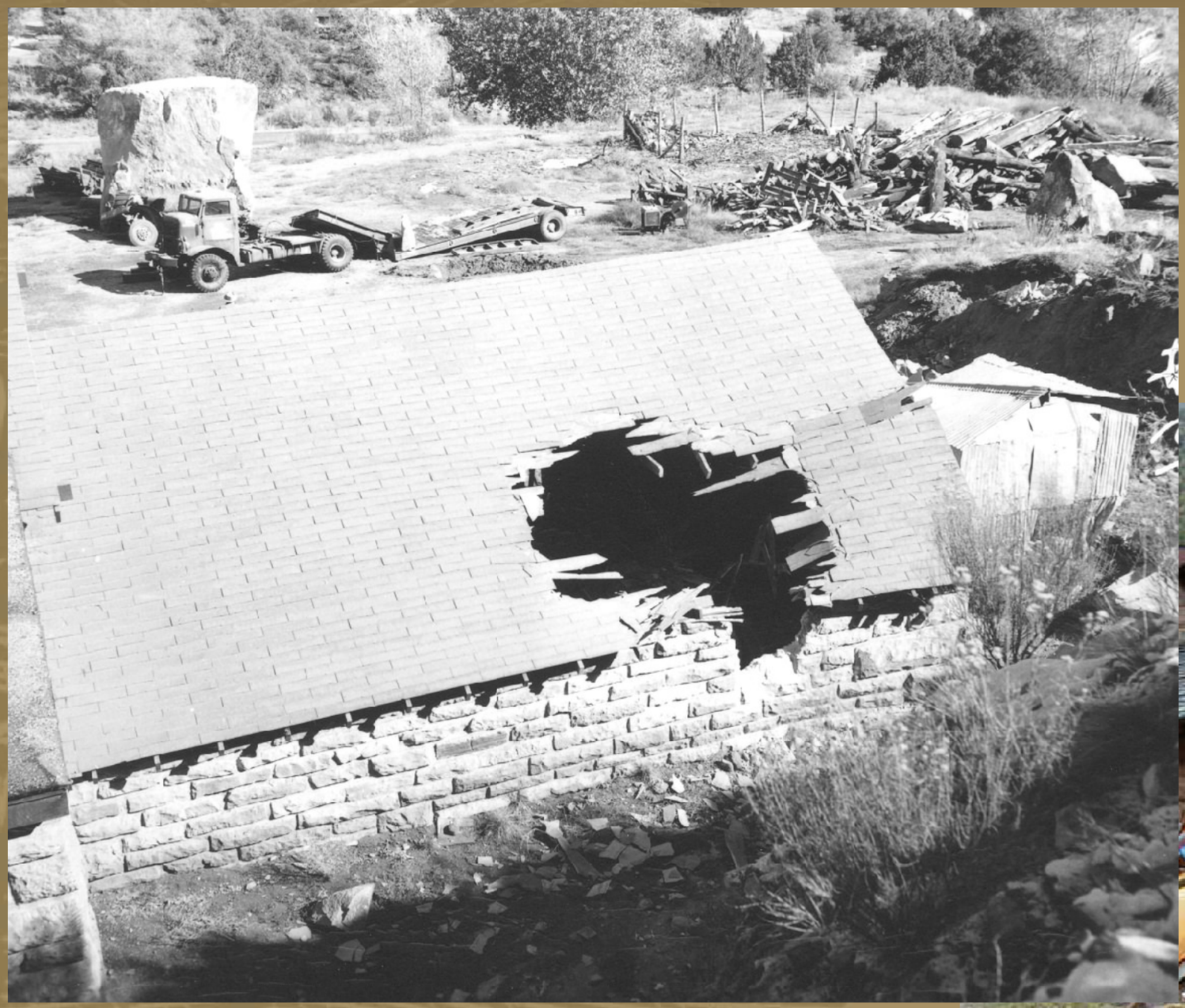
Quantitative Risk Analysis (QRA)

Timpanogos Cave National Monument

- The QRA is a module within the USMP.
- It is another decision-support tool.
- QRA can be used to further prioritize slopes, as part of a benefit-cost analysis, or as a stand alone module.
- The QRA uses numerical estimates of severity, probability, and exposure to place estimated risk into a societal context.

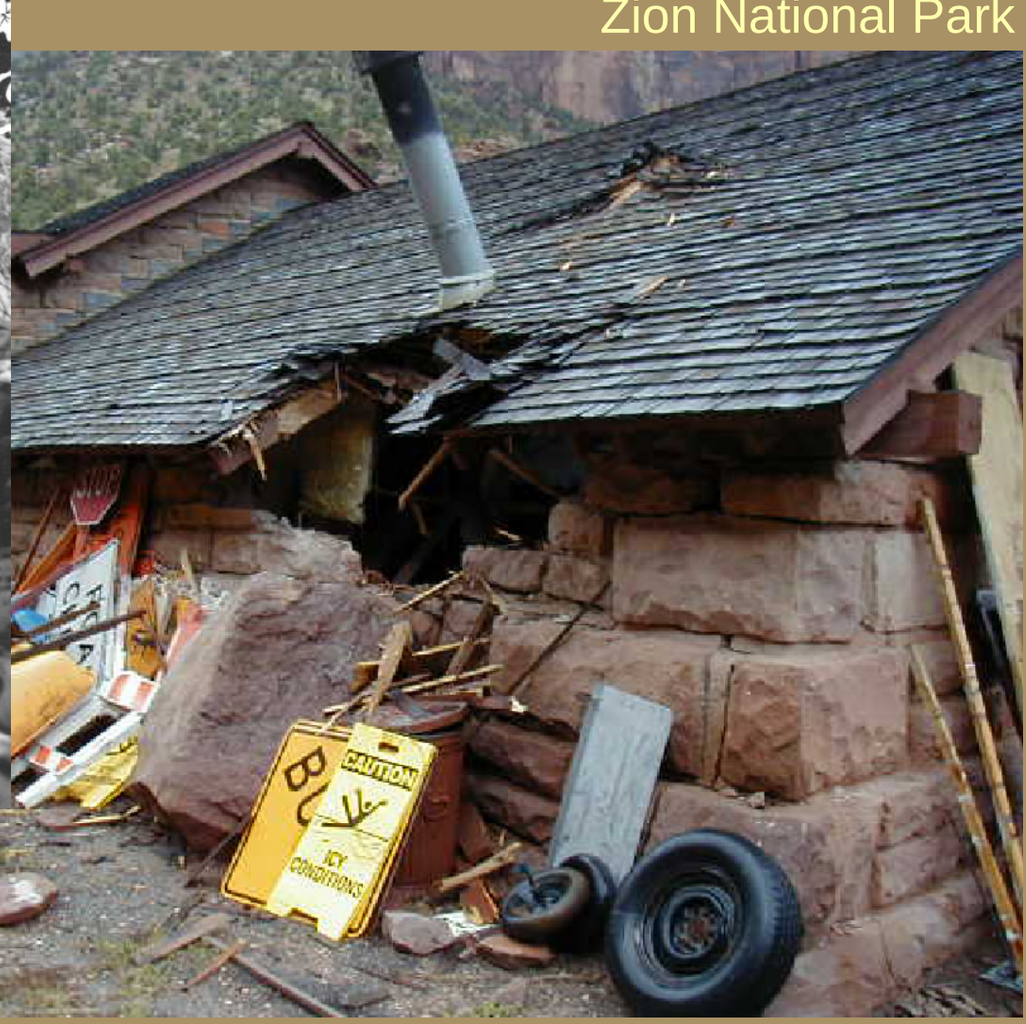
What is hazard?

What is risk?



1947

Zion National Park



2010

Hazard: Something that poses a theoretical possibility of harm to life, health, property or environment.

Risk: Is a probability. Risk takes into account the probability that a certain event will occur and what the consequence is if the hazard is realized.

Occurrence = two events in 63 years

Consequence =

Zion National Park

Holmes, R. R., Jr., Jones, L. M., Eidenshink, J. C., Godt, J. W., Kirby, S. H., Love, J. J., Neal, C. A., Plant, N. G., Plunkett, M. L., Weaver, C. S., Wein, Anne, & Perry, S. C., 2012, U.S. Geological Survey natural hazards science strategy- Promoting the safety, security, and economic well-being of the Nation: U.S. Geological Survey Circular 1383-F, 79 p.

Slope Hazard Quantitative Risk Estimate

Places estimated risk from a perceived hazard into a societal context.

General Risk Equation:

Annual Individual Fatality or Injury Risk

=

probability of occurrence - $P_{(occ)}$

×

probability of being affected by the event - $P_{(loc)}$

×

probability of people being in the hazard zone - $P_{(pres)}$

×

probability of a fatal consequence or injury - $P_{(vul)}$

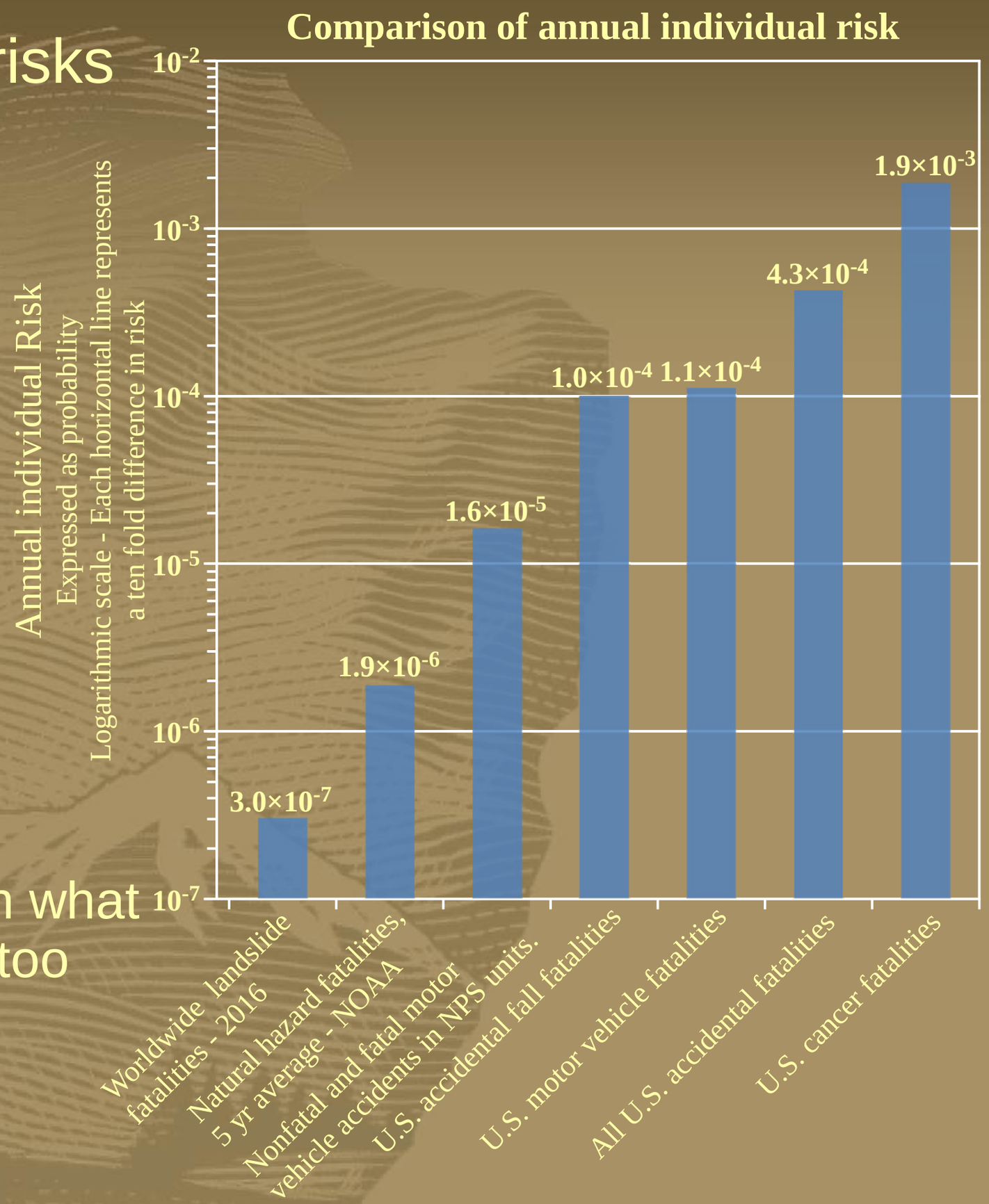
This kind of problem is a form of a Fermi estimate

This risk estimate equation is far from unique.

- Australian Geomechanics Society
- Used to evaluate rockfall risk following the 2010 and 2011 Chirstchurch, NZ earthquakes (Massey et al., 2012, 2014).

Main drawback: Some factors may need to be estimated
Main benefit: Risk related to rockfall or landslides can be compared with other societal risks, even back-of-the-envelope estimates are useful.

Societal risks



Risks of death from common causes of mortality such as cancer or heart disease.

1 in a Thousand

Largely acknowledged and accepted societal risks

1 in 10,000

1 in 100,000

Typical natural hazard risks

1 in a Million

No policy on what risk level is too high

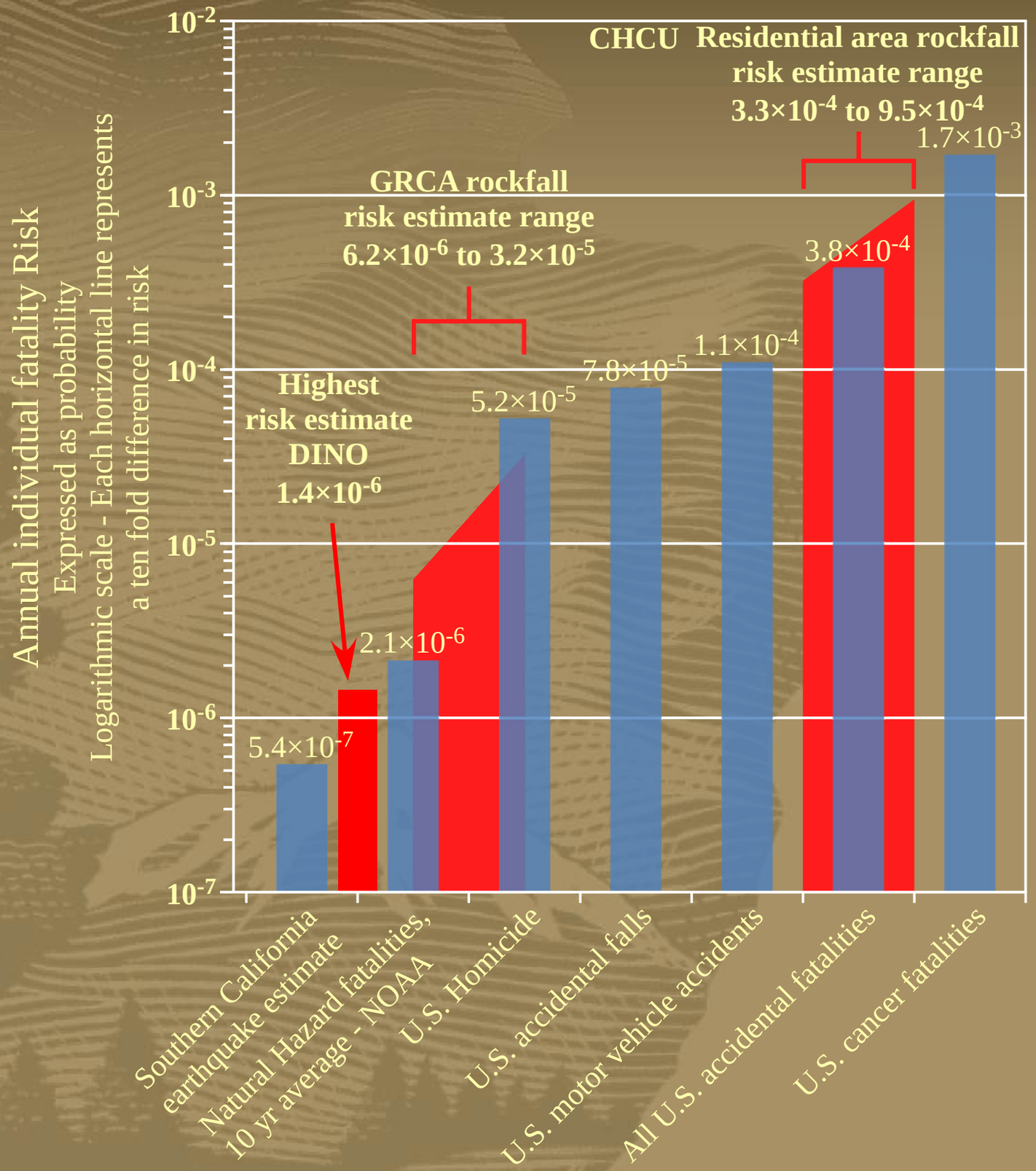
5 number Powerball
1 in 11.7 Million
Jackpot
1 in 292.2 Million

CHCU

DINO

GRCA

Comparison of annual individual fatality risk



Risks of death from common causes of mortality such as cancer or heart disease.

1 in a Thousand

Largely acknowledged and accepted societal risks

1 in 10,000

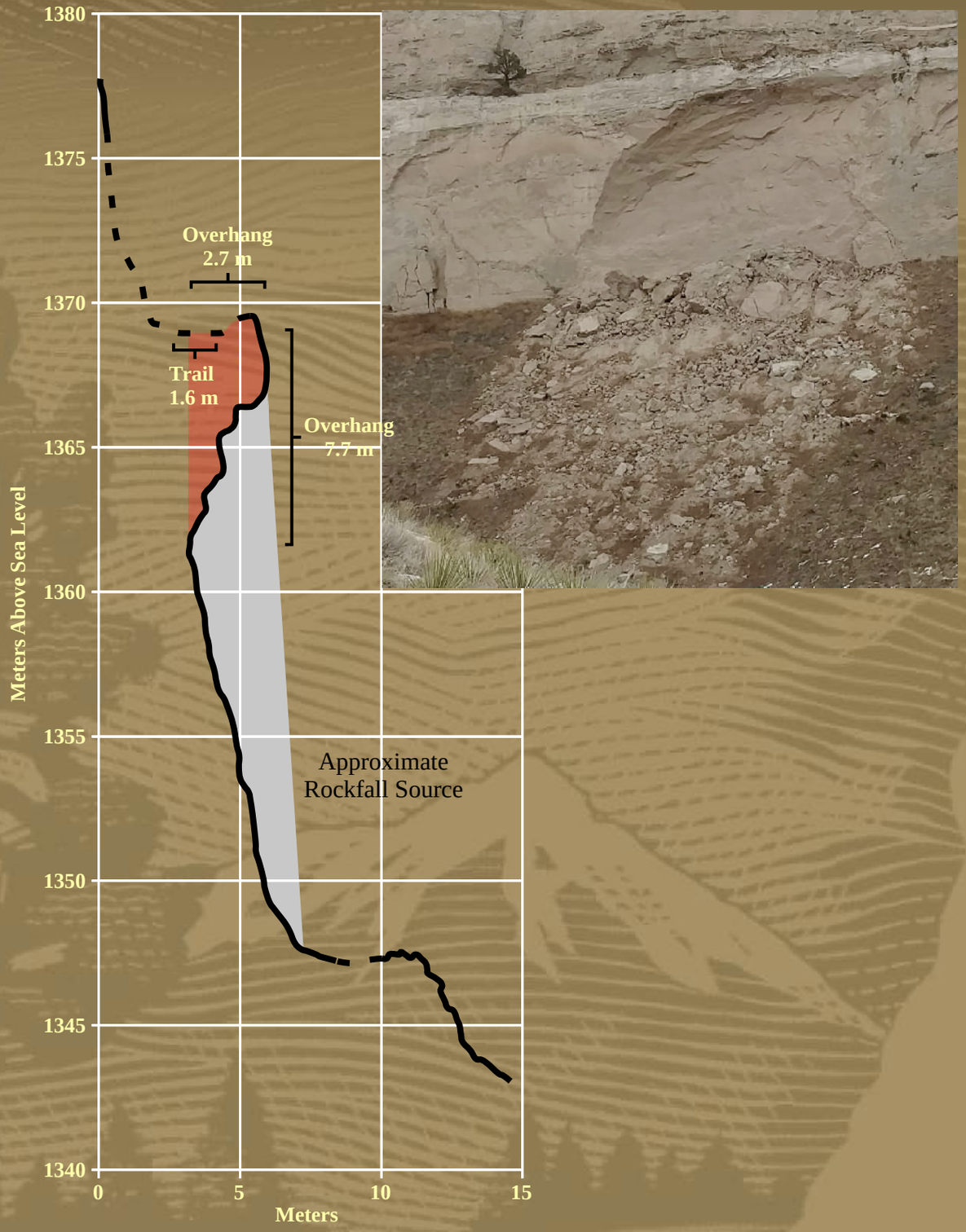
1 in 100,000

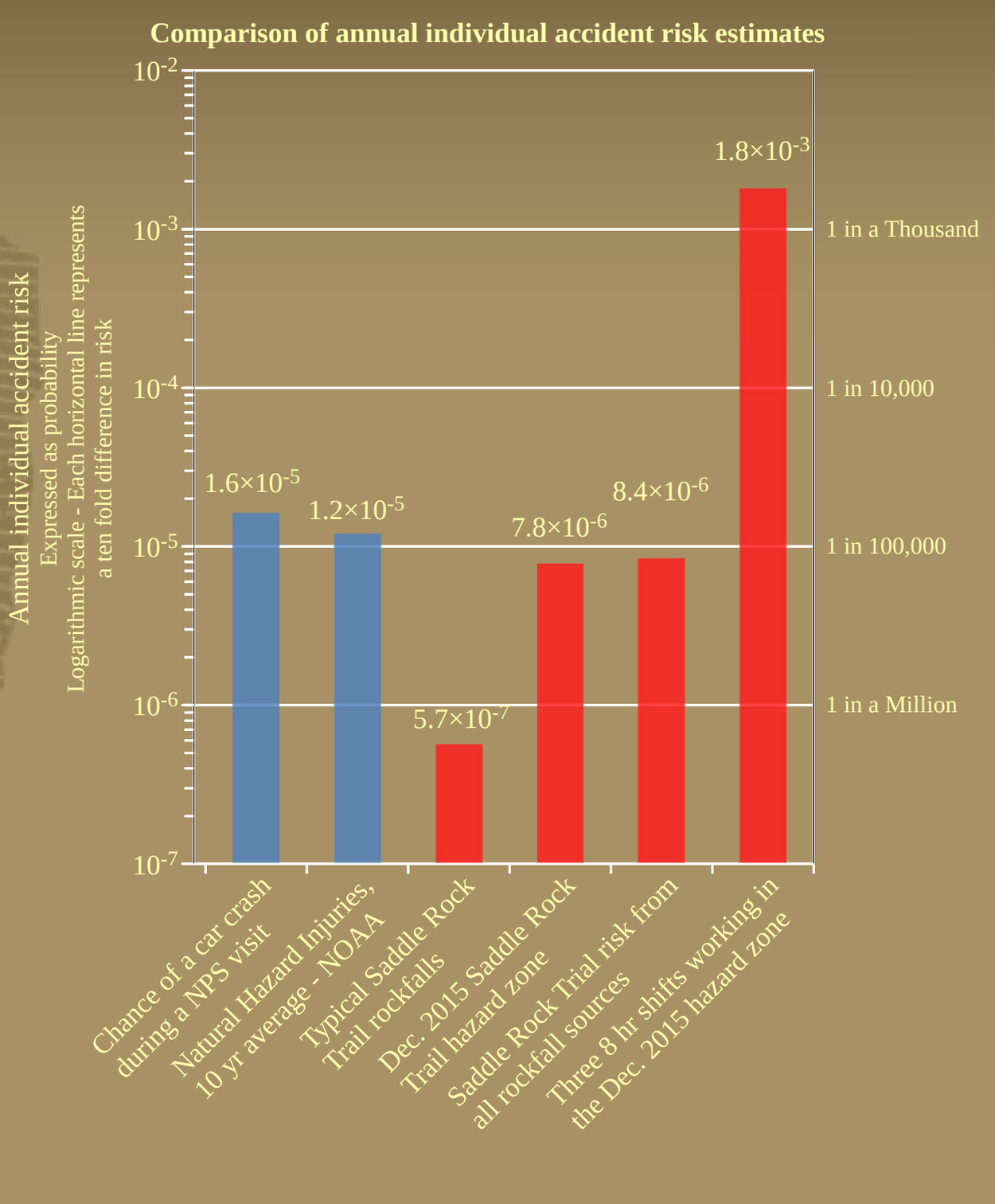
Typical natural hazard risks

1 in a Million

5 number Powerball
1 in 11.7 Million
Jackpot
1 in 292.2 Million

Scotts Bluff National Monument





Slope Hazard Quantitative Risk Estimate Work Sheet

Unstable Slope Management Program

Map | Slope Rating Form | New Slope Event | Maintenance Form | QRA | Account | Logout

Annual Individual Risk

Hazard Zone Attributes

Hazard zone name (for display in P_{AIR} graph):	
Form units	(•) US ( ) Metric
Length of hazard zone (length affected roadway, trail, or other area) (ft):	
Do most people travel the hazard zone once or twice (round trip) during a typical visit to the area?	(•) One way ( ) Two way
Average travel speed (mph) (Average walking pace is 2.73 mph):	

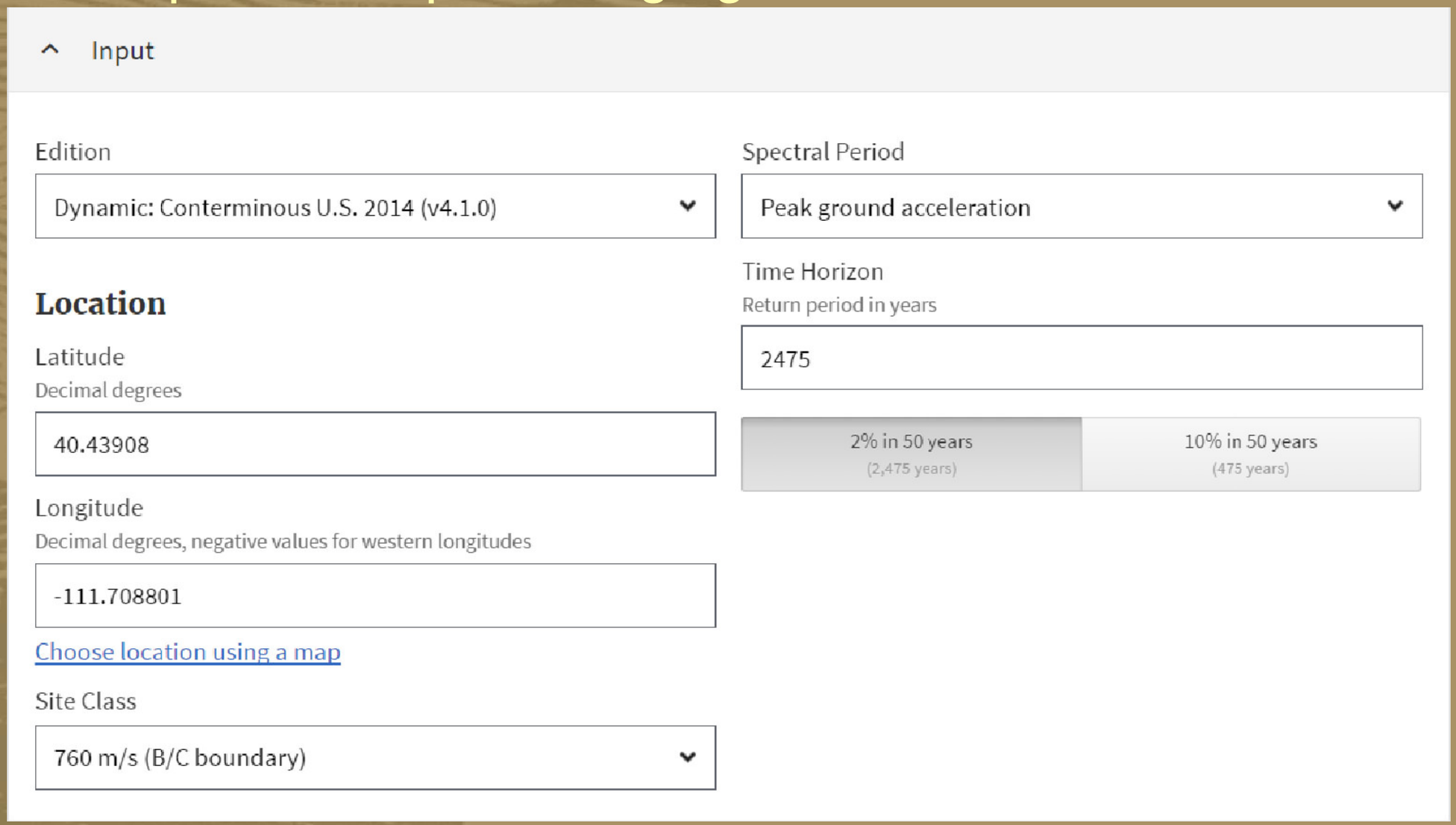
Stopping Sight Distance (SSD) added to the length of the hazard zone at speeds above 15 km/h or 9.3 mph.

SSD equation from the National Cooperative Highway Research Program Report 400 (1997)

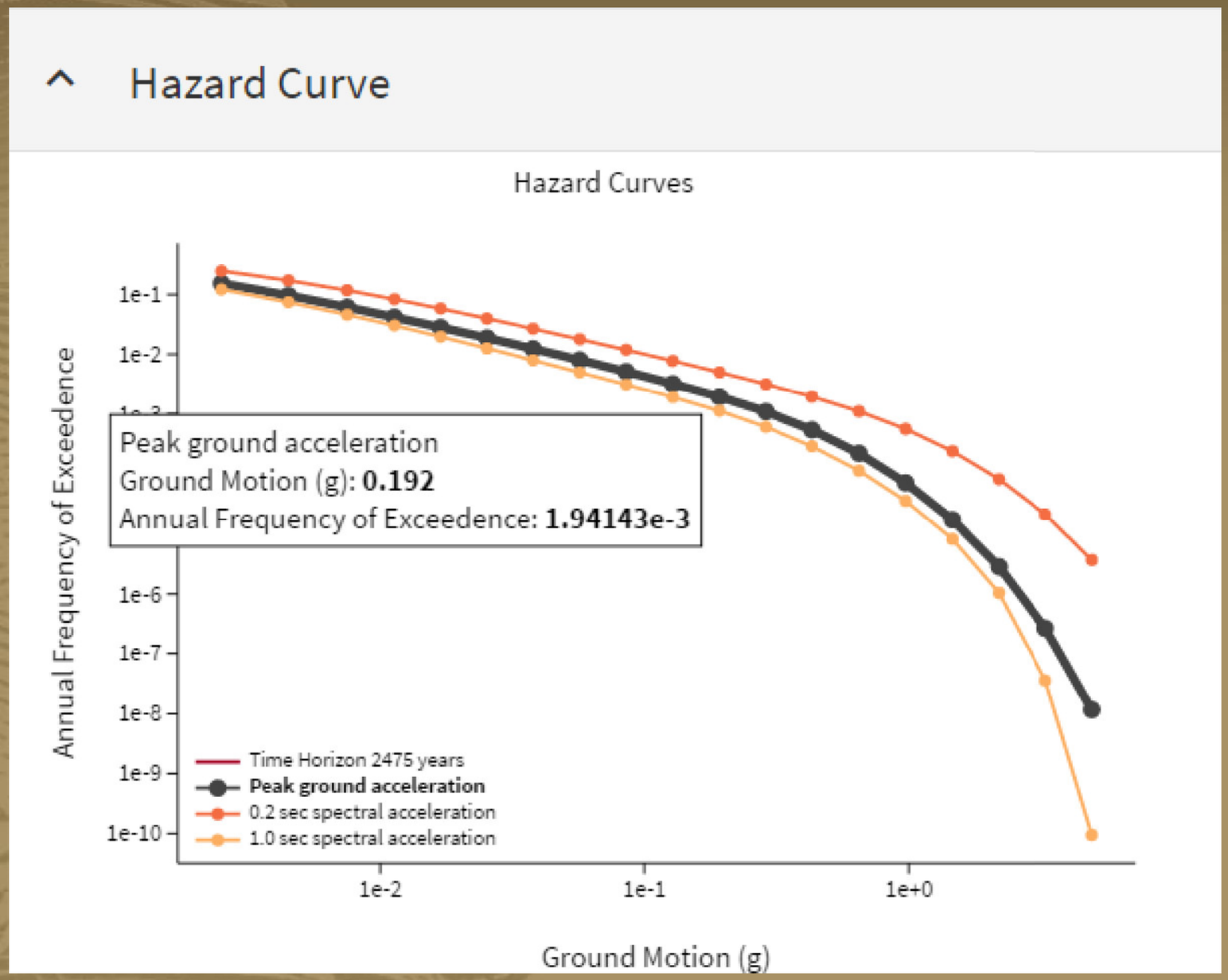
Probability of Occurrence (P_{occ}) Probability of an unstable slope event being triggered by an earthquake.		Probability of an unstable slope event not triggered by an earthquake	Probability of an unstable slope event triggering earthquake
Recurrence Interval: Number of events or event probability within [ ] years.		[ ]	[ ]
	P_{occ}:	NaN	NaN

Seismic Hazard - Ground motions trigger rockfall and landslides.

https://earthquake.usgs.gov/hazards/interactive/



Use USGS hazard curve to find the probability of greater than 0.2g



Mackey, B. H., & Quigley, M. C., 2014. Strong proximal earthquakes revealed by cosmogenic 3He dating of prehistoric rockfalls, Christchurch, New Zealand. Geology, 42(11), 975-978.

Massey, C. I., McSaveney, M. J., Heron, D., & Lukovic, B., 2012. Canterbury Earthquakes 2010/11 Port Hills slope stability: Pilot study for assessing life-safety risk from rockfalls (boulder rolls), GNS Science Consultancy Report 2011/311.

Massey, C. I., McSaveney, M. J., Taig, T., Richards, L., Litchfield, N. J., Rhoades, D. A., McVerry, G. H., Lukovic, B., Heron, D. W., Ries, W., & Van Dissen, R. J., 2014. Determining rockfall risk in Christchurch using rockfalls triggered by the 2010-2011 Canterbury earthquake sequence, New Zealand. Earthquake Spectra, 30, 155-181.

Probability of Location (P_{loc}) The probability of a person, if present in the hazard zone, being acted on by the unstable slope event.		**Non-earthquake Trigger (P_{loc})**	**Earthquake Trigger (P_{loc})**
Rockfall (manually entered probability)/Landslide (100%): ◉ Rockfall ○ Landslide			
Boulder size (ft):		0.000	0.000
Number of boulders:			
	P_{loc}:	0.00e+0	0.00e+0
Occupancy time (P_{pres}) The amount of time a person spends in the hazard zone.		**Non-earthquake Trigger P_{pres}**	**Earthquake Trigger P_{pres}**
Use ◉ calculated travel time, or ○ minutes per year:			
	P_{pres}:	NaN	NaN
Probability of Vulnerability (P_{vul}) Probability of a person being killed or injured by an unstable slope event or an asset being damaged by an unstable slope event.		**Non-earthquake Trigger P_{vul}**	**Earthquake Trigger P_{vul}**
Vulnerability of death or injury: (1 equals 100 percent chance of death injury or damage)			
	P_{vul}:	NaN	NaN

10-20 Kilojoule rockfall probably fatal.

1 ft rock (146 lb) dropped from 55 ft

Oso landslide, WA 43 people killed, 74% (0.74) chance of fatality

Grant, A., Wartman, J., Massey, C. I., Olsen, M. J., O'Banion, M., & Motley, M., In Review. The impact of rockfalls on dwellings during the 2011 Christchurch, New Zealand earthquakes. Landslides, submitted 2016.

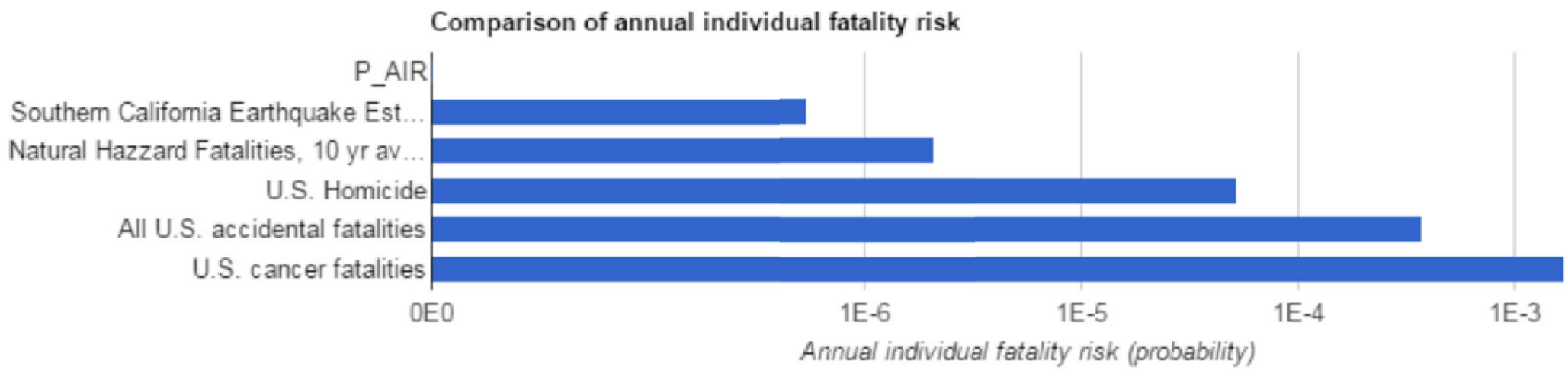
[redacted]

Annual Individual Risk (P_{AIR}) The annual probability of an individual being killed or injured in an unstable slope event.		Non-earthquake Trigger	Earthquake Trigger
	P_{AIR}:	NaN	NaN
	Annual P_{AIR} of background, or Earthquake: Non-earthquake or earthquake trigger.		NaN

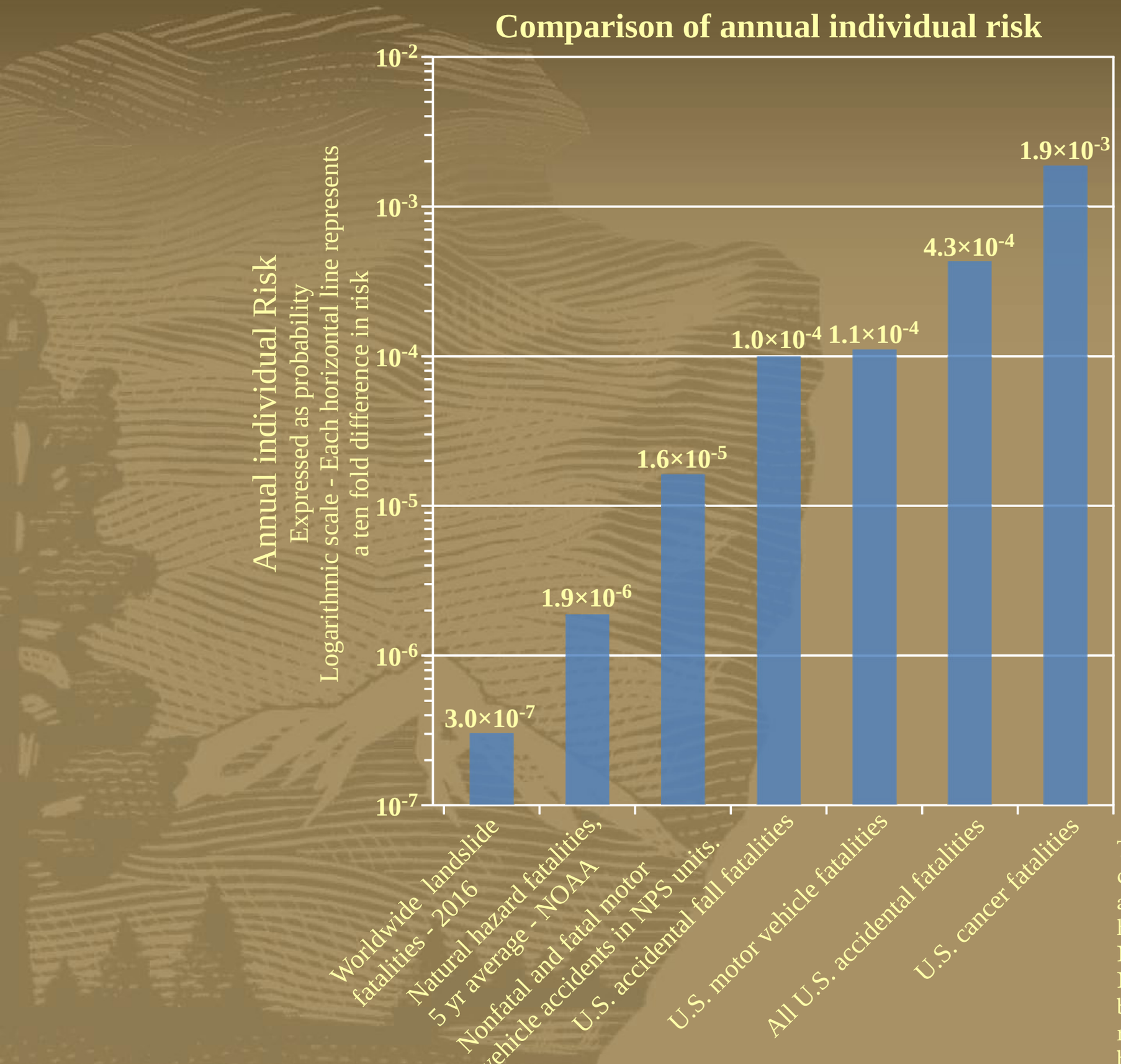
Comparison with probabilities of other events

Event name	Probability	In 10,000
Southern California Earthquake Estimate	5.4e-7	5.4e-3
Natural Hazzard Fatalities, 10 yr average - NOAA	2.1e-6	2.1e-2
U.S. Homicide	5.2e-5	5.2e-1
All U.S. accidental fatalities	3.8e-4	3.8e-0
U.S. cancer fatalities	1.7e-3	1.7e1

Show (•) probability, or ( ) ratio.



Comparison of annual individual risk



Risks of death from common causes of mortality such as cancer or heart disease.

1 in a Thousand

Largely acknowledged and accepted societal risks

1 in 10,000

1 in 100,000

Typical natural hazard risks

1 in a Million

The worldwide landslide fatality data is compiled by Dave Petley, University of Shetfield, after Petley, 2012. The 5 year average natural hazard fatality risk is compiled from 2011-2015 NOAA data. The chance of a car crash during a NPS visit is a 15 year average using NPS data between 1990 and 2005. Other societal risks represented by blue bars are from data collected by the CDC for the 2014 calendar year.

Risk Reduction Cost/Benefit Analysis		
Only for estimates of mortality.		
Value of a Statistical Life (VSL) based on a USDOT estimate (USD):	9500000	
Number of People visiting the hazard zone per year:		
Value an individual would asses to reduce estimated annual risk of death from the hazard to less than 1 in a Million (USD):		NaN
Value assessed to reduce the estimated annual risk of death from the hazard to less than 1 in a Million for all the individuals who visit the hazard zone (USD):		NaN

Risk Reduction Cost/Benefit Analysis

The benefit of preventing a fatality can be measured by:

"Value of a Statistical Life"
(VSL)

VSL in 2017 dollars ~ $9.6 million
(US DOT VSL Gudance 2013)

This is a valuation in the reduction in risk.

Example

Point Reyes National Seashore
Fatal bluff collapse on March 21st, 2015

Arch Rock

After dilation cracks appeared - high probability of failure within a month.
30 m hazard zone.
30 minutes on the point.
50% chance of mortality.

AIRD about
1 in 3,000

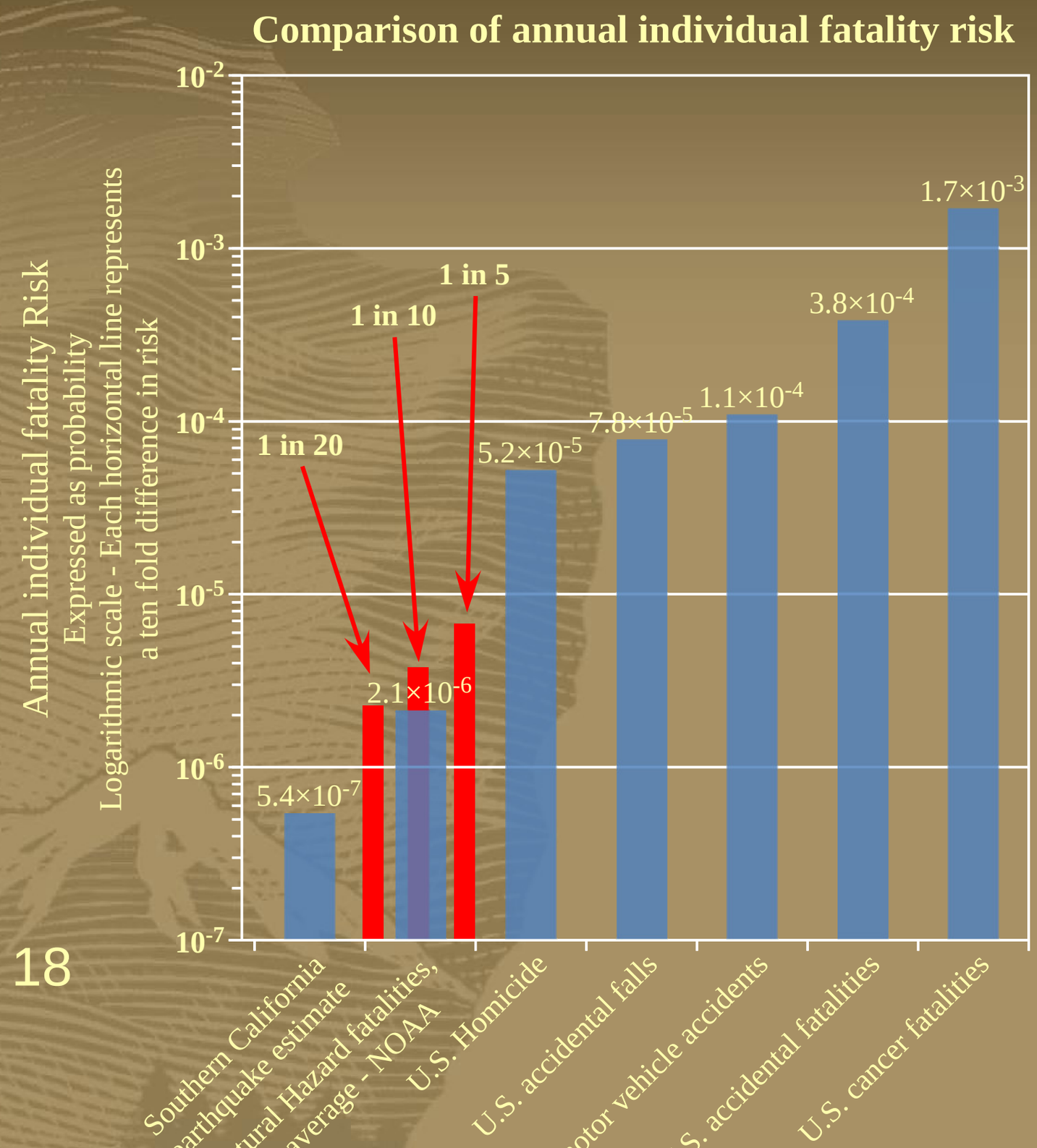
3.4×10^{-4}

Higher than vehicle accidents

<u>Monthly</u> valuation of reducing the risk is estimated at about:
$557,000

If 2,000 people spend 30 min at the point a month.

Arch Rock Remaining Hazard



Risks of death from common causes of mortality such as cancer or heart disease.

1 in a Thousand

Largely acknowledged and accepted societal risks

1 in 10,000

1 in 100,000

Typical natural hazard risks

1 in a Million

1 in 6 - 1 in 18 Closure Monitoring

Questions?