United Services Automobile Association	$3,816	7%	X
6	AXIS Surplus Insurance Company	$2,005	4%	
7	Everest Indemnity Insurance Company	$1,776	3%	
8	Insurance Company of the West	$1,772	3%	X
9	Westchester Surplus Lines Insurance Company	$1,721	3%	
10	USAA Casualty Insurance Company	$1,681	3%	X
	Industry Total	$55,277		

Figure 56
ALASKA EARTHQUAKE WRITTEN PREMIUM AND GROWTH SINCE 2004 COMPARED TO OTHER PROPERTY LINES

Year	Written Premium
2004	12,941
2005	14,327
2006	16,396
2007	18,994
2008	19,398
2009	20,840
2010	21,491
2011	23,180
2012	25,328
2013	24,973
2014	24,676
2015	25,182
2016	25,554
2017	25,121
2018	27,964
2019	30,264
2020	37,166
2021	48,988
2022	55,277



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6.9 HAWAII

Figure 57

MAP OF EARTHQUAKES SINCE 1900 - HAWAII

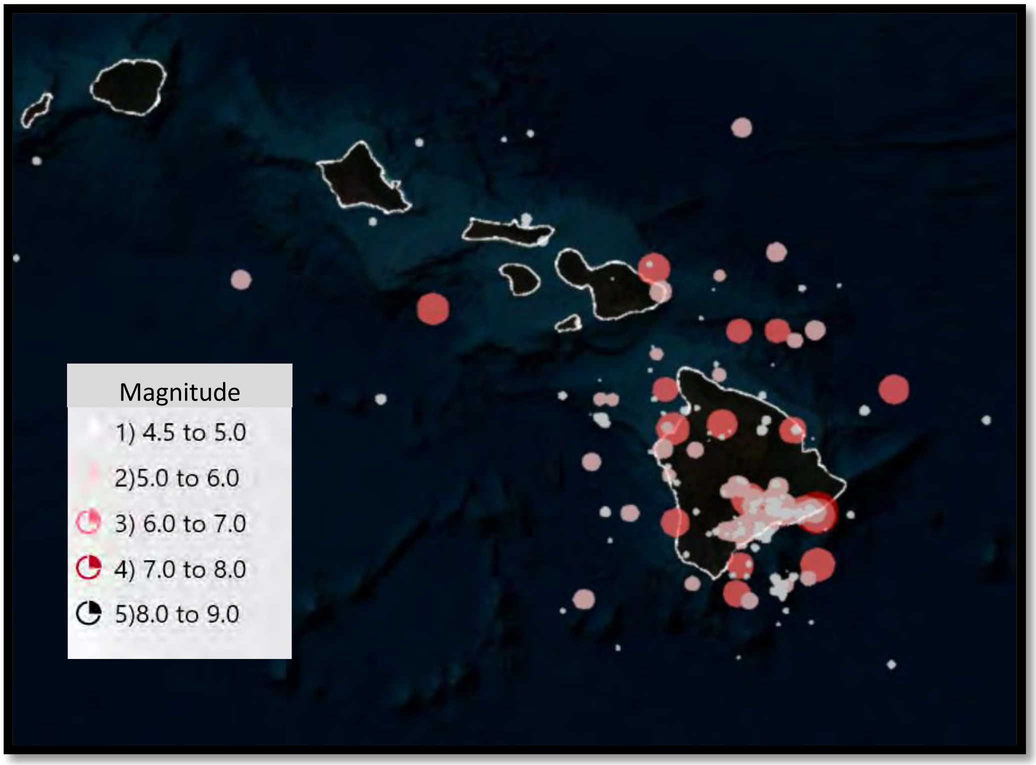

Table 76

EARTHQUAKES SINCE 1900 - HAWAII

Magnitude	Counties in Top 50th Percentile	Counties in Top 70th Percentile	Counties in Top 90th Percentile	Total
1) 4.5 to 5.0	108	108	107	108
2) 5.0 to 6.0	96	96	96	96
3) 6.0 to 7.0	10	10	10	10
4) 7.0 to 8.0	1	1	1	1
5) 8.0 to 9.0	-	-	-	-
6) 9.0 and above	-	-	-	-

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Table 77
TOP 10 EARTHQUAKES IN PAST 100 YEARS: HAWAII

Rank	Date	Magnitude	Location
1	1975-11-29	7.7	17 km SSW of Leilani Estates, Hawaii
2	2018-05-04	6.9	18 km SSW of Leilani Estates, Hawaii
3	1983-11-16	6.7	22 km W of Volcano, Hawaii
4	2006-10-15	6.7	14 km SW of Puako, Hawaii
5	1929-10-06	6.4	14 km SSE of Waimea, Hawaii
6	1951-08-21	6.3	20 km SSW of Honaunau-Napoopoo, Hawaii
7	1989-06-26	6.2	13 km SSE of Fern Forest, Hawaii
8	1973-04-26	6.2	3 km WSW of Honomu, Hawaii
9	1918-11-02	6.2	8 km SW of Volcano, Hawaii
10	1962-06-28	6.2	21 km N of Pahala, Hawaii

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Hawaii – Risk Statistics

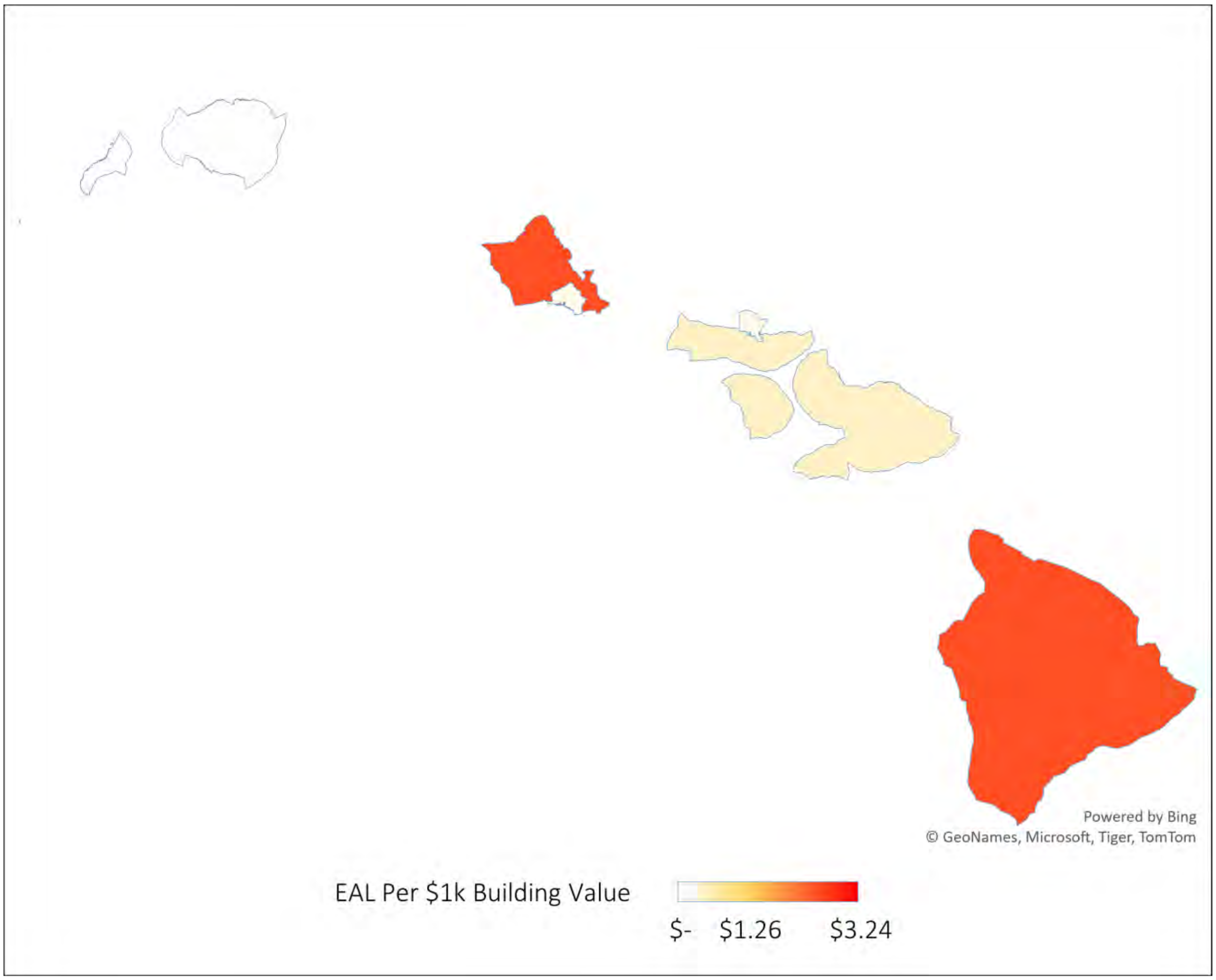
Table 78

HAWAII EARTHQUAKE RISK BY AFFECTED COUNTY PERCENTILE GROUPS

Share of State	Building Stock		Expected Annual Losses		Risk Metrics	
Affected Counties	Building Value ($ Billions)	% of Value	Earthquake ($ Millions)	Tsunami ($ Millions)	EAL Per $1k Building Val	Economic Losses Per $1k Income
Hawaii Total	228	100%	127	1.92	228	100%
> 50th %-ile Counties	213	94%	127	1.73	213	94%
> 70th %-ile Counties	213	94%	127	1.73	213	94%
> 90th %-ile Counties	66	29%	103	0.58	66	29%
			National Average		$0.24	$1.50

Figure 58

HAWAII EXPECTED ANNUAL LOSSES BY COUNTY



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Hawaii – Vulnerability Statistics

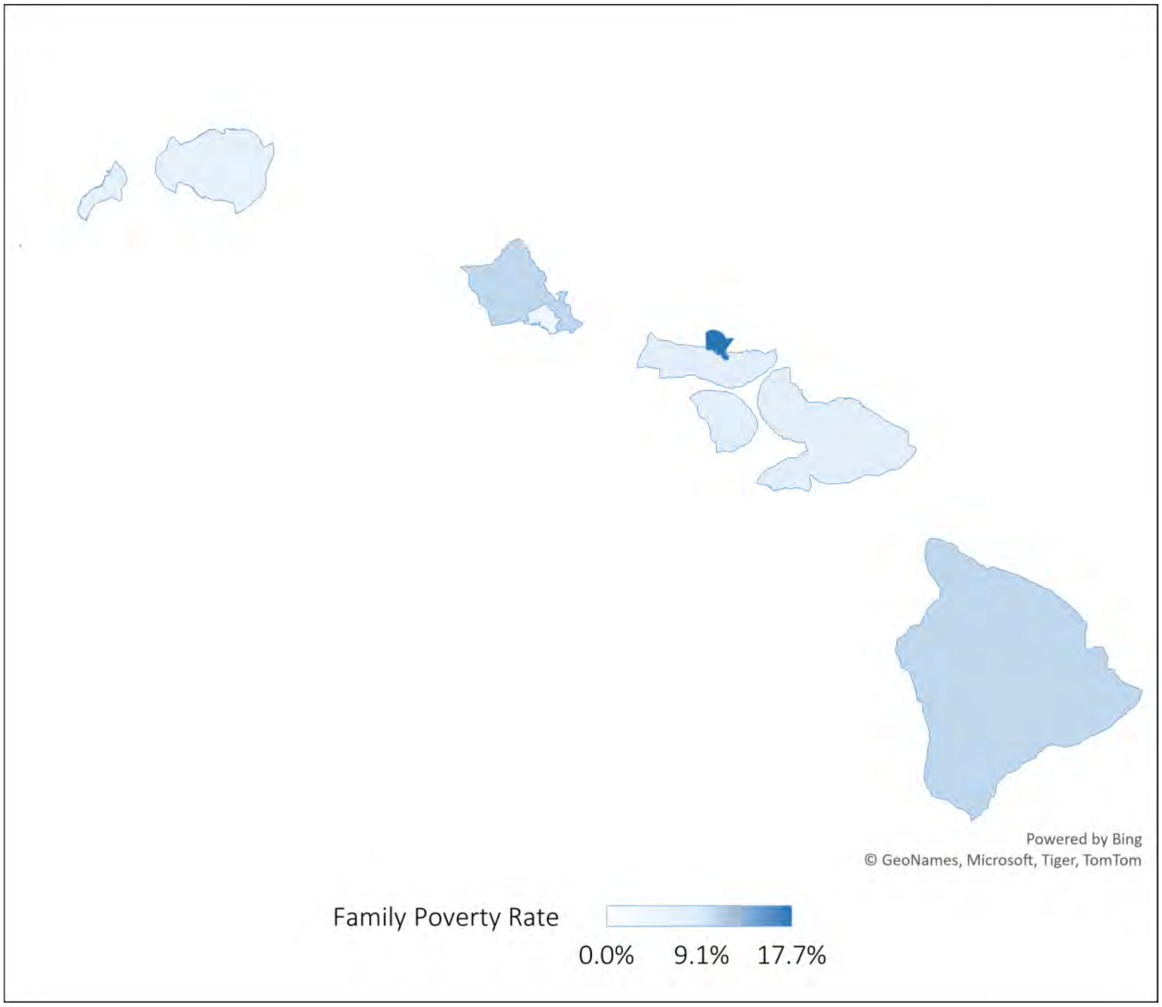
Table 79

HAWAII VULNERABILITY STATISTICS BY AFFECTED COUNTY PERCENTILE GROUPS

Affected Counties	Family Poverty Rate	% Population over 65	Social Vulnerability Score	Community Resilience Score
Hawaii Total	6.4%	20%	53	73
> 50th %-ile Counties	6.4%	20%	54	73
> 70th %-ile Counties	6.4%	20%	54	73
> 90th %-ile Counties	9.3%	22%	56	72
National Average	8.8%	18%	58	57

Figure 59

HAWAII FAMILY POVERTY RATE BY COUNTY



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Hawaii – Insurance Statistics

Table 80

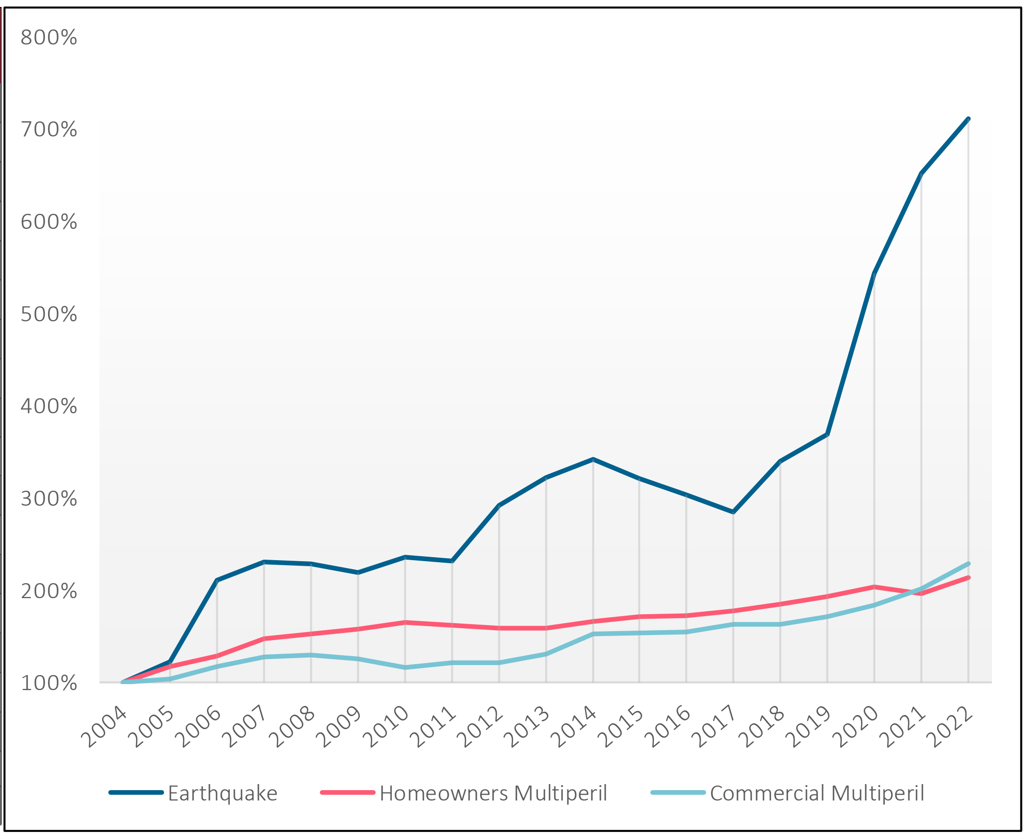
TOP 10 HAWAII EARTHQUAKE INSURERS BY WRITTEN PREMIUM FOR 2022

Rank	Insurer	Written Premium	Market Share	Active License
1	Factory Mutual Insurance Company	$6,518	25%	X
2	Swiss Re Corporate Solutions Elite	$1,550	6%	X
3	Zurich American Insurance Company	$1,409	5%	X
4	Westchester Surplus Lines Insurance Company	$1,198	5%	
5	Endurance American Specialty Insurance Company	$1,033	4%	
6	Centauri Specialty Insurance Company	$1,031	4%	X
7	Evanston Insurance Company	$878	3%	
8	Landmark American Insurance Company	$809	3%	
9	Commerce and Industry Insurance Company	$799	3%	X
10	Arch Specialty Insurance Company	$711	3%	
	Industry Total	$25,630		

Figure 60

HAWAII EARTHQUAKE WRITTEN PREMIUM AND GROWTH SINCE 2004 COMPARED TO OTHER PROPERTY LINES

Year	Written Premium
2004	3,604
2005	4,410
2006	7,583
2007	8,307
2008	8,231
2009	7,878
2010	8,494
2011	8,344
2012	10,513
2013	11,602
2014	12,303
2015	11,557
2016	10,924
2017	10,260
2018	12,257
2019	13,296
2020	19,580
2021	23,509
2022	25,630



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Project Oversight Group members:

C. Ian Genno, FSA, CERA, FCIA

Himchan Jeong, FSA

Hoang Long Nguyen

Jianxi Su, FSA

Emiliano A. Valdez, FSA

At the Society of Actuaries Research Institute

Rob Montgomery, ASA, MAAA, FLMI

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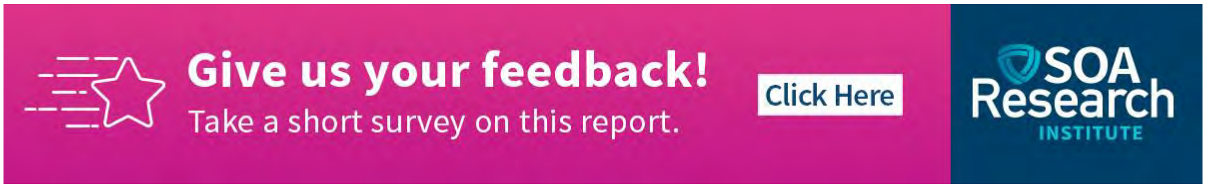
Feedback



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8770 W Bryn Mawr Ave, Suite 1000
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