Workers' Compensation Risk Assessment California Earthquake

Report Prepared For:

Workers' Compensation Insurance Rating Bureau

December 14, 2017

RMS®

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Executive Summary

RMS conducted a probabilistic earthquake analysis for the Workers' Compensation Insurance Rating Bureau (WCIRB) to provide insight into the types of earthquake events that could impact California and at what frequency. RMS quantified the total workers' compensation losses resulting from earthquake events based on an analysis of exposure data from member companies of the WCIRB. RMS executed a detailed review of the exposure data for quality and completeness as well as quantification of earthquake risk under various time-of-day scenarios.

Below are the key highlights of the analysis. A more detailed review of exposure and analysis results can be found throughout the rest of the report.

Exposure Overview and Assumptions

Given that injuries are dependent on building damage and collapse, modeled results are very sensitive to the underlying exposure data and time of event. Positional accuracy of an exposed location greatly influences the retrieval of geotechnical data (e.g., soil type). Building attributes govern the distribution of structural damage and potential for building collapse. The following is a summary of the data provided and assumptions for analysis:

- The portfolio consisted of 11.4 million full-time equivalent (FTE*) employees with an aggregate payroll of $544 billion across 543,502 distinct locations in California. Data for each location was grouped by occupation class, with a total of 993,123 records in the dataset.
- RMS was able to achieve a high level of positional accuracy (street address or better) for 98% of the exposure.
- Building attributes, such as number of stories or construction classification, were not available. RMS was able to supplement this data by identifying the number of stories and construction classification for locations that geocoded to a building centroid. The remaining locations utilize the RMS U.S. Building Inventory Database, which is a representation of the current regional building stock mix in the U.S., to infer the likely building inventory mix based on building occupancy.
- While geographic location of exposure is essential to assess risk, the portion of employees that are exposed to any particular event is another important consideration since employees are only insured while engaged in work-related activities. The model considers a number of data elements to most accurately capture the exposure, including shift data, if available. Otherwise, RMS utilizes an average industry distribution by occupation class to determine the FTE exposed at the time of an event.

*FTE: the equivalent number of employees who work 40 hours/week.

- Earthquakes are random events and the resulting casualties are likely to vary significantly depending on when the event occurs, hence RMS modeled the exposure under two time-of-day scenarios, as described below:

- Temporal Exposure Adjustment Scenario: This analysis applies weighted average to distribute exposure throughout the day and week based on the occupation type.
- Peak (specific time of day) Exposure Adjustment Scenario: This analysis estimates the exposure at a specific time of day and day of the week and applies this estimate to determine the employees at work when an event occurs. This is based on occupation type. For this analysis, we used 11 a.m. on weekdays as our time-of-day scenario as it represents peak occupancy levels for most occupations.

RMS estimates the average cost expected (medical and indemnity) given a particular injury state on a U.S. state-level basis using a simulation approach that accounts for legal, regulatory, demographic, and medical treatment information. For the calculation of indemnity death benefits, RMS caps the maximum benefit to $320,000, which is the maximum benefit for those with three or more dependents. Per WCIRB's request, RMS has revised the death benefit to assume a maximum benefit of $290,000, which is the maximum benefit for those with two dependents. On re-running the simulation with the updated input of $290,000 maximum on cases with dependents, the overall state-level death benefit is reduced from $282,000 to $274,000.

Table 1 provides the average cost severities in the state of California using the above modified simulation. All other values in the table use the 2016 RMS Default Cost Severity estimates.

Table 1: Workers' compensation cost severities in California

Cost component	Medical only	Temporary total	Permanent partial-minor	Permanent partial-major	Permanent total	Fatal
Medical	$1,440	$10,300	$73,000	$365,000	$2,000,000	$120,000
Indemnity	$0	$73,000	$47,200	$194,000	$1,658,000	$274,000
Total	**$1,440**	**$17,600**	**$120,200**	**$559,000**	**$3,658,000**	**$394,000**

Loss Modeling

The results of this analysis, accounting for the temporal work patterns of different occupations, indicate the following key metrics:

- 1-in-100-year loss of $300 million
- 1-in-250-year loss of $1.4 billion
- The average loss per year is $29 million, with an average loss rate per FTE of $2.52 and average loss rate per $100 payroll of $0.005

Due to the rare occurrence, high severity, and inherent uncertainty in earthquake casualty events, the tail risk (i.e., long return period loss) is high. The 1-in-500-year loss is at least $3.5 billion; the 1-in-1,000-year loss is at least $6.4 billion.

Although rare, permanent total injuries account for a disproportionate amount of loss, accounting for 35% of the expected loss.

Los Angeles County is expected to generate the highest loss, with an average loss per year of $6.8 million, because its contribution to the total FTE is the highest at 25%. On a payroll-adjusted basis (per $100), San Benito County, a low-population area where the Hayward and San Andreas Faults intersect, ranks the highest with an average loss rate per $100 payroll of $0.042.

This modeling was conducted using Version 17 of the RMS U.S. Earthquake Casualty Model, released in April 2017. This model incorporates significant advances in the application of earthquake science and engineering. In particular, Version 17.0 includes seismic hazard data from the 2014 U.S. Geological Survey National Seismic Hazard Mapping Project report, which includes the Uniform California Earthquake Rupture Forecast, Version 3 (UCERF3), model, providing the most up-to-date view of earthquake risk in the U.S. A more detailed description of the model methodology used to generate these results can be found below in the "U.S. Earthquake Casualty Model Methodology" section.

Risk Assessment

Exposure Summary

Exposure Summary

The WCIRB provided a dataset containing 993,123 records in the state of California. The dataset consisted of geographical coordinate information and street-level address information by employer for each member company. Exposure is represented by the aggregate payroll and associated FTE by occupation class.

For purposes of analysis, RMS utilized the FTE and street-level address information for each location and occupation type. The street-level address information was used for geocoding purposes, resulting in 98% of exposure corresponding to a high-resolution geocode match (street level or better). The geocoding process pinpoints the locations so that it can be used with geospatial data (such as soil type) to estimate hazard. Table 2 summarizes the WCIRB portfolio by geocode resolution.

Table 2: Total FTE and total payroll by geocode resolution

Geocode resolution	Number of records	Total FTE*	Total payroll (in millions)	% of total FTE	% of total payroll	Description of resolution
Building	30,386	630,290	$37,498	5.6%	6.9%	Geocodes to the exact center of the building footprint.
Parcel	713,817	8,210,299	$390,324	72.3%	71.8%	Geocodes to the exact center of the parcel boundaries for street address match.
Street	234,057	2,328,739	$107,157	20.5%	19.7%	Geocoder achieves a fine level of positional accuracy by interpolating the location of the property along a street segment.
Street name	4,108	59,156	$2,645	0.5%	0.5%	Geocoder achieves a level of positional accuracy based on the centroid along a set of street segments representing the street and an enclosing geography, such as the postal code.
Postal code	10,755	127,369	$5,966	1.1%	1.1%	Geocoder places the location on the centroid of the postal code (e.g., U.S. zip code) in which it falls. Postal-code centroids are exposure and population weighted to provide a better representation of exposure. Population-weighted centroids and geographic centroids are not usually the same place.
Total	**993,123**	**11,355,852**	**$543,586**	**100%**	**100%**	

* The FTE has been rounded to 0 decimal places for the purpose of presentation only. The model captures the fractional employees.

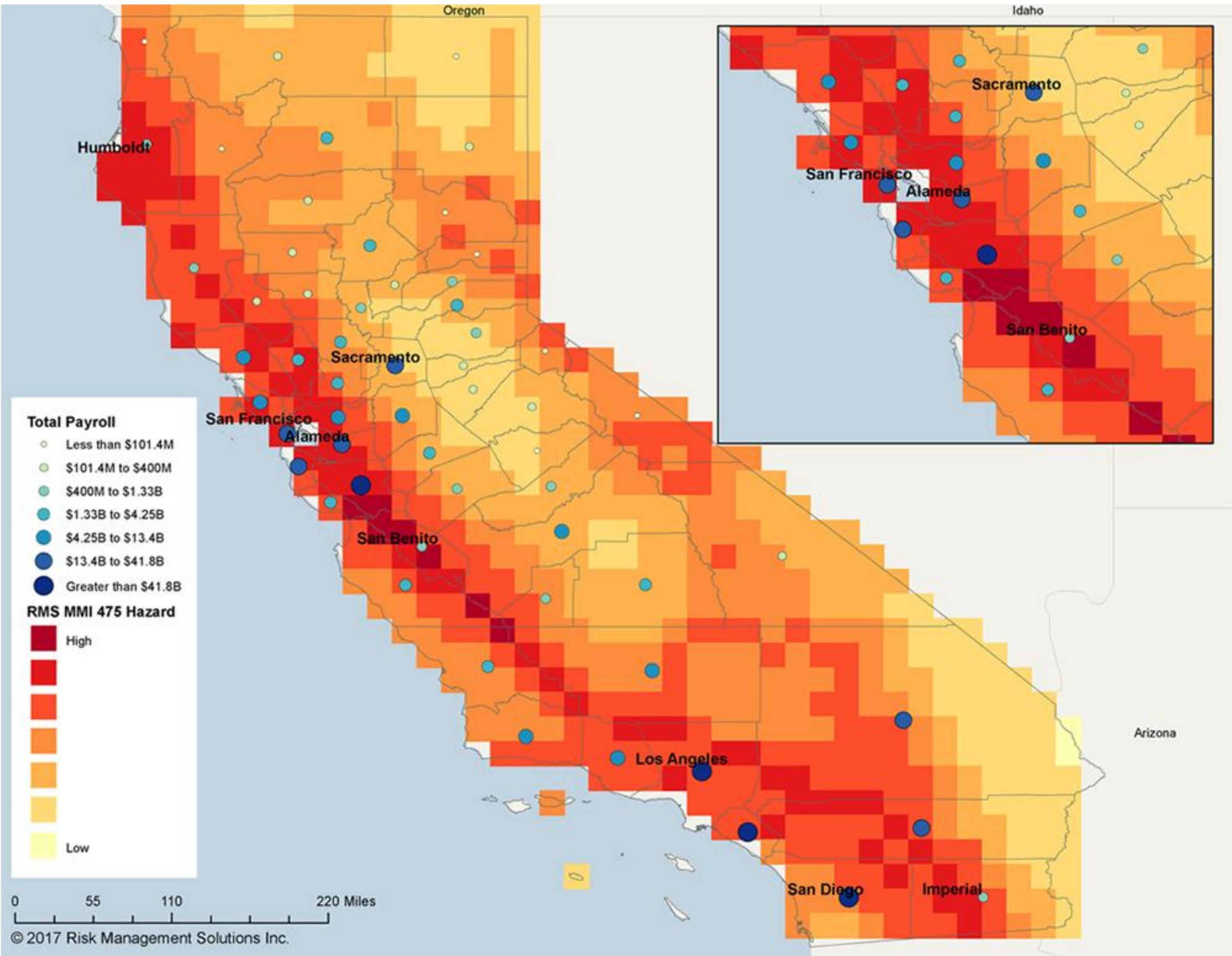
Note: Employees of temporary staffing firms are allocated to their estimated places of employment.

Table 3 summarizes the top 10 counties ranked by FTE. Los Angeles, Santa Clara, and Orange County have the highest concentrations of FTE and payroll, accounting for almost 50% of the total. Figures 1 and 2 show the hazard for the 475-year return period compared to the WCIRB portfolio.

Table 3: Top 10 counties in the state of California ranked by total FTE

County	Total FTE	Total payroll (in millions)	% of total FTE	% of total payroll
Los Angeles County	2,806,566	$130,765	25%	24%
Santa Clara County	1,254,441	$75,403	11%	14%
Orange County	1,172,837	$55,473	10%	10%
San Diego County	1,013,942	$47,116	9%	9%
San Francisco County	602,619	$36,964	5%	7%
Alameda County	559,161	$28,481	5%	5%
San Mateo County	394,170	$23,634	3%	4%
San Bernardino County	397,432	$16,041	3%	3%
Riverside County	364,566	$14,426	3%	3%
All Others	2,790,057	$115,284	25%	21%
Total	**11,355,792**	**$543,586**	**100%**	**100%**

Figure 1: Payroll exposure map

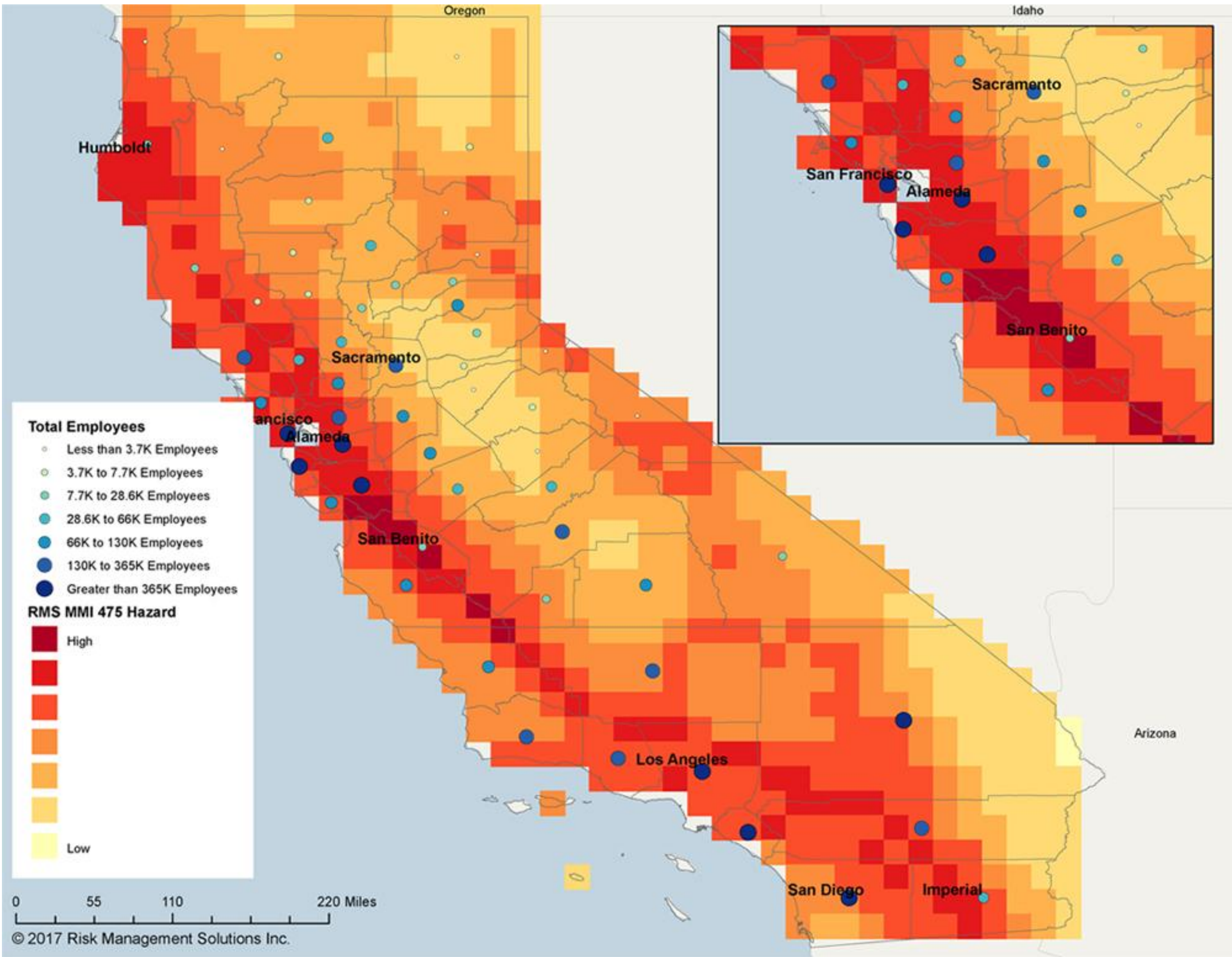


The portfolio has a total payroll of $544 billion, with the top three counties making up 48% of the total. Those counties are: Los Angeles County (24%), Santa Clara County (14%), and Orange County (10%).

As can be seen in the figure, the highest concentration of payroll coincides with the highest hazard regions. These high hazard regions are caused by the Cascadian Subduction Zone, the intersection of the San Andreas and the Hayward Calaveras Fault lines, the Imperial Fault, and the Brawley Seismic Zone.

The map illustrates the MMI 475-year return period hazard.

Figure 2: Employee exposure map



Of the portfolio's 11.4 million FTE, the top three counties comprise 46% of the total. Those counties are: Los Angeles County (25%), Santa Clara County (11%), and Orange County (10%).

Similar to Figure 1, Figure 2 shows that the highest concentration of employees coincides with the highest hazard regions. These high hazard regions are caused by the Cascadian Subduction Zone, the intersection of the San Andreas and the Hayward Calaveras Fault lines, the Imperial Fault, and the Brawley Seismic Zone.

The map illustrates the MMI 475-year return period hazard.

Exposure by RMS Employee Occupation Classification

WCIRB provided employee occupation in the columns "Class" and "Class Desc" to denote the occupation of each FTE employee in their portfolio. RMS used these descriptions to map to the RMS workers' compensation occupation classification (WCOCC) scheme, as used by our model. Table 4 depicts the occupation classification present in the data with the time-of-day adjustments made to each occupation class.

Table 4: Total FTE and total payroll by RMS occupation classification

RMS workers' compensation occupation classification	Total FTE	Total payroll (in millions)	% of total FTE	% of total payroll	Time-of-day adjustment temporal / 11 a.m.
1 - Office	6,157,080	$362,477	54%	67%	23% / 75%
14 - Medical	348,028	$15,043	3%	3%	26% / 70%
8 - Hotel/Motel	72,403	$2,869	1%	1%	28% / 53%
5 - Retail trade	1,365,352	$46,049	12%	8%	25% / 62%
4 - Wholesale trade	365,066	$12,719	3%	2%	25% / 75%
13 - Construction	348,623	$13,637	3%	3%	23% / 82%
3 - Heavy and other manufacturing	1,356,548	$55,647	12%	10%	26% / 73%
2 - Light manufacturing	633,819	$17,670	6%	3%	26% / 70%
6 - Restaurant	708,933	$17,475	6%	3%	30% / 52%
Total	**11,355,852**	**$543,586**	**100%**	**100%**	

Risk Assessment

Exceedance Probability Analysis

- Overview
- Temporal Exposure Adjustment
- Peak Exposure Adjustment

Exceedance Probability Analysis: Overview

Table 5 illustrates the probability of losses exceeding various thresholds due to multiple events in a given year for each of the time-of-day scenarios: the Temporal Exposure Adjustment Scenario and the Peak Exposure Adjustment Scenario.

RMS analysis suggests that there is a 1.0% probability (corresponding to the 100-year return period) that one or more events will cause at least $300 million in ground-up (total) loss from 4,758 casualties, accounting for temporal work patterns of different occupations. There is a 1% probability of losses exceeding $1.4 billion if an event were to occur during peak exposure.

On a long-term average basis, the WCIRB portfolio is expected to sustain about $29 million in average loss per year, which corresponds to an average loss rate per $100 payroll of $0.005 and an average loss rate per FTE of $2.52. At peak exposure, the WCIRB portfolio is expected to sustain $84 million in average loss per year, which corresponds to an average loss rate per $100 payroll of $0.016 and an average loss rate per FTE of $7.43.

Table 5: Key return period loss comparison

Critical probability	Return period (years)	Temporal Exposure Adjustment Scenario		Peak Exposure Adjustment Scenario (11 a.m.)	
		Ground-up loss (in millions)	Total number of casualties	Ground-up loss (in millions)	Total number of casualties
2.00%	50	$62	1,583	$409	6,691
1.00%	100	$301	4,758	$1,463	16,270
0.40%	250	$1,432	13,365	$5,105	36,387
0.20%	500	$3,407	23,104	$9,862	55,903
0.10%	1,000	$6,489	35,108	$16,125	78,060
0.02%	5,000	$17,292	69,558	$35,082	136,910
Average loss per year*		$29	220	$84	650
Average loss rate per $100 payroll		$0.005		$0.016	
Average loss rate per FTE		$2.52		$7.43	

* Average loss per year represents the loss averaged over all aggregate exceedance probability (AEP) levels

Exceedance Probability Analysis: Temporal Exposure Adjustment

Table 6 illustrates the probability of losses exceeding various thresholds due to multiple events in a given year for the Temporal Exposure Adjustment Scenario.

On a long-term average basis, it is expected that about 10% of total casualties and 24% of ground-up loss will result from fatal injury. The contribution of fatal injury to non-fatal injury increases with the severity of the event.

Figures 3 and 4 provide a graphical representation of this relationship between exceedance probabilities and losses by injury level.

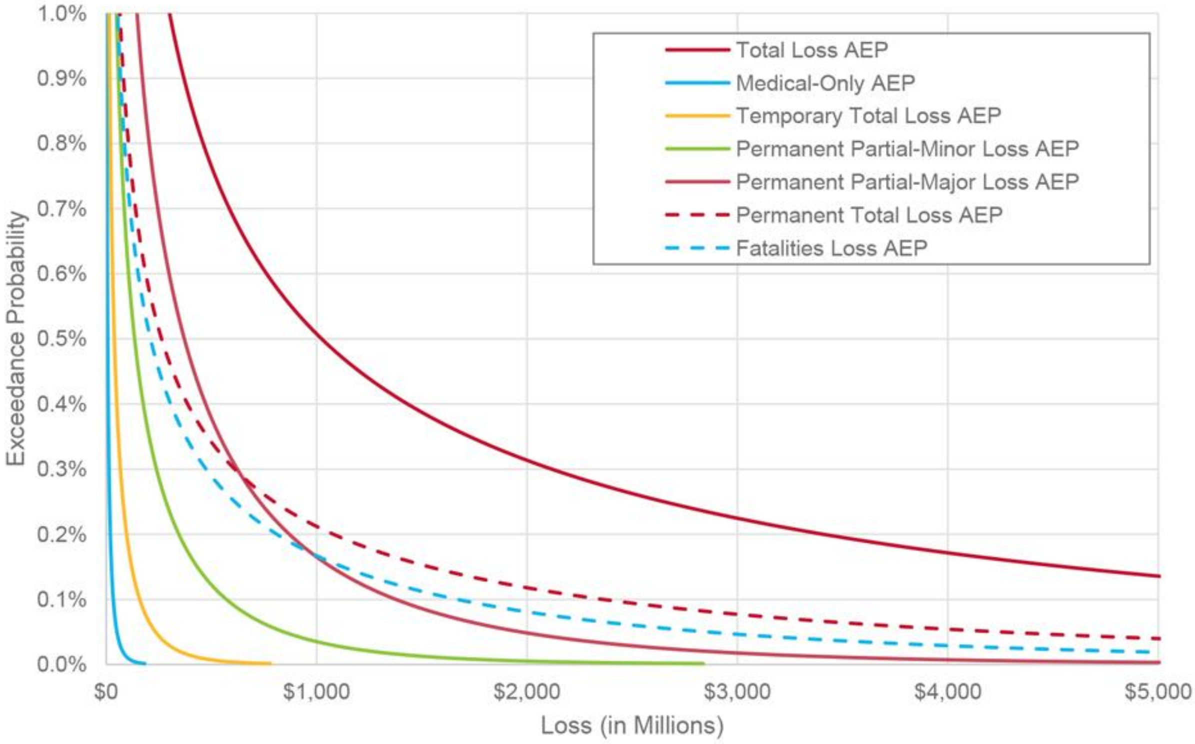
Table 6: Key return period losses for the Temporal Exposure Adjustment Scenario

Critical probability	Return period	Ground-up losses (in millions)	Losses from fatalities (in millions)	Total number of casualties	Total number of fatalities
2.00%	50	$62	$8	1,583	84
1.00%	100	$301	$54	4,758	306
0.40%	250	$1,432	$306	13,365	1,085
0.20%	500	$3,407	$811	23,104	2,102
0.10%	1,000	$6,489	$1,668	35,108	3,427
0.02%	5,000	$17,292	$4,859	69,558	7,382
Average loss per year		**$29**	**$7**	**220**	**18**
Average loss rate per $100 payroll		**$0.005**			
Average loss rate per FTE		**$2.52**			

Exceedance Probability Curve – Ground-Up and Injury-Level Losses

Figure 3 shows the aggregate exceedance probability (AEP) curves for the total ground-up loss and broken out by injury level. At low return periods, losses are driven by the permanent partial-major injury level. At higher return periods, losses are driven by the permanent total and fatal injury levels. The major cause of injury from earthquakes is due to building collapse or heavy damage. In California, buildings engineered to the seismic design codes have lower failure rates and are designed to sustain heavy damage without endangering their occupants. However, a percentage will still fail under extreme loads leading to more severe and costly injuries.

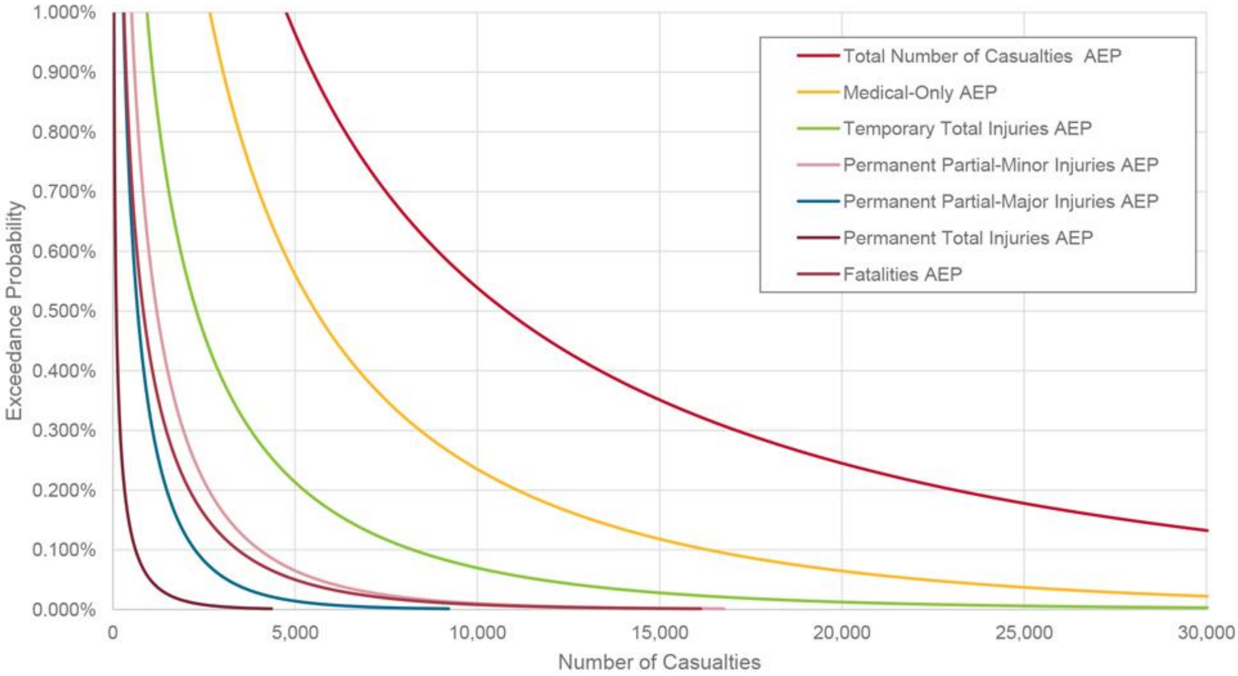
Figure 3: Aggregate exceedance probability loss curves for the Temporal Exposure Adjustment Scenario



Exceedance Probability Curve – Number of Casualties

Figure 4 shows the AEP curves for the total number of casualties and broken out by injury level. While losses are driven by permanent total and fatal injuries, the number of casualties is driven by medical only and temporary total injuries. Based on the WCIRB portfolio, there is an annual probability of 0.4% (235-year return period) that an earthquake could cause 1,000 or more fatalities.

Figure 4: Aggregate exceedance probability casualty curves for the Temporal Exposure Adjustment Scenario



Exceedance Probability Analysis: Peak Exposure Adjustment

Table 7 illustrates the probability of losses exceeding various thresholds due to multiple events in a given year for the Peak Exposure Adjustment Scenario.

On a long-term average basis, it is expected that about 10% of total casualties and 24% of ground-up loss will result from fatal injury. The contribution of fatal injury to non-fatal injury increases with the severity of the event.

Figures 5 and 6 provide a graphical representation of this relationship between exceedance probabilities and losses by injury level.

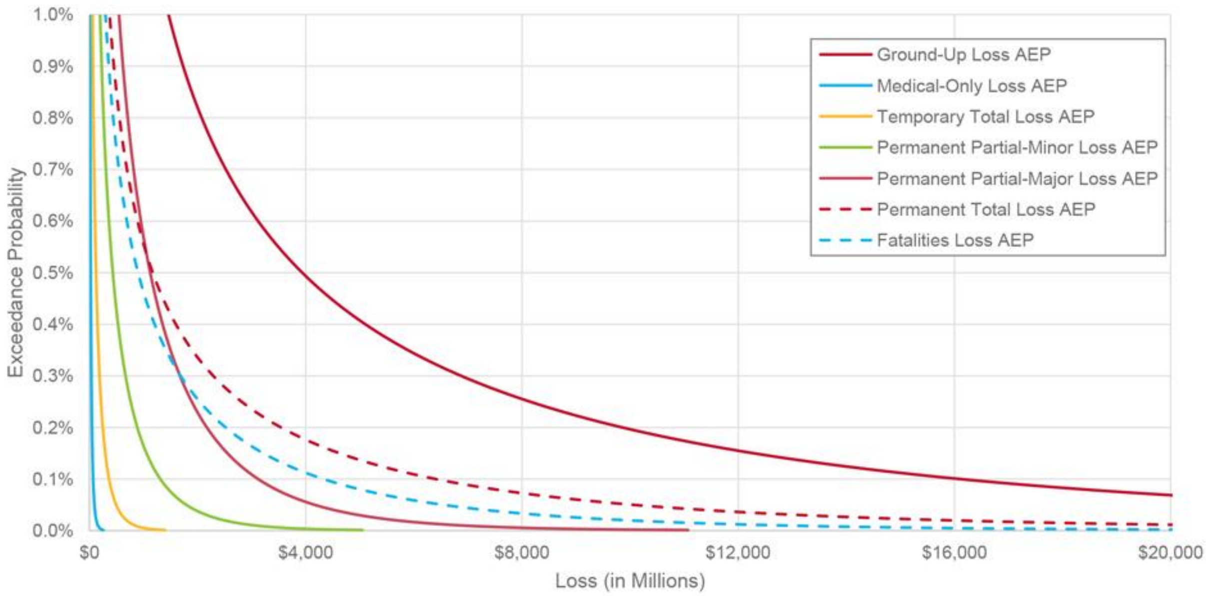
Table 7: Key return period losses for the Peak Exposure Adjustment Scenario

Critical probability	Return period (years)	Ground-up losses (in millions)	Losses from fatalities (in millions)	Total number of casualties	Total number of fatalities
2.00%	50	$409	$72	6,691	404
1.00%	100	$1,463	$297	16,270	1,202
0.40%	250	$5,105	$1,206	36,387	3,255
0.20%	500	$9,862	$2,522	55,903	5,429
0.10%	1,000	$16,125	$4,336	78,060	7,979
0.02%	5,000	$35,082	$10,012	136,910	14,888
Average annual loss		**$84**	**$21**	**650**	**52**
Average loss rate per $100 payroll		**$0.016**			
Average loss rate per FTE		**$7.43**			

Exceedance Probability Curve – Ground-Up and Injury-Level Losses

Figure 5 shows the AEP curves for the total ground-up loss and broken out by injury level. At low return periods, losses are driven by the permanent partial-major injury level. At higher return periods, losses are driven by the permanent total and fatal injury levels. The major cause of injury from earthquakes is due to building collapse or heavy damage. In California, buildings engineered to the seismic design codes have lower failure rates and are designed to sustain heavy damage without endangering their occupants. However, a percentage will still fail under extreme loads leading to more severe and costly injuries.

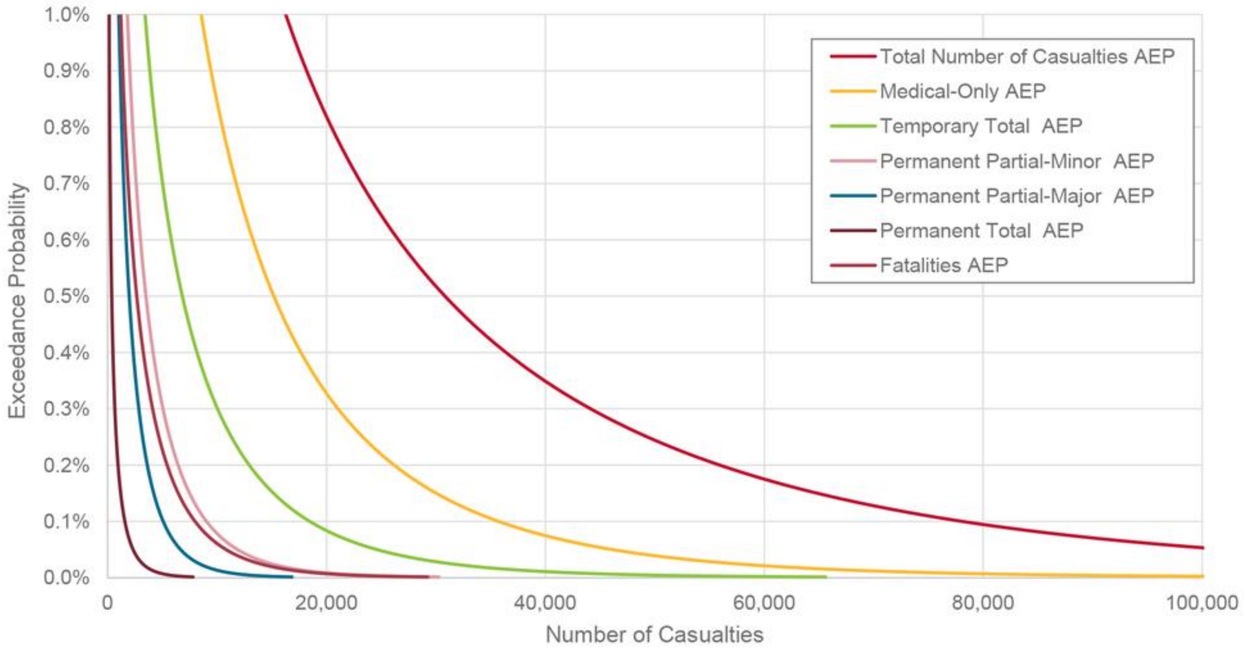
Figure 5: Aggregate exceedance probability casualty curves for the Peak Exposure Adjustment Scenario



Exceedance Probability Curve – Number of Casualties

Figure 6 shows the AEP curves for the total number of casualties and broken out by injury level. While losses are driven by the permanent total and fatal injury levels, the number of casualties is driven by medical only and temporary total injuries. Based on the WCIRB portfolio, there is an annual probability of 1.1% (88-year return period) that an earthquake could cause 1,000 or more fatalities.

Figure 6: Aggregate exceedance probability casualty curves for the Peak Exposure Adjustment Scenario



Risk Assessment

Loss by County

- Temporal Exposure Adjustment
- Peak Exposure Adjustment

Loss by County: Temporal Exposure Adjustment

Table 8 ranks the top five counties by average loss per year, contributing 70% to the overall average loss per year of the portfolio. Los Angeles County contributes 24% to the overall average loss per year but, as we saw in table 3, contains 24% of the total exposure.

Table 8: Top five counties ranked by average loss per year for the Temporal Exposure Adjustment Scenario

County	Total FTE	Total payroll (in millions)	Average loss per year (in millions)	Average loss rate per $100 payroll	Average loss rate per FTE	% of average loss per year
Los Angeles County	2,806,566	$130,765	$6.846	$0.005	$2.44	24%
Santa Clara County	1,254,441	$75,403	$5.424	$0.007	$4.32	19%
Alameda County	559,161	$28,481	$4.228	$0.015	$7.56	15%
San Francisco County	602,619	$36,964	$1.987	$0.005	$3.30	7%
Orange County	1,172,837	$55,473	$1.642	$0.003	$1.40	6%
All Others	4,960,227	$216,503	$8.439	$0.004	$1.70	30%
Total	**11,355,852**	**$543,589**	**$28.568**	**$0.005**	**$2.52**	**100%**

Table 9 ranks the top five counties by average loss rate per $100 payroll. The average loss rate per $100 payroll provides a comparison of the relative risk between counties to identify what geographical regions are driving risk.

Unlike Table 8, the five counties in Table 9 represent only 18% of the overall average loss per year of the portfolio, but they represent the portfolio's riskiest counties. Much of this can be attributed to the fact that these counties lie in high hazard areas. For example, San Benito County, which lies at the intersection of the Hayward Fault and San Andreas Fault, represents less than 1% of the total exposure and 0.6% of the total loss, but its average loss rate per $100 in payroll is nearly eight times greater than the portfolio's overall loss rate.

Table 9: Top five counties ranked by average loss rate per $100 payroll for the Temporal Exposure Adjustment Scenario

County	Total FTE	Total payroll (in millions)	Average loss per year (in millions)	Average loss rate per $100 payroll	Average loss rate per FTE	% of average loss per year
San Benito County	11,327	$441	$0.183	$0.042	$16.16	0.6%
Imperial County	33,859	$1,202	$0.407	$0.034	$12.02	1.4%
Humboldt County	20,612	$761	$0.156	$0.021	$7.58	0.5%
Alameda County	559,161	$28,481	$4.228	$0.015	$7.56	14.8%
Mendocino County	17,022	$601	$0.087	$0.013	$4.74	0.3%
All Others	10,713,871	$512,103	$23.512	$0.005	$2.19	82%
Total	**11,355,852**	**$543,589**	**$28.568**	**$0.005**	**$2.52**	**100%**

Loss by County: Peak Exposure Adjustment

Table 10 ranks the top five counties by average loss per year for the Peak Exposure Adjustment Scenario. The list of the top five counties and their contribution is similar to the ones we saw in table 8 for the Temporal Exposure Adjustment Scenario. This is expected as the time-of-day scenarios are meant to capture the variation in exposure and resulting loss, yet the site-specific hazard is the same. Expected losses for the peak scenario are, on average, about three times that of the temporal scenario.

Table 10: Top five counties ranked by average loss per year for the Peak Exposure Adjustment Scenario

County	Total FTE	Total payroll (in millions)	Average loss per year (in millions)	Average loss rate per $100 payroll	Average loss rate per FTE	% of average loss per year
Los Angeles County	2,806,566	$130,765	$19.954	$0.015	$7.11	24%
Santa Clara County	1,254,441	$75,403	$16.702	$0.022	$13.31	20%
Alameda County	559,161	$28,481	$12.486	$0.044	$22.33	15%
San Francisco County	602,619	$36,964	$6.145	$0.017	$10.20	7%
Orange County	1,172,837	$55,473	$4.792	$0.009	$4.09	6%
All Others	4,960,227	$216,503	$24.322	$0.011	$4.90	29%
Total	**11,355,852**	**$543,589**	**$84.405**	**$0.016**	**$7.43**	**100%**

Similarly, the top five counties ranked by average loss rate per $100 payroll for the peak scenario, as shown in table 11, will be the same as that of the temporal scenario.

Table 11: Top five counties ranked by average loss rate per $100 payroll for the Peak Exposure Adjustment Scenario

County	Total FTE	Total payroll (in millions)	Average loss per year (in millions)	Average loss rate per $100 payroll	Average loss rate per FTE	% of average loss per year
San Benito County	11,327	$441	$0.52	$0.117	$45.65	0.6%
Imperial County	33,859	$1,202	$1.17	$0.097	$34.52	1.4%
Humboldt County	20,612	$761	$0.43	$0.057	$20.98	0.5%
Alameda County	559,161	$28,481	$12.49	$0.044	$22.33	14.8%
Mendocino County	17,022	$601	$0.22	$0.037	$13.05	0.3%
All Others	10,713,871	$512,103	$69.58	$0.000	$6.49	82%
Total	**11,355,852**	**$543,589**	**$84.40**	**$0.016**	**$7.43**	**100%**

Risk Assessment

Historical Scenario Loss Summary

Historical Scenario Loss Summary

In this section, we discuss the impact of losses due to two historical scenarios as if they were to occur today. Details can be found in table 12.

1906 San Francisco Earthquake

On April 18, 1906, at 5:12 a.m. local time, an M7.8 earthquake shook the city of San Francisco and the surrounding region for approximately 45 to 60 seconds. The event ruptured 296 mi (477 km) of the northern section of the San Andreas Fault from north of Shelter Cove in Humboldt County to San Juan Bautista in San Benito County. For the WCIRB portfolio, the total loss, accounting for the temporal work patterns of different occupations, would result in 7,261 injuries and $1,043 million of loss. At peak occupancy, losses could exceed $3,176 million from 22,070 injuries.

1989 Loma Prieta Earthquake

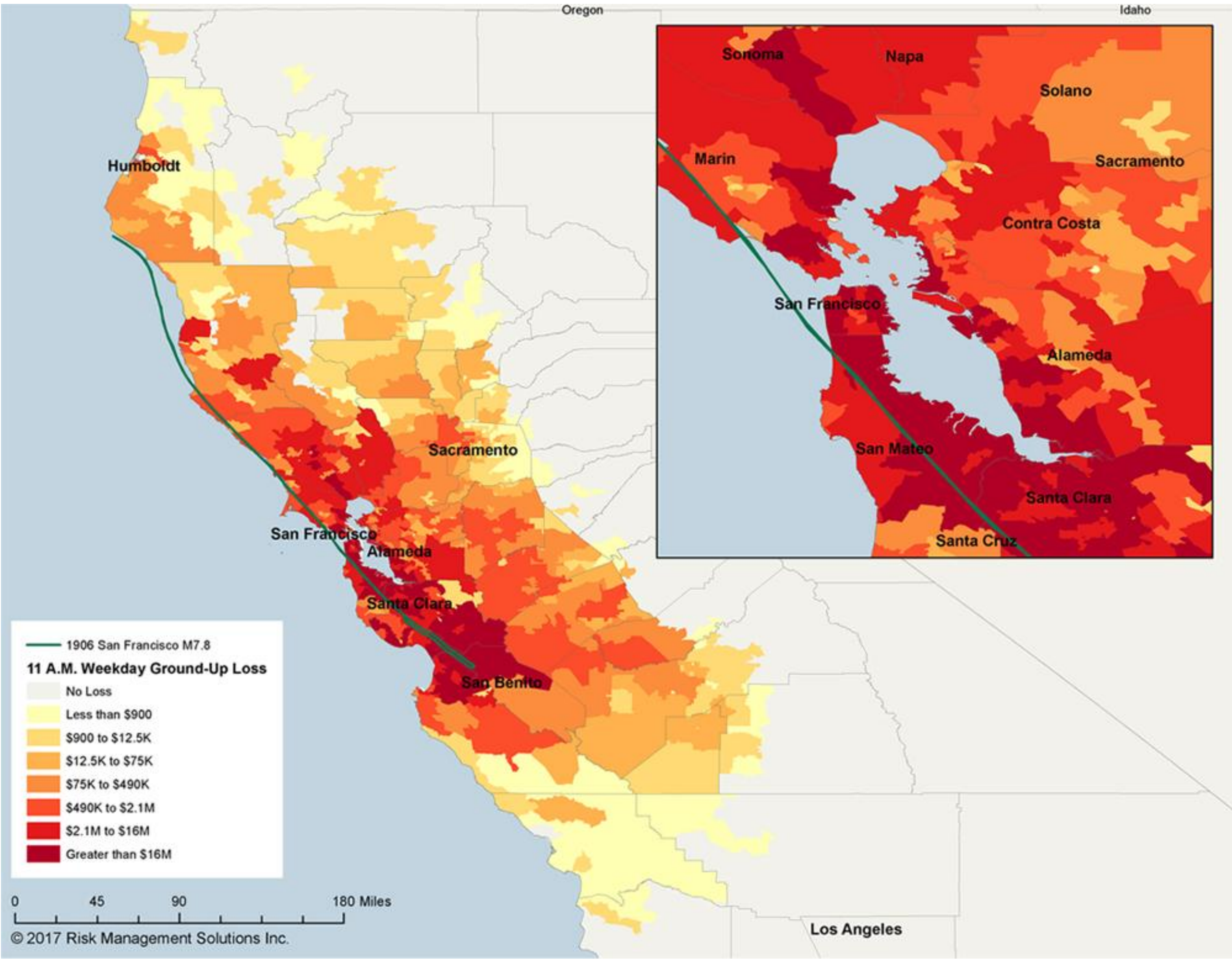
On October 17, 1989, at 5:04 p.m. local time, an M6.9 earthquake occurred in the Santa Cruz Mountains, south of San Francisco. The ground motion was felt across the San Francisco Bay Area. For the WCIRB portfolio, the total loss, accounting for the temporal work patterns of different occupations, would result in 766 injuries and $84 million of loss. At peak occupancy, losses could exceed $250 million from 2,299 injuries.

Table 12: Historical scenario losses for the Temporal and Peak Exposure Adjustment Scenarios

	Temporal Exposure Adjustment Scenario		Peak Exposure Adjustment Scenario	
	CA 1906 San Francisco	CA 1989 Loma Prieta	CA 1906 San Francisco	CA 1989 Loma Prieta
Magnitude	7.8	6.9	7.8	6.9
Total casualties	7,261	766	22,070	2,299
Ground-up loss (in millions)	$1,043	$84	$3,176	$250
Loss of medical only	0.5%	0.7%	0.5%	0.7%
Loss temporary total	2.7%	3.2%	2.7%	3.2%
Loss temporary partial-minor	9.8%	10.6%	9.8%	10.7%
Loss temporary partial-major	26.2%	27.3%	26.2%	27.4%
Loss permanent total injuries	34.7%	34.9%	34.7%	34.8%
Loss fatalities	26.1%	23.4%	26.1%	23.2%

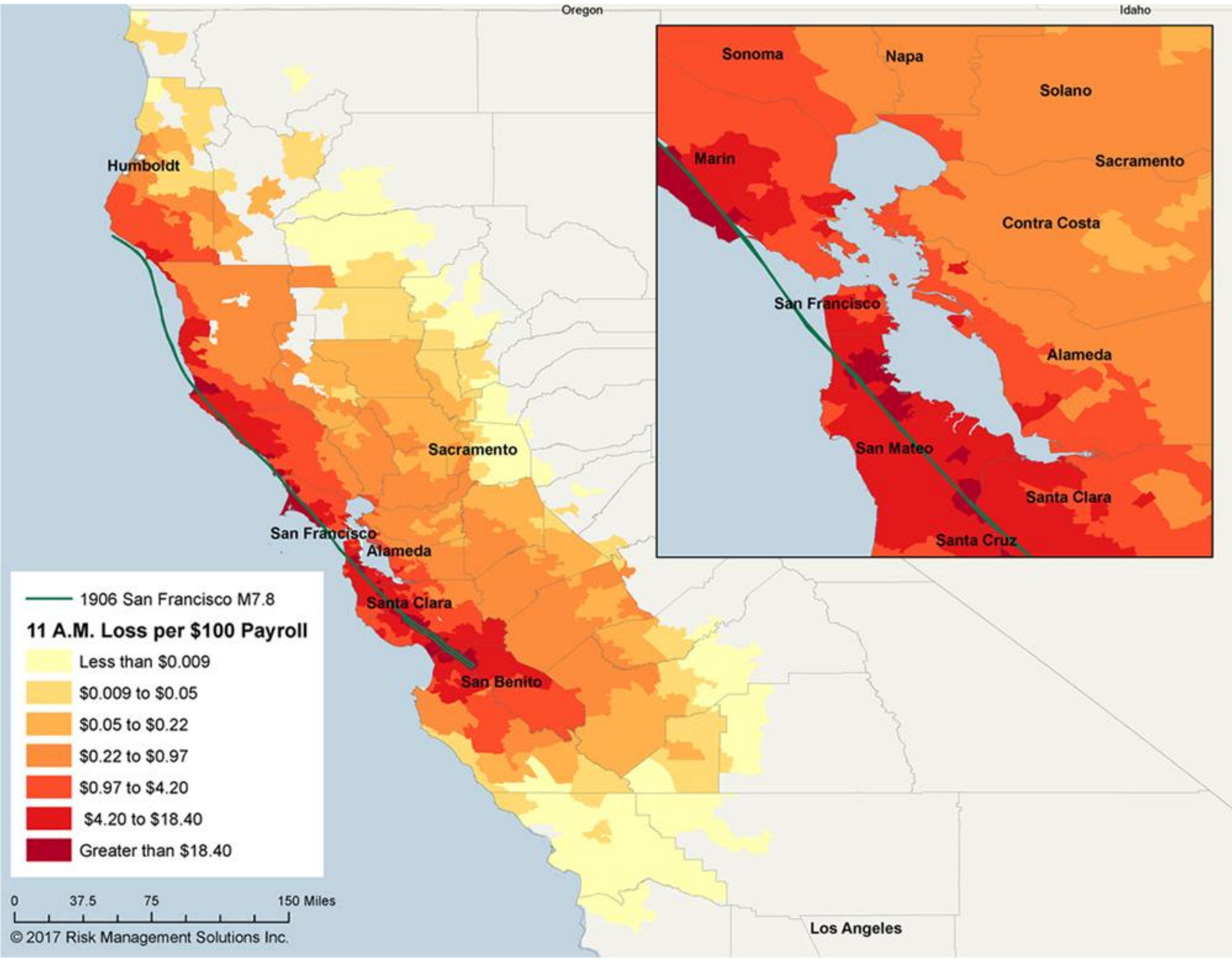
Ground-up loss by postal code is shown in Figure 7 for the 1906 San Francisco Earthquake event for the Peak Exposure Adjustment Scenario.

Figure 7: 1906 San Francisco earthquake – ground-up loss by postal code for the Peak Exposure Adjustment Scenario



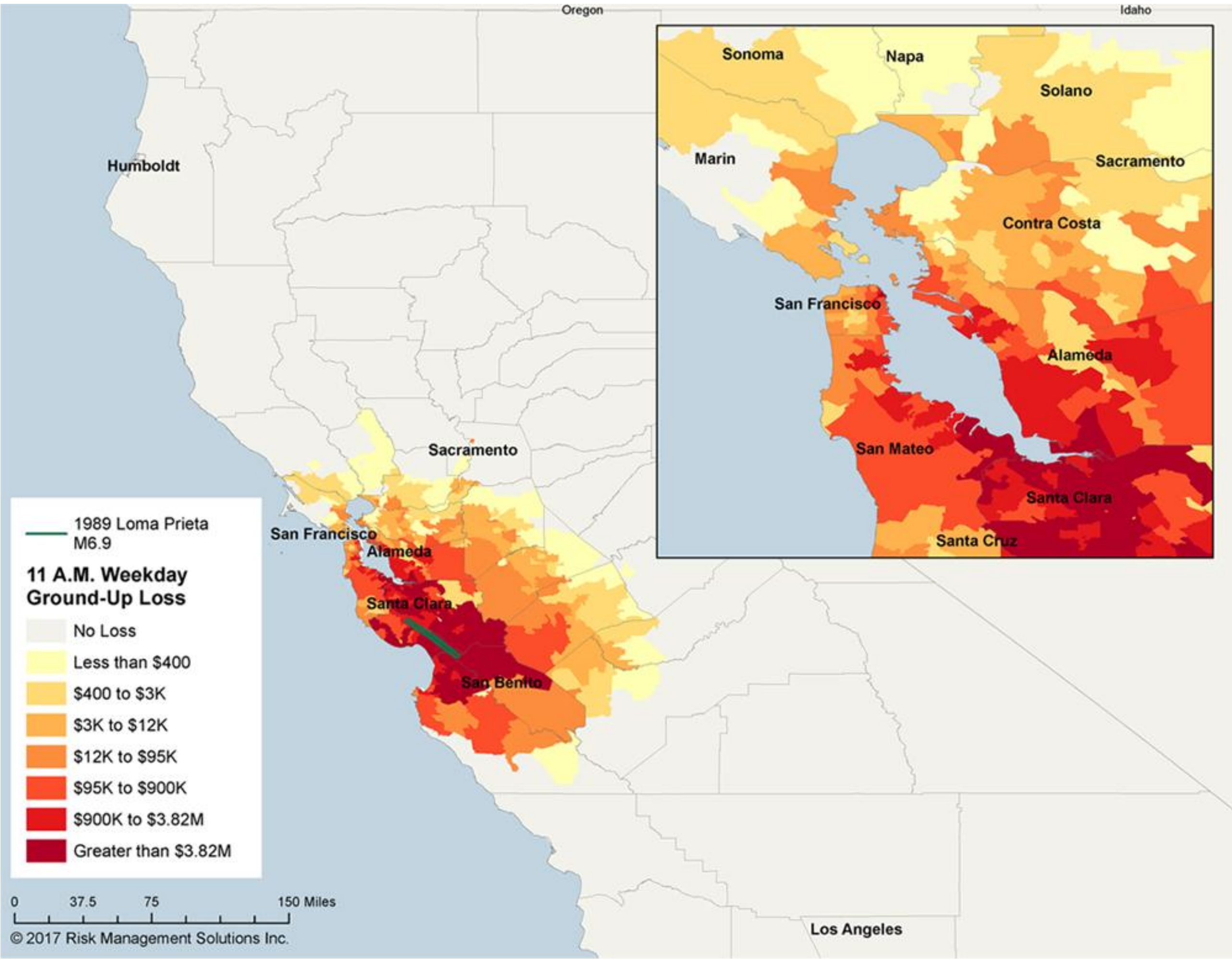
Loss per $100 payroll by postal code is shown in Figure 8 for the 1906 San Francisco Earthquake event for the Peak Exposure Adjustment Scenario.

Figure 8: 1906 San Francisco earthquake – loss per $100 payroll by postal code for the Peak Exposure Adjustment Scenario



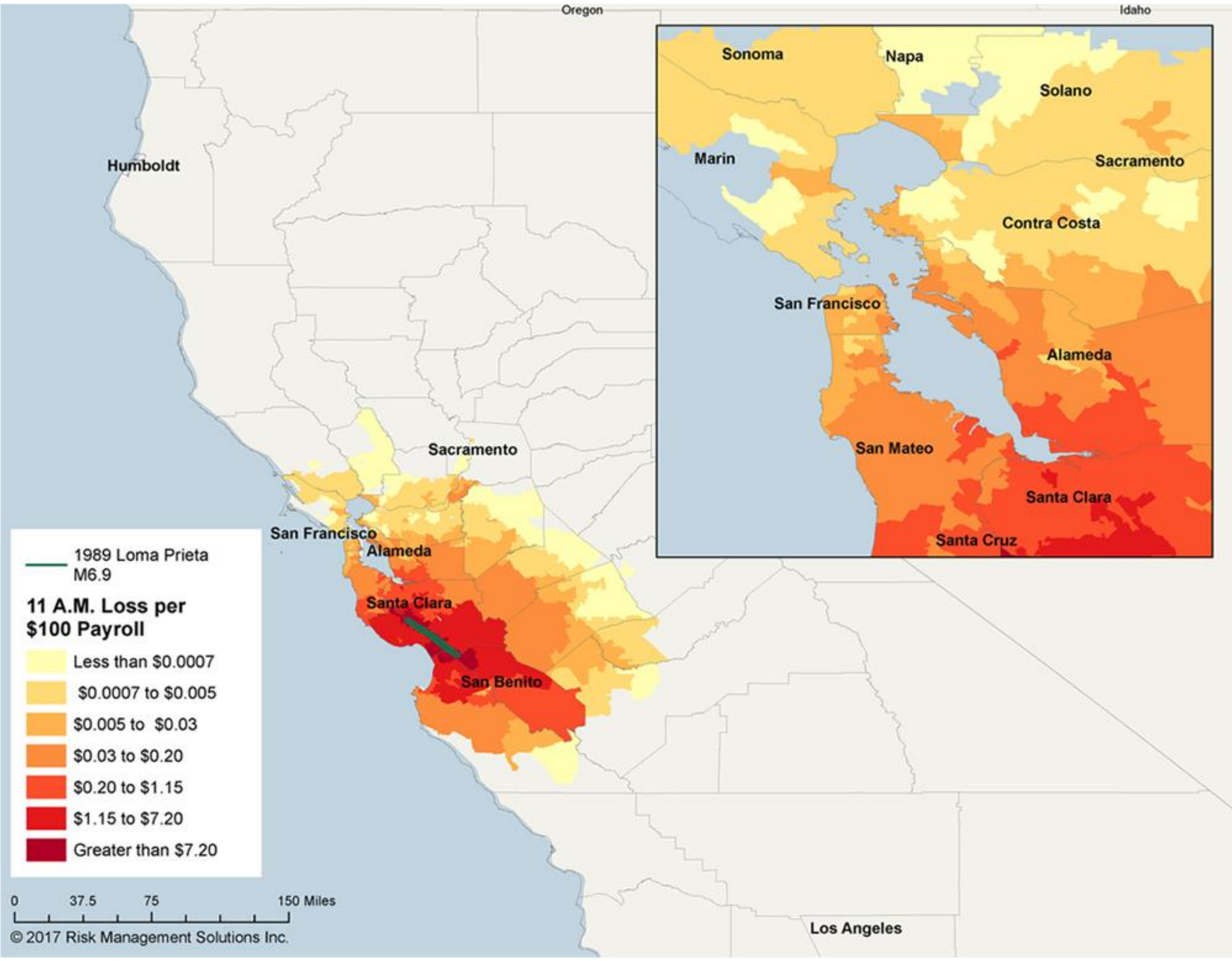
Ground-up loss by postal code is shown in Figure 9 for the 1989 Loma Prieta Earthquake event for the Peak Exposure Adjustment Scenario.

Figure 9: 1989 Loma Prieta Earthquake – ground-up loss by postal code for the Peak Exposure Adjustment Scenario



Loss per $100 payroll by postal code is shown in Figure 10 for the 1989 Loma Prieta Earthquake event for the Peak Exposure Adjustment Scenario.

Figure 10: 1989 Loma Prieta Earthquake – loss per $100 payroll by postal code for the Peak Exposure Adjustment Scenario



Risk Assessment

Selected Earthquake Scenarios

Selected Earthquake Scenarios

Tables 13 and 14 explore the impacts of different sources of earthquakes and the resulting injuries and losses.

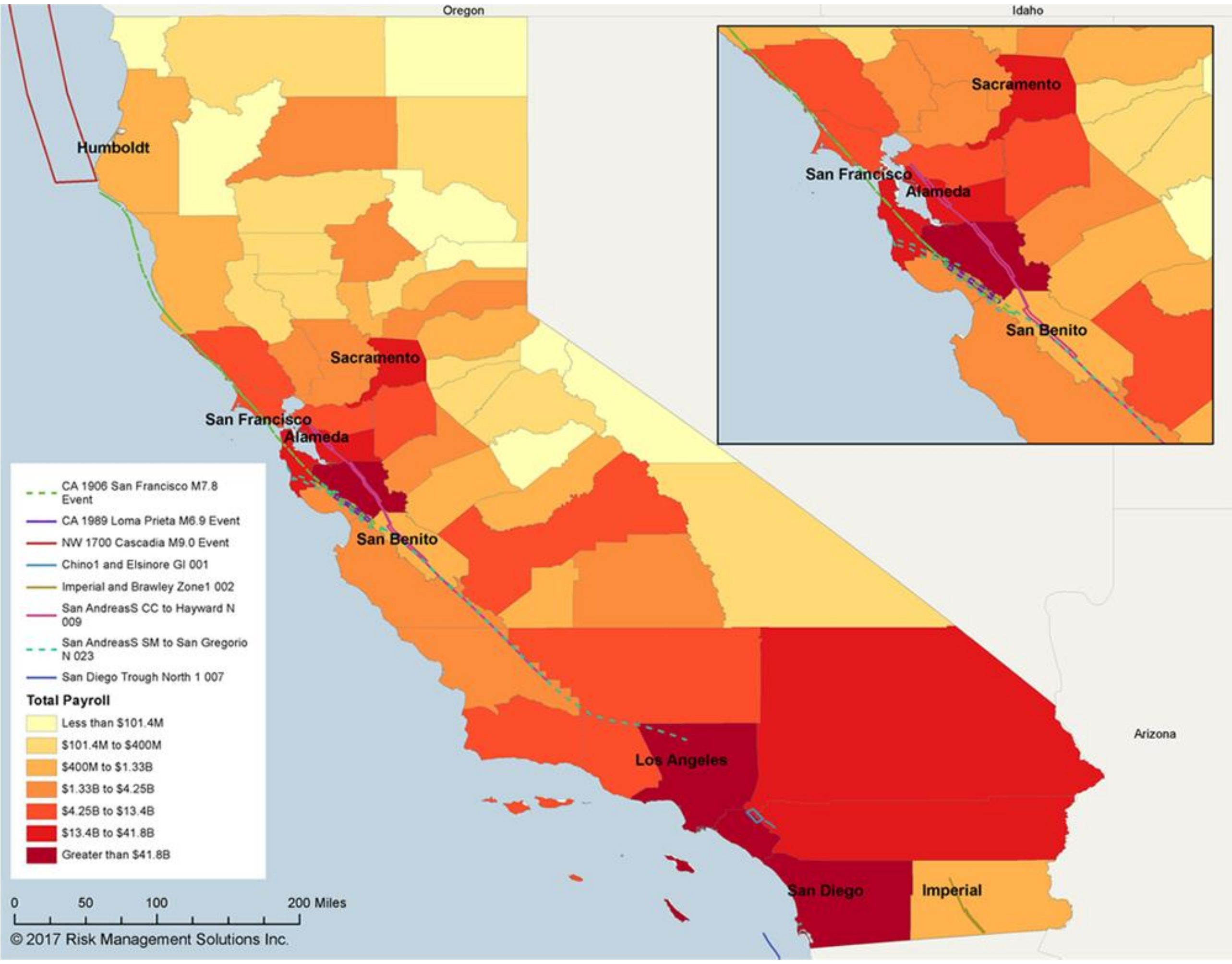
Table 13: Total and injury-level losses from selected earthquake scenarios for the Temporal Exposure Adjustment Scenario

	CA 1906 San Francisco	San Andreas S CC to Hayward N 009	San Andreas S SM to San Gregorio N 023	Chino1 and Elsinore GI 001	CA 1989 Loma Prieta	NW 1700 Casca dia	Imperial and Brawley Zone 1 002	San Diego Trough North 1 007
Magnitude	7.8	7.6	7.9	6.6	6.9	9.0	6.7	6.5
Total casualties	7,261	7,043	4,332	1,064	766	202	89	18
Ground-up loss (in millions)	$1,043	$1,016	$515	$122	$84	$24	$13	$2
Loss medical only	0.5%	0.7%	0.7%	0.5%	0.7%	0.5%	0.7%	0.9%
Loss temporary total	2.7%	3.4%	3.2%	2.7%	3.2%	2.7%	3.2%	3.5%
Loss temporary partial-minor	9.8%	11.3%	11.0%	9.6%	10.6%	9.7%	10.8%	12.5%
Loss temporary partial-major	26.2%	28.1%	27.7%	25.9%	27.3%	26.1%	27.4%	29.8%
Loss permanent total injuries	34.7%	34.8%	34.8%	35.1%	34.9%	34.9 %	34.6%	36.9%
Loss fatalities	26.1%	21.7%	22.5%	26.2%	23.4%	26.1%	23.3%	16.4%

Table 14: Total and injury-level losses from selected earthquake scenarios for the Peak Exposure Adjustment Scenario

	CA 1906 San Francisco	San Andreas S CC to Hayward N 009	San Andreas S SM to San Gregorio N 023	Chino 1 and Elsinore GI 001	CA 1989 Loma Prieta	NW 1700 Cascadia	Imperial and Brawley Zone 1 002	San Diego Trough North 1 007
Magnitude	7.8	7.6	7.9	6.6	6.9	9.0	6.7	6.5
Total casualties	22,070	21,210	12,980	3,098	2,299	590	255	51
Ground-up loss (in millions)	$3,176	$3,057	$1,542	$356	$250	$68	$38	$5
Loss medical only	0.5%	0.7%	0.7%	0.5%	0.7%	0.5%	0.7%	0.9%
Loss temporary total	2.7%	3.4%	3.2%	2.7%	3.2%	2.7%	3.2%	3.5%
Loss temporary partial-minor	9.8%	11.3%	11.0%	9.6%	10.7%	9.7%	10.8%	12.5%
Loss temporary partial-major	26.2%	28.1%	27.7%	25.9%	27.4%	26.1%	27.4%	29.8%
Loss permanent total injuries	34.7%	34.8%	34.8%	35.1%	34.8%	34.9%	34.6%	36.9%
Loss fatalities	26.1%	21.6%	22.5%	26.3%	23.2%	26.1%	23.3%	16.4%

Figure 11: Map of selected earthquake scenarios overlaid with county-level payroll



Risk Assessment

U.S. Earthquake Casualty Model Methodology

U.S. Earthquake Casualty Model Methodology

This section describes the methodology used in the RMS U.S. Earthquake Casualty Model and includes general aspects of the following:

- Exposure modeling
- U.S. earthquake modeling
- Workers' compensation cost severities

Exposure Modeling

There are three key inputs to modeling human exposures: geographic resolution, demographics, and the time of the event occurrence. Each of these is described in the following sections:

Geographic Resolution

The physical location of people when an earthquake occurs is critical to assess the impacts of the event.

The address geocoding process translates an input address into a geographical spatial reference system, which pinpoints the location so that it can be used with other geospatial data (such as soil type) for analysis.

Demographics

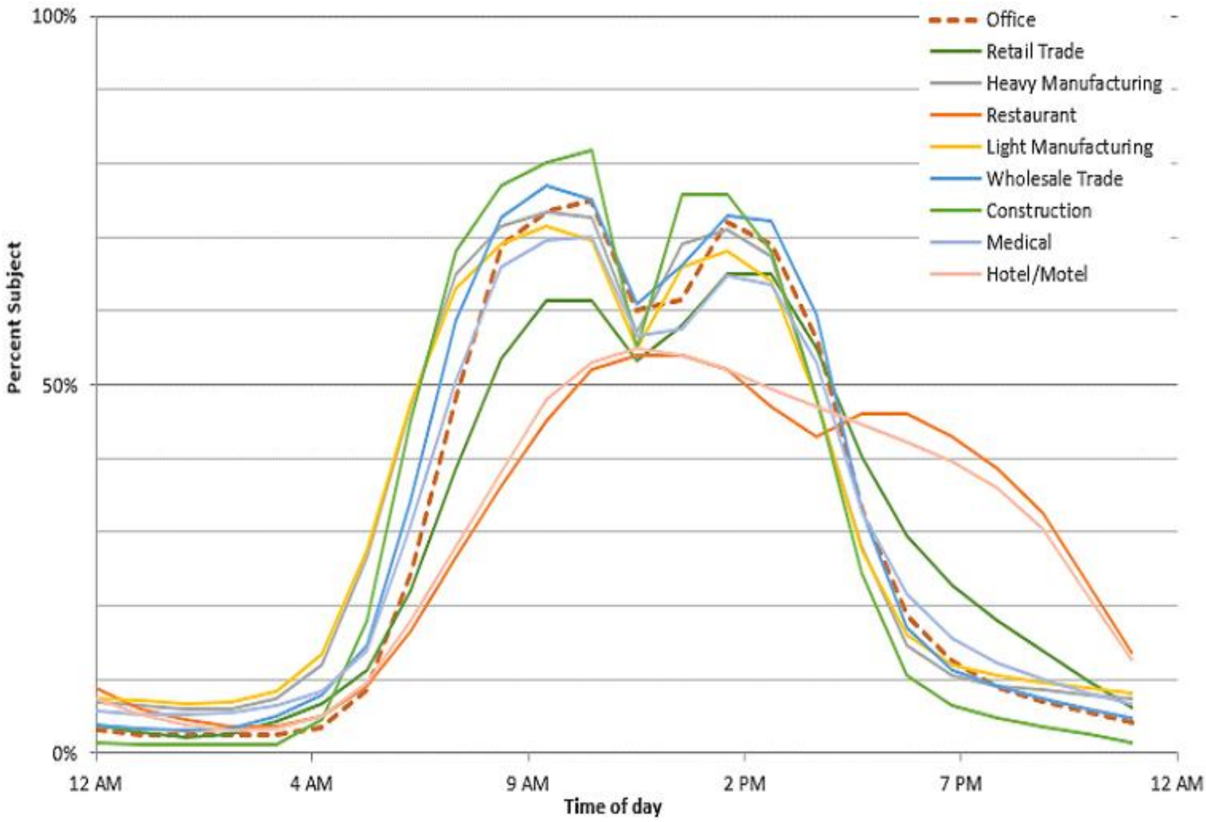
In casualty modeling, geographic and structural factors are significantly more important than demographic factors in determining loss. RMS designed the U.S. Earthquake Casualty Model primarily to assess impacts on groups of individuals in the population. The demographics of greatest concern are those that play a role in determining geographic and structural factors, such as the number of individuals in a group, their occupation type, and their daily work schedule.

Event Occurrence

Given the mobility of human exposure, population and demographics play a key role in estimating the number of people exposed to an event and their resulting injuries. Since earthquakes can occur at any time, how exposure varies by time of day (and day of week) is necessary to determine the geographic distribution of exposure and the type of applicable insurance coverage (e.g., workers' compensation insurance covers individuals while engaged in occupational activities only).

RMS estimates the average percentage of employees at work by hour and day of week (weekday and weekend) by occupation type. These time-of-day distributions are used to determine the population-at-risk based on the analysis profile and exposure data. The Version 17 release provides updated time-of day-distributions based on the most recent available data provided by the U.S. Census Bureau and U.S. Bureau of Labor Statistics. An example of the weekday time-of-day distributions by occupation is in Figure 12.

Figure 12: Industry average occupancy levels by time of day – weekday



U.S. Earthquake Modeling

The RMS U.S. Earthquake Casualty Model has four principal components, or modules:

- Stochastic Event Module: Contains a database of stochastic earthquake events that represents the full spectrum of likely events that can affect exposures in the U.S. Each event is described by its physical parameters, location, and frequency of occurrence.
- Hazard Module: Determines the earthquake intensity at each location for every stochastic earthquake event that is likely to cause losses at that location.
- Earthquake Casualty Vulnerability Module: Calculates the mean injury/casualty rates and coefficients of variation for the exposed population at each analyzed location.
- Financial Analysis Module: Calculates losses to different financial perspectives, considering the insurance and reinsurance structures specified.

The model analyzes locations against a database of over 380,000 simulated earthquakes, which are separated into different seismic regions across North America. Each of these earthquakes is defined by its fault and magnitude, and the database represents the range of all physically possible variations of the earthquakes and associated rates. The U.S. California earthquake region comprises over 70,000 of these events.

The model calculates the number of casualties and resulting loss for each stochastic event that has been run against a given exposure dataset. Results of a probabilistic analysis are provided in the form of (1) a loss probability distribution and (2) the corresponding expected annual loss. The loss probability distribution provides a spectrum of possible losses and the related probability of exceedance given specific insurance exposures under policies in force. The expected annual loss reflects the theoretical long-term average amount of loss that can be expected annually.

Stochastic Event Module

The U.S. Earthquake Casualty Model uses the same stochastic event module and underlying methodology that the RMS U.S. Earthquake Model uses for property loss calculations.

Version 17.0 was released in April 2017 and incorporates significant advances in the application of earthquake science and engineering, providing the most up-to-date view of earthquake risk for the U.S. Version 17.0 includes a source model update for the continental U.S., Alaska, and Hawaii. The seismic model for the U.S. is founded on a database of earthquake sources produced by the 2014 U.S. Geological Survey (USGS) from the National Seismic Hazard Maps Project (NSHMP), which includes the Uniform California Earthquake Rupture Forecast, Version 3 (UCERF3), model. The source models for Alaska and Hawaii, which were not part of the 2014 USGS update, have also been rebuilt based on recent scientific research.

Hazard Module

The U.S. Earthquake Casualty Model uses two intensity measures: the Modified Mercalli Intensity (MMI) and spectral acceleration (SA).

An earthquake's impact depends on several geological and building factors including geological condition of the site, distance from the fault-rupture plane, construction class, age of building, and building height. For this reason, a magnitude-based scale (e.g., the Richter scale) is insufficient to assess earthquake impact at a site as it has no mathematical basis and uses a system of 12 Roman numerals to represent observed effects, based on qualitative assessments that include human observation, building response, and ground failure processes.

Since most areas of the world that are frequently affected by earthquakes now have instruments to record ground motion quantitatively, researchers can determine the response spectrum, which records the amount of energy at different periods. Structural damage will be greatest when high levels of ground acceleration match the natural period of the building. Periods much shorter or much longer than the natural period of the building are unlikely to significantly damage the structure. Therefore, a specific SA value at the natural period of vibration of buildings is the best indicator of building damage.

If the location coded in is geocoded at postal-code resolution or better, the model uses spectral acceleration as the ground motion intensity measure. For locations geocoded at lower resolutions, such as county level, the model uses the MMI measure.

The Version 17.0 U.S. Earthquake Model incorporates the latest advances in ground motion prediction equations published from the Next Generation Attenuation Relationships for Shallow-Crustal Earthquakes in the Western U.S. (NGA-West 2), in addition to other recently released global and local ground motion models.

In areas with shallow soil profiles, the Version 17.0 U.S. Earthquake Model includes an upgraded soil amplification methodology that reflects the latest science and explicitly uses Vs30 (average shear wave velocity in the top 30 meters at a site). To enable the new methodology, RMS developed a high-resolution Vs30 data layer covering the entire U.S and derived from direct Vs30 measurements and surficial geology.

In areas with deep soil profiles, the U.S. Earthquake Model continues to incorporate basin models in the calculation of local soil amplification. Version 17.0 includes updates to all existing basin models in the U.S. to reflect the latest science. Each basin model is custom built based on simulations, incorporating site-specific data and/or observed data where available.

Earthquake Casualty Vulnerability Module

For a given location and a given event, the hazard module estimates the ground motion intensity. The vulnerability module of the U.S. Earthquake Casualty Model combines this ground motion intensity with other location-level attributes to estimate the number of injuries in each injury state at that location.

Earthquakes can cause a wide range of fatal and non-fatal injuries. RMS divides the modeled injuries into seven states based on (1) whether an injury occurs and (2) the severity of the injury. Table 15 lists and describes the injury states used by the RMS U.S. Earthquake Casualty Model. For each of the seven injury states described in table 15, the model defines the casualty rate as the ratio of the number of people injured to the total number of people exposed for a given level of ground motion intensity.

Table 15: Injury states used in the RMS U.S. Earthquake Casualty Model

Injury state	Description
No injury*	No bodily harm.
Medical only	Minor injury that can be easily treated and will not cause any permanent impairment. Examples include abrasions, lacerations, strains, sprains, contusions.
Temporary total	Injury that results in an individual's inability to work but from which the individual can fully recover within a reasonably short period of time. Examples include simple broken bones, loss of consciousness, serious strains, and sprains.
Permanent partial-minor	A permanent injury that results in ongoing partial disability. Examples include complicated fractures, serious joint injury, concussions, or minor crush injury.
Permanent partial-major	A permanent injury that results in a disability level greater than 25%, but less than total disability with no return to work. Examples include massive organ injury, heart laceration, loss of limb(s), or crushed extremities.
Permanent total	The most severe type of non-fatal injury. Results in a total disability state where the individual is unable to work again. Examples include spinal cord syndrome, crush syndrome, and massive head injury. These injuries require extended hospitalization.
Fatal	Immediate death or fatal injuries resulting in death.

* No loss is associated with the "no injury" classification, so there is no modeled output for this injury state

Earthquake Injuries

The type and severity of earthquake injury is extremely variable. Most earthquake injuries are comparatively minor and complete recovery can be expected with medical treatment. However, conditions such as amputations, burns, neurological injury, and crush syndrome can lead to permanent disability. Most victims who are trapped in collapsed buildings suffer multiple trauma and often extensive injuries. Those rescued after being trapped for an extended period have low survival rates or face permanent disability. Long-term disability can be extremely taxing on local health care systems and the insurance industry.

Extreme injuries occur in a small number of victims and include head injuries, severe crushing of the thorax and abdomen, or the amputation of limbs by extreme pressure.

Historically, most injuries in U.S. earthquakes are extremity injuries, including fractures, lacerations, and sprains. Hospitalized injuries have most often consisted of injuries to the lower and upper extremities, followed by spinal and head injuries.

Earthquake Fatalities

In the absence of secondary hazards, such as tsunami, the major cause of fatalities from earthquakes is building damage or collapse. The more damage an individual building sustains, the greater the likelihood of the occupants being injured or killed during the earthquake. Mortality is greatest among people located within buildings that are destroyed.

The type of damage, specifically the type of collapse mechanism, is also a strong driver in the number of casualties. Certain construction classes, such as unreinforced masonry and masonry, are much more likely to collapse without survival space, contributing to the large numbers of casualties attributable to these construction classes. In contrast, many modern engineered structures and wood-framed structures are designed to maximize survival space even in the event of collapse.

Components of Casualty Rates

Casualty rates represent the mean percentage of individuals that fall into a specific injury state given a level of ground shaking. This relationship between injury states and casualty rates varies depending on factors such as construction class and building height. RMS compiles casualty rates using an event-tree approach that considers the following general conditions that give rise to injuries and fatalities:

- People outside buildings that are injured by falling cladding or building collapse.
- People inside buildings that do not sustain significant structural damage who suffer injuries from non-structural hazards. This is a key cause of morbidity in earthquakes, but mortality is usually limited.
- People inside buildings that partially collapse, totally collapse, or sustain heavy damage. This is the most important cause of casualties in large earthquakes. These broad conditions account for several model components that all contribute to the injury severity distribution (i.e., the casualty rates) resulting from an earthquake. These components include:
    - Injury causes: Casualty rates account for all injury causes resulting from earthquake, including direct consequences of buildings that collapse, and also fire, smoke inhalation, and injuries sustained while trying to evacuate.
    - Collapse: The model estimates the probability of collapse for each building, given the level of ground shaking. This approach considers that, for a given building stock, there could be a small fraction of buildings that collapse even though, on average, the building stock is unlikely to suffer significant damage for a given level of shaking. At a given damage state, more casualties tend to occur in buildings that experience the extreme of the damage distribution rather than the mean damage. To reflect this, the model uses a distribution around collapse state and probability to model the casualty vulnerability.
    - Spectral response: The U.S. Earthquake Casualty Model considers spectral response to assess the performance of buildings and is factored into casualty rates.

The model computes two statistical measures of the casualty rate in each injury state:

- Mean casualty rate (MCR): Estimated using a series of unique vulnerability functions that provide a mapping between the level of the ground motion intensity and the MCR.
- Coefficient of variation (CV): Estimated as a function of the level of the MCR for that location.

The model estimates the MCR and CV for each injury state and calculates six pairs of MCR-CV functions for each analyzed location.

The casualty vulnerability functions depend on several building characteristics. Among them, construction class, occupancy type, year of construction, and number of stories are referred to as the building's primary characteristics. For earthquake casualty estimation, construction class and number of stories are the most important primary attributes. This is mainly because these two primary attributes can cause important changes in the level of spectral displacement for a building. These attributes therefore govern both the distribution of structural damage across the building height and the type of collapse mechanism.

For a location with all the four primary attributes coded as known, the vulnerability module contains a unique casualty vulnerability function for each injury state. However, if one or more of the primary characteristics of a building is not known, the vulnerability module uses a building inventory database to determine the inventory distribution.

The model calculates the probability that a building in a specific construction class falls within a certain damage state (partial collapse, total collapse, and heavy damage) to evaluate the full distribution of building damage, not just the mean damage. This distribution for a given construction class is then used to establish fatality and injury rates as a function of the collapse state. Thus, the severity of the injury distribution increases as the probability of partial collapse, total collapse, and heavy damage increases.

RMS analyzed historical data in detail, supplementing this analysis with analytical research from a combination of data sources including earthquake performance from past events, studies of epidemiological reports, and engineering research. Using observed data from over 100 historical earthquakes around the world, RMS calibrated various model components by considering the casualty severity distribution for different construction classes, with a primary focus on totally and partially collapsed buildings. The development of earthquake vulnerability functions considers regional design, construction practices, and past earthquake performance.

Construction Class

Construction class is an important factor in assessing casualty rates. As most severe injuries occur when buildings collapse, the performance of the structure is critical. Well-built structures are capable of sustaining earthquake lateral loads and are therefore less likely to collapse.
When construction class is not known for a location, RiskLink infers it from the inventory

database, which creates composite construction information based on geography and other known attributes; see the section “Building Inventory Data.”

Occupancy Type

Generally, the occupancy type of the building does not impact the casualty vulnerability curves except in the following cases: single-family dwelling (ATC 1) of wood frame construction or multifamily dwellings (ATC 2) of wood-frame construction and acute care hospitals (ATC 49 and ATC 50). Occupancy class ATC 50 only applies to hospitals located in California and evaluated with the Office of Statewide Health Planning and Development (OSHPD) seismic performance guidelines.

Occupation Class

The U.S. Earthquake Casualty Model uses employee occupation class to assume a distribution of employees inside a building when specific information in the exposure data, such as shift data, is missing. RMS used the occupancy codes and descriptions provided by WCIRB to map it to the most appropriate of 10 more general RMS occupation classes.

This list of general occupation types is shown in Table 16. Based on this mapping, the model may then use this information to do the following:

- Make assumptions about building inventory if that data has not been provided
- Make assumptions about temporal work patterns for employed persons

Table 16: General RMS occupation types

WCOCC code	Commercial occupation classification	Occupation description
1	Office	▪ Personal and repair services ▪ Professional, technical, and business services ▪ Religion and nonprofit ▪ Education ▪ General services
2	Light manufacturing	▪ Light industrial manufacturing ▪ Food and beverage manufacturing ▪ Agricultural production ▪ Printing and publishing
3	Heavy and other manufacturing	▪ Heavy fabrication and assembly ▪ Processing services ▪ Metal mining ▪ Industrial commercial machinery and computers
4	Wholesale	▪ Wholesale trade durable goods ▪ Wholesale trade non-durable goods ▪ Recreational-related wholesale trade

WCOCC code	Commercial occupation classification	Occupation description
5	Retail	▪ Retail stores and other retail trade ▪ Entertainment and recreation
6	Restaurant	▪ Eating and drinking establishments
8	Hotel	▪ Temporary lodging
13	Construction	▪ General contractors ▪ Residential and commercial construction
14	Medical	▪ Hospitals ▪ Nursing homes ▪ Ambulances
12	Other/Unknown	▪ Unknown occupancy

Number of Stories

The height of a building impacts its vulnerability and therefore resulting casualties from earthquakes. Furthermore, building height is one of the key parameters used in the development of the spectral displacement-based casualty vulnerability functions. The model uses ranges of numbers of stories to differentiate vulnerability based on height.

Year Built

The vulnerability of buildings changes as the authorities update seismic building codes, or when significant changes occur in construction practices. The year built field affects casualty rates; older buildings have inferior modeled performance, and the model therefore predicts a greater number and severity of casualties for such buildings. These year-built impacts reflect experience in historical earthquakes.

Earthquake resistant construction can be effective in preventing morbidity and mortality, but in the event of structural failure, seismically resistant construction can do more harm than good. Extricating victims from seismically reinforced masonry or concrete buildings requires heavy machinery and specialized skills.

Building Inventory Data

In cases where a building's construction class, year built, and/or number of stories are not specified, the RMS vulnerability module uses a building inventory database to determine the percentage breakdown of the primary attributes that are unknown. The building inventory database contains an industry mix of the different building types, height ranges, and year built bands found in various regions of the U.S.

The building inventory database is only invoked if sufficient information for RiskLink to select a predefined vulnerability curve is not provided. In cases where only a subset of construction class, year built, or number of stories are provided, this information is used to select a more appropriate vulnerability curve.

The inventory distribution of different building types is based primarily on the following factors:

- Geography: Different parts of the U.S. have different construction standards and practices. The model accounts for this by considering a separate inventory for each geographic area.
- Occupancy: The use of buildings is closely related to buildings' occupancy – that is, the business use of buildings' occupants. Building inventory varies for different occupancies.

Uncertainty

Given the complex cause-and-effect steps in the physical epidemiology of injuries in an earthquake, large uncertainty exists in the actual casualty rates for a given situation. Uncertainty arises from almost every component of the model. This uncertainty is expressed as an aggregate standard deviation around the mean, and it uses the mean and standard deviation to model the full probabilistic distribution of the results (both casualties and losses) with a beta distribution. Given that an event of a specific magnitude has occurred, the following components are the primary contributors of the uncertainty for a particular location:

- Ground motion intensity: Actual ground motion at a location can vary based on uncertainty in the earthquake source characterization, the attenuation pattern of ground motion along the path of travel, and soil conditions.
- Building damage level: A significant amount of uncertainty is introduced from the variability of damage a building may sustain.
- Building collapse: Modeling the likelihood that a building will collapse introduces additional uncertainty that a collapse outcome will occur.
- Spatial correlation: Portfolios of locations benefit from the diversity effect of having multiple risks such that fewer risks are correlated with one another.

Other Sources of Uncertainty

Uncertainty that does not directly relate to the vulnerability and casualty rates also arises from other sources, such as exposure uncertainty. Though separate, this additional uncertainty is factored into the aggregate standard deviation during analysis.

Exposure uncertainty exists because the random nature of earthquakes does not guarantee that the portfolio of people being analyzed will be exposed. In fact, the exposure may vary significantly for employed individuals with compensation insurance who are covered only while working. There are two types of exposure uncertainty:

- Temporal: This uncertainty deals with whether exposures are at a physical location at the time of the earthquake. Multiple analysis settings on time of occurrence of earthquake are supported to control the exposure subject to injury. While some of these options hold exposures fixed, one option – temporal distribution – accounts for the range of exposure levels throughout the day and week.
- Physical location: This uncertainty deals with exposures that are not typically at a single physical location, such as construction occupations. If the exposure being modeled is not at the location when the earthquake occurs, there is a chance they will be far away and not at all exposed, but there is also a possibility that they are in an area of even greater risk. The model does not account for this uncertainty or the potential impact on mean losses.

Workers' Compensation Cost Severities

A catastrophe model such as the RMS U.S. Earthquake Casualty Model produces an injury severity distribution, or the number of injuries expected for different injury states. The nature of workers' compensation coverage is such that there is no pre-defined or specified limit of insurance coverage. The amount for which an insurer is ultimately liable depends on many components, including the severity of injuries, the extent of physical impairment, and the duration over which benefits will be paid.

Catastrophic impact is quantified in terms of the expected loss amount by applying mean cost severities that capture statutory indemnity benefits and the cost of medical treatment.

The development of RMS cost severities considers many different factors, or cost components. Each of these cost components, as well as other considerations in estimating ultimate cost, is explained in greater detail in this section.

Medical Costs

All statutory workers' compensation laws provide for the full coverage of medical costs arising from the treatment of injuries and lifesaving procedures.

Generally, injuries result in two forms of medical treatment: acute and maintenance. Acute care is provided in order to immediately treat the injury, but may last for a longer period of time depending on how long it takes to stabilize the injured employee. Beyond acute care, there are maintenance costs. For minor injuries, medical treatment may consist of only acute care, but permanent injuries may require regular maintenance in the form of check-ups, medication, physical therapy, at-home care, nursing care, or a combination of these. Because there is no limit on the medical component covered by workers' compensation insurance, medical inflation is of particular concern.

Indemnity Costs

Typically, indemnity benefits refer to the benefits that an injured employee receives to compensate for lost wages. RMS has interpreted indemnity costs more broadly to include not only traditional indemnity benefits, but also legal fees, vocational rehabilitation, and funeral costs.

- Indemnity benefits: Injured employees are compensated for lost wages. Although they vary by state, indemnity benefits are typically two-thirds (2/3) of the injured employee's average weekly wage. The indemnity component is highly regulated, and almost every state imposes a maximum and minimum to which the benefit is subject. Many states also have a maximum benefit. Indemnity benefits begin after an initial injury period that varies by state but is between three and seven days. If the employee misses a greater amount of work, then that employee is usually entitled to indemnity benefits for the entire period for the entire duration of the injury. In the case of a permanent disability, this means that indemnity benefits would last for the life of the injured employee unless the state's workers' compensation laws limit the amount or duration of benefits.
- Survivor benefits: For fatality claims under workers' compensation, the surviving spouse and/or dependents are awarded benefits according to state law. These have been included as part of the fatal injury indemnity benefits.
- Legal fees: Many severe workers' compensation claims involve mediation, arbitration, or, in some cases, court trials. Most states allow the injured employee to recover these fees as part of their workers' compensation coverage. These legal costs have been factored into the RMS cost severities for permanent partial and permanent total disability claims.
- Vocational rehabilitation: Workers' compensation insurance in most states also includes a provision to retrain employees who sustain permanent injuries if they can no longer perform their job but are capable of performing a different job. These vocational rehabilitation costs have also been factored into the RMS cost severities for permanent partial disability claims.

- Funeral and burial costs: Each state includes a workers' compensation funeral benefit provision to assist the family of a deceased employee to cover the funeral and burial costs. RMS has included each state's specific funeral benefits as part of the overall indemnity cost.

Uncertainty

RMS has produced mean cost severities, with associated variability. Due to a number of factors, there may be a significant range in a workers' compensation claim – even for the same type of injury within the same state – due to the worker's income, marital status, and number of dependents, as well as the age at injury and the lifespan of an individual. Together, these factors may determine the duration over which benefits are paid and the weekly payment, each of which varies.

The significant variability around the cost severities is captured within RMS cost severity data. For each injury state, RMS has included a coefficient of variation (CV) to reflect the distribution around the mean cost severity. Separate CVs are provided for both the medical and indemnity components of the cost severity, and the CVs are the same between states. For example, if the mean cost severity for the medical portion of a permanent total disability is $750,000 and the CV is 2, then the implied standard deviation is $1,500,000 (or $750,000 * 2). Accounting for this uncertainty allows the distribution of insured claims to vary around the mean and reach into the multiple millions for outlying cases.

Uncertainty in the cost severities is taken into consideration by RMS during modeling as part of a probabilistic catastrophe analysis and is reflected in the resulting analysis outputs.

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