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Structure Engineering is served by USGS math, but not Public Safety

The history of USGS event probability calculation

Prerequisite math: the reader is expected to understand the national standard mortgage math underlying every mortgage contract ever written in the USA.

1984

Establishing geologic risk as a standard "37% in 50 years" can be useful for specifying structural design and is mathematically sound.

1. Designing structures (buildings, bridges, overpasses, dams, tunnels) that can withstand anything is literally an unaffordable concept. The question is, what design is technically good enough?
2. Science is interested in events that repeat (storms, floods, earthquakes, tsunamis, epidemics, wildfires).
3. One useful approach is to study the intervals between repeating events, employing the idea of a "**mean recurrence interval**" observed across a span of historical events found in evidence that represents observable fact (MRI). Find the best closed form equation that can characterize observed data.

Example 1: Wildfire or floods that have an MRI of 100 years after thousands of years of history, let's say 20,000 years. With 200 samples, you get an MRI of 100 years

20,000years / 200 samples = 100 years average.

Conventional probability is defined such that an absolute certainty (death, taxes) is represented as "1.0". So, considering the probability of an event happening in any given year, we figure
1 / MRI = 1 / 100 = 0.01

The chance of it NOT happening is 1 – 0.01 = 0.99, expressed as 99%. This is fairly safe, because this means the chance of bad news ACTUALLY happening is only 1%.

<u>Probability of occurrence</u>
The probability that the 1% event will occur for an exposure time of 5 years is:
P5 = 1%x1%x1%x1%x1% = $(1\%)^5 = (0.01)^5$ = 0.000000001. This is not easily understood, so the probability of it NOT happening is a much more convenient method, with less chance of missing or adding a "0" in error.

<u>Probability of NOT occurring</u>
The probability that the event will NOT occur for an exposure time of 5 years is:
PN5 = $(1 – 1\%)^5 = (0.99)^5$ = 0.951, approximated as 95%, still relatively safe. This means the chance of bad news is 5%.

Expressed as a generalization, the probability that the event will not occur for an exposure time of x years is:

$$PN = (1-1/MRI)^x$$

Example 2:
For a 100-year mean recurrence interval, and if one is interested in the risk over an exposure period of 100 years, the chance the event will not occur in that exposure period is:

$PN = (1 - 1/100)^{100} = 0.366$, or there is a 37% chance it will not occur, and a 67% chance it will. At 60% the odds of a quake event are 3 to 2, so this would imply very high exposure.

Building codes often tie the level of seismic hazard used in design to the ground horizontal acceleration that on average will be reached or exceeded in 475 years, (a mean recurrence interval of 475 years). This can be expressed as the chance this criterion for earthquake shaking--reaching or exceeding a specified value in units of acceleration--will be met in various exposure periods:

Calculate for a 50-year structure design in a region with an MRI of 475 years:
$PN = (1-1/475)^{50} = 90\%$ chance it will not occur, and 10% chance it will occur. Thus, a relatively safe 475 year design standard that is affordable. Ref: https://www.earthquakecountry.org/library/12685.pdf

1990

The M6.9 Loma Prieta quake in California occurred in 1989 and in 1990 USGS employed a 30-year risk standard to the local faults known at the time. Allen_1990_USGS_Circular1053.pdf

2012

In their Paleoseismicity Report in 2012 the USGS presents at least 15 different theoretical 50-year probability numbers to characterize the known 10,000 years of Cascadia seismic events, a variety of choices ranging between 7% and 85%. OregonLive reports the average interval (MRI taken from raw data) as 246 years.

Example 3:
We can calculate the chance of a Cascadia megaquake not happening:
$PN(Cascadia) = (1 - 1/MRI)^{50} = (1 - 1/246)^{50} = (1 - 0.0041)^{50} = 0.81$

This math assumes that in any 50 period in a 10,000-year era, the chance of an event happening is 1-0.81 = 0.19 or 19%. The math is correct. The sense is not.

Tectonic plate theory is widely accepted and holds that colliding plates build up massive stress where they impinge on each other. With an MRI of 246 years, stress builds up for 246 years on average, then the megaquake returns as stress is again released, historically for at least 40 events. Stress increases during a 50-year interval so it is not constant, as assumed by the USGS standard math choices.

Conventional 50-year structural standards based on regional MRI facts are valid. This math does not characterize the chance of returning stress-cycle megaquakes.

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The question remains: What math that represents the tectonic stress cycle should be used to guide public safety policy?

One approach is to start with the last Cascadia recurrence in 1700 and look at the 10,000 years of recurrences to see when the historically shortest interval was exceeded (it was in 1727), then the next (it was 1737) and so on. By 2018, 83% of known recurrence intervals had been exceeded.
https://better-energy-llc.com/wp-content/uploads/2023/03/10k-vs-6k.pdf

This appears to suggest that there is an 83% chance of a recurrence, since all the shorter recurrences are behind us.

Employing lognormal math to Cascadia raw interval data tables, which characterizes increasing tectonic stress, gives the same approximately 80% result. This is how odds of a Cascadia return are estimated, based on the only data available from best science, without employing math that assumes constant stress.

Percent Likelihood	Probability P	Odds ratio P / (1-P)	Odds
5%	0.05	0.05	1 to 20
10%	0.10	0.11	1 to 10
15%	0.15	0.18	1 to 6
20%	0.20	0.25	1 to 4
25%	0.25	0.33	1 to 3
30%	0.30	0.43	2 to 5
35%	0.35	0.54	1 to 2
40%	0.40	0.67	2 to 3
45%	0.45	0.82	4 to 5
50%	0.50	1.00	1 to 1
55%	0.55	1.22	5 to 4
60%	0.60	1.50	3 to 2
65%	0.65	1.86	7 to 4
70%	0.70	2.33	2 to 1
75%	0.75	3.00	3 to 1
80%	0.80	4.00	4 to 1
85%	0.85	5.67	6 to 1
90%	0.90	9.00	9 to 1
95%	0.95	19.00	19 to 1

