PEER-CEA Woodframe Project

Task 3: Ground Motion & Loading Protocol

Panel Of Experts Mtg I

Silvia Mazzoni, Yousef Bozorgnia

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Meeting Presentations

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CEA CALIFORNIA EARTHQUAKE AUTHORITY

Meeting Agenda

- Introductions
- Review Objectives
- High-level discussion of each deliverable
- Detailed Discussion Topics:
  - Site selection & site class
  - Sample PSHA of one site (Nick & Linda)
- Detailed discussion of each deliverable

Meeting Participants

- Yousef Bozorgnia, UC Berkeley — PI
- Silvia Mazzoni, UC Berkeley — Ground Motions & Simulation
- Linda AlAtik, consultant — Seismology
- Nick Gregor, consultant — Seismology
- Jack Baker, Stanford — Ground Motions
- Greg Dieirlein, Stanford — Numerical Simulation
- Farzin Zareian, UC Irvine — Numerical Simulation
- Chia-Ming Uang, UC San Diego — Experiments
- Badie Rowshandel — CEA
- Shizza Fatima — PEER

Task 3: Ground Motion & Loading Protocol

3. Selecting Ground-Motion Records and Developing Loading Protocols

- **Task 3.1: Selecting and Scaling Ground-Motion Records**
  - Deliverable:
    - Sets of selected and scaled ground motions appropriate for testing and analytical investigations
    - Experts Workshop
    - Written report documenting the process and outcome.
    - Workshops
    - Report
- **Task 3.2: Adoption of a Loading Protocol**
  - Deliverable:
    - Loading protocols appropriate for testing and analysis studies
    - Written report documenting the process and outcomes

3.1.2g Expert Workshop

- Schedule two workshops
  - **Workshop 1 -- Preview recommendations for procedures for determining:**
    - Target Spectra
    - Ground-Motion Selection and Modification
    - Available synthetic records
    - Inelastic response spectra models and procedures
    - Variability and uncertainty
  - Workshop 2 – Review progress
    - Decision-making process for the final recommendations

Methodology

A. Ground motions for analysis

1. Determine objective of ground motions: Fragility-Curve Development
2. Select number of ground-motion suites per site
3. Select Sites & Site Conditions
4. Perform Seismic Hazard Analysis
5. Define Uniform-Hazard Spectra, different hazard levels
6. Define Target Spectra for ground-motion suites at each hazard level
   - UHS – one Target Spectrum per hazard level
   - CMS – one Target Spectrum per hazard level + conditioning period
7. Determine number of ground motions in each suite
8. Determine dimensions and directionality of ground motions
   - 2D
     - The Target Spectrum was computed for rotD50
     - How do you handle each component response
   - 1D
     - How do you determine equivalency
     - Decision based on scope of Fragility curves
9. Search records based on deaggregation at size, hazard and period
10. Consider Synthetic Records
11. Scale records based on target spectrum. Modify records, if necessary
12. Compute inelastic spectra for records
13. Deliver Records to analyst

B. Ground Motions for experimental testing

1. Define objective of ground motions
2. Select Records based on the objectives and results from analysis
3. Discuss with researchers

A'. Additional Topics

14. Variability & Uncertainty

1. Objective of GM

A. Ground motions for analysis

1. Determine objective of ground motions: Fragility-Curve Development

- Multiple Stripe Analysis (MSA)
- Select sets of ground motions corresponding to a particular Intensity Measure
- Can use different ground motions at different IM levels
- Fraction of collapses does not necessarily increase with IM levels because different records are used at different IM, not just scaling. A higher IM level may have fewer collapses.
- Don't need to run analyses to high IM levels, they are not practical nor relevant
- Need more effort in fitting fragility function (no problem)

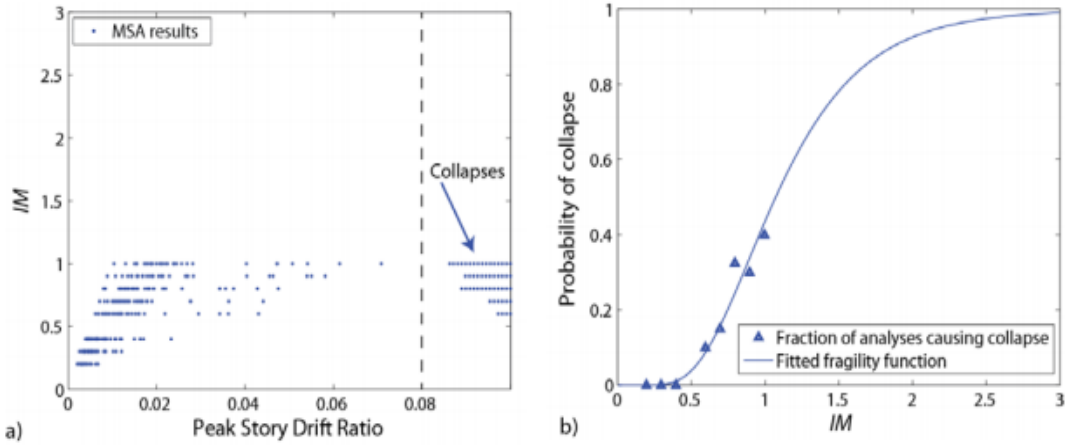


Figure 3. a) Example MSA analysis results. Analyses causing collapse are plotted at Peak Story Drift Ratios of greater than 0.08, and are offset from each other to aid in visualizing the number of collapses. b) Observed fractions of collapse as a function of *IM*, and a fragility function estimated using equation 11.

PANEL DISCUSSION:

A. Confirm MSA

B. Select IM
   - Spectral acceleration (need T)
   - Return Period

C. Number of GM Suites

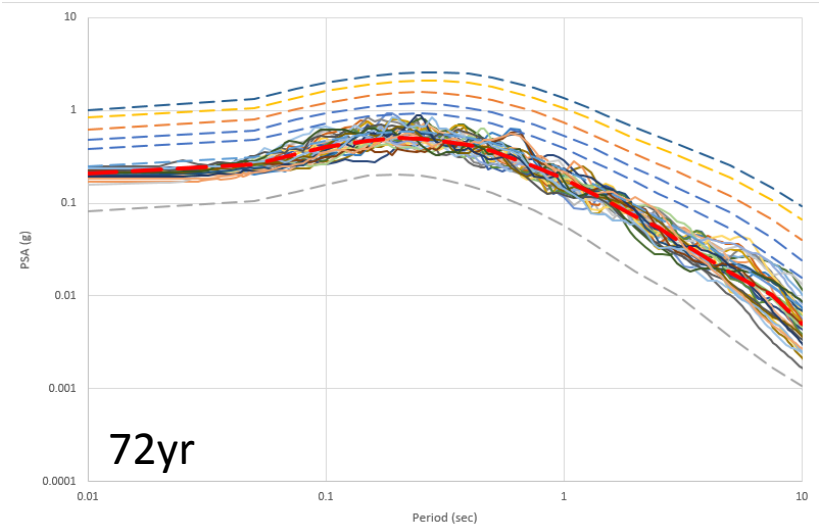
2.Number of GM suites per site

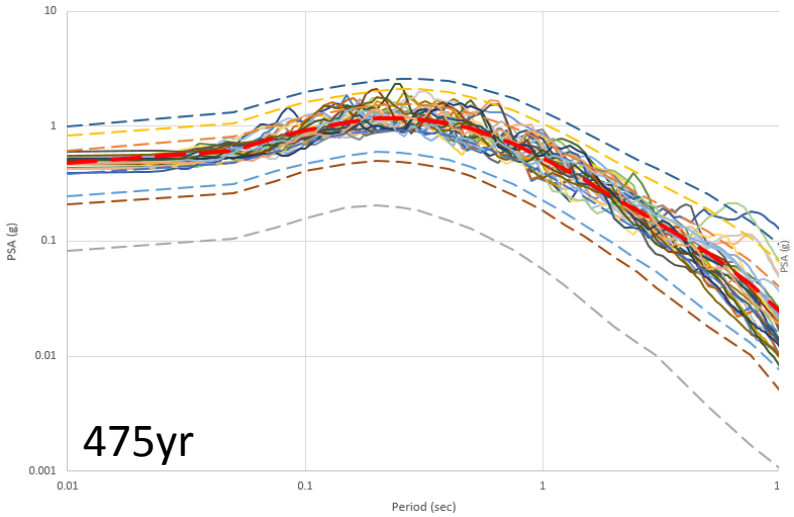
A. Select one ground motion suite and scale factors for hazard levels
   - Pro: Small number of defined ground motions
   - Con: Spectrum Shape is not maintained

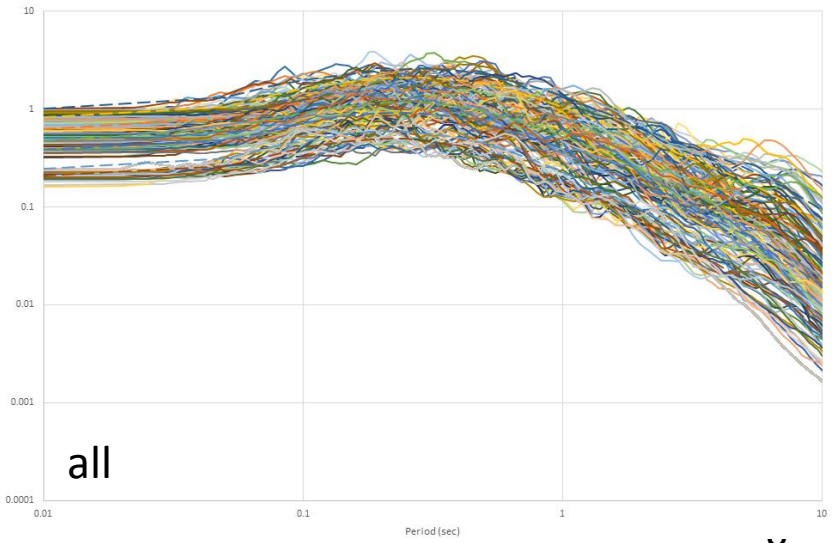
B. Select different ground motion suites for different hazard levels to preserve spectral shape
   - Pro: Maintain spectrum shape
   - Con: Book-keeping of ground motions, easy with OpenSees/scripts

PANEL DISCUSSION:

- Approve multiple suites







3. Select Sites & Site Condition

- Selection based on:
  - Region
  - Population
  - Seismicity

This will be discussed further later in presentation

PANEL DISCUSSION:

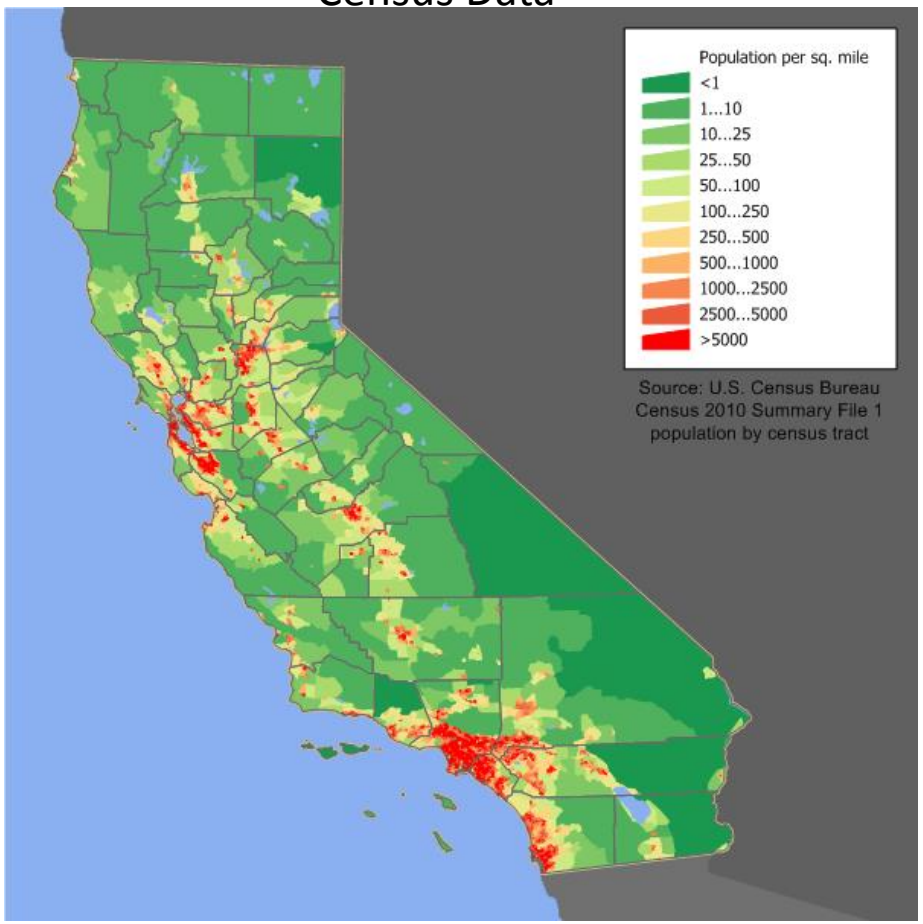
A. Number of sites

B. Site Class

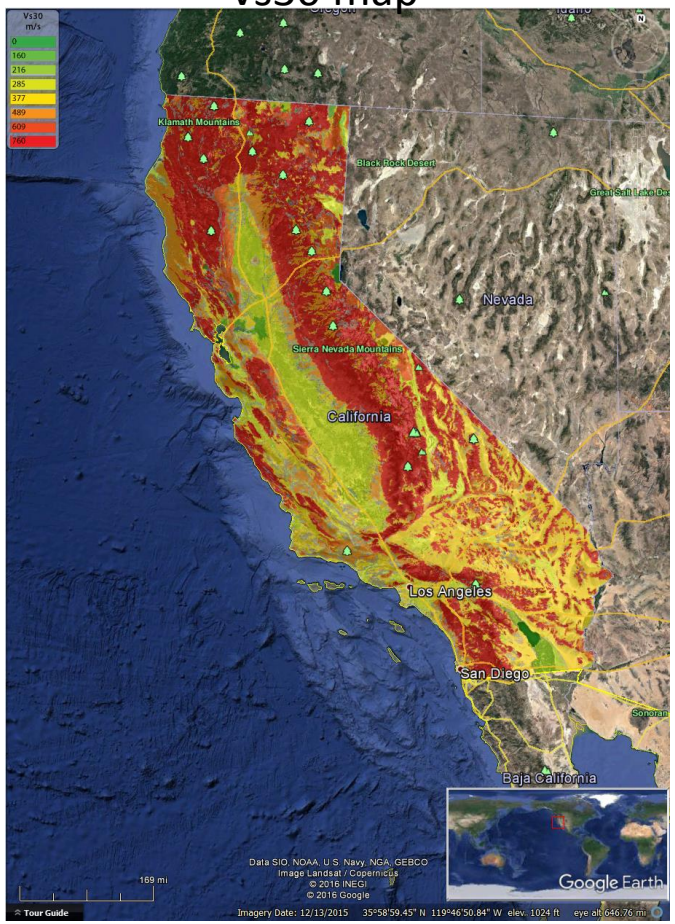
   A. One representative Site Class, Vs30=360m/s

   B. Site-specific site class

Census Data



Vs30 map



4. Perform Seismic Hazard Analysis (PSHA)

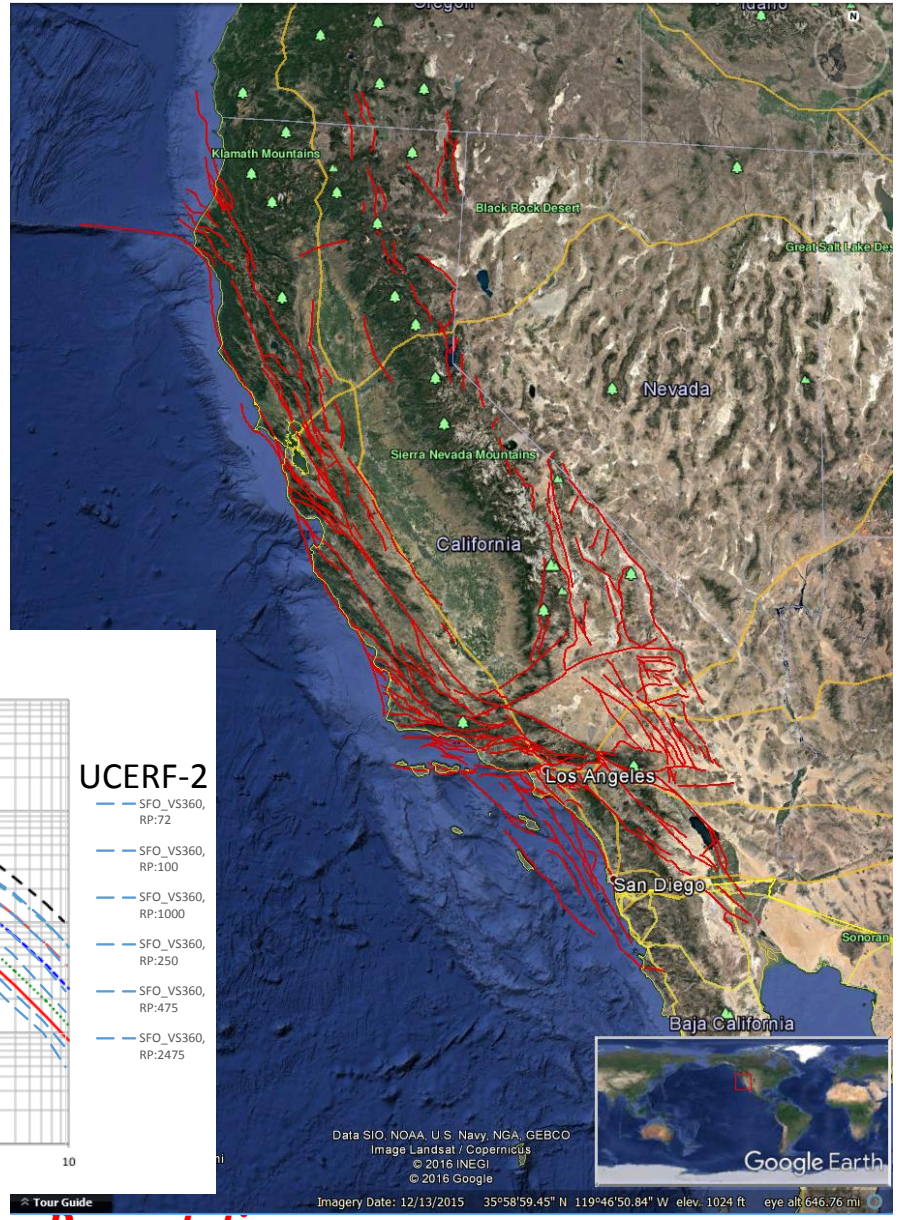
- PSHA Program
  - Haz-45 – developed by PEER scientists (Abrahamson, et al.)
- Seismic Sources
  - UCERF-2 or UCERF-3
  - Is UCERF-3 more accurate?
- Near-Field Effects
  - Period of interest < 1sec → no need to consider
- Basin Effects
  - Period of interest < 1sec → no need to consider

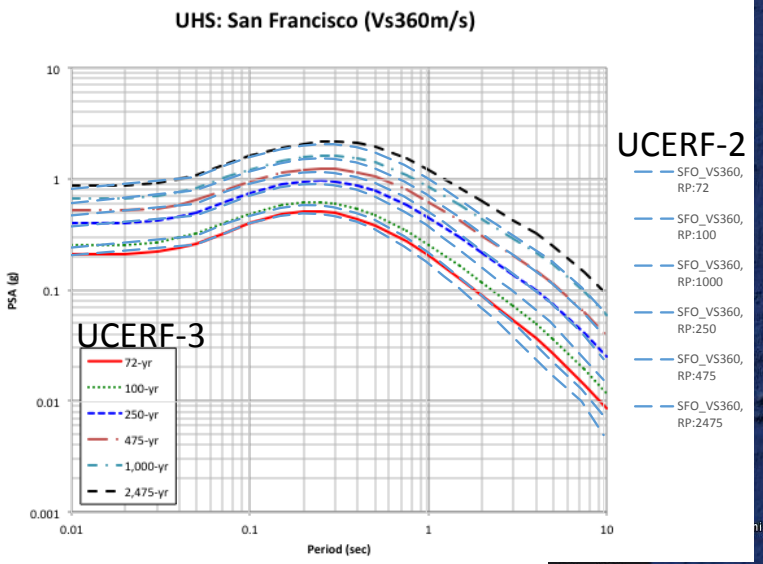
- Will be discussed in detail by Nick and Linda

PANEL DISCUSSION:

- Approve use of Haz-45
- Approve use of UCERF-3

UCERF-3





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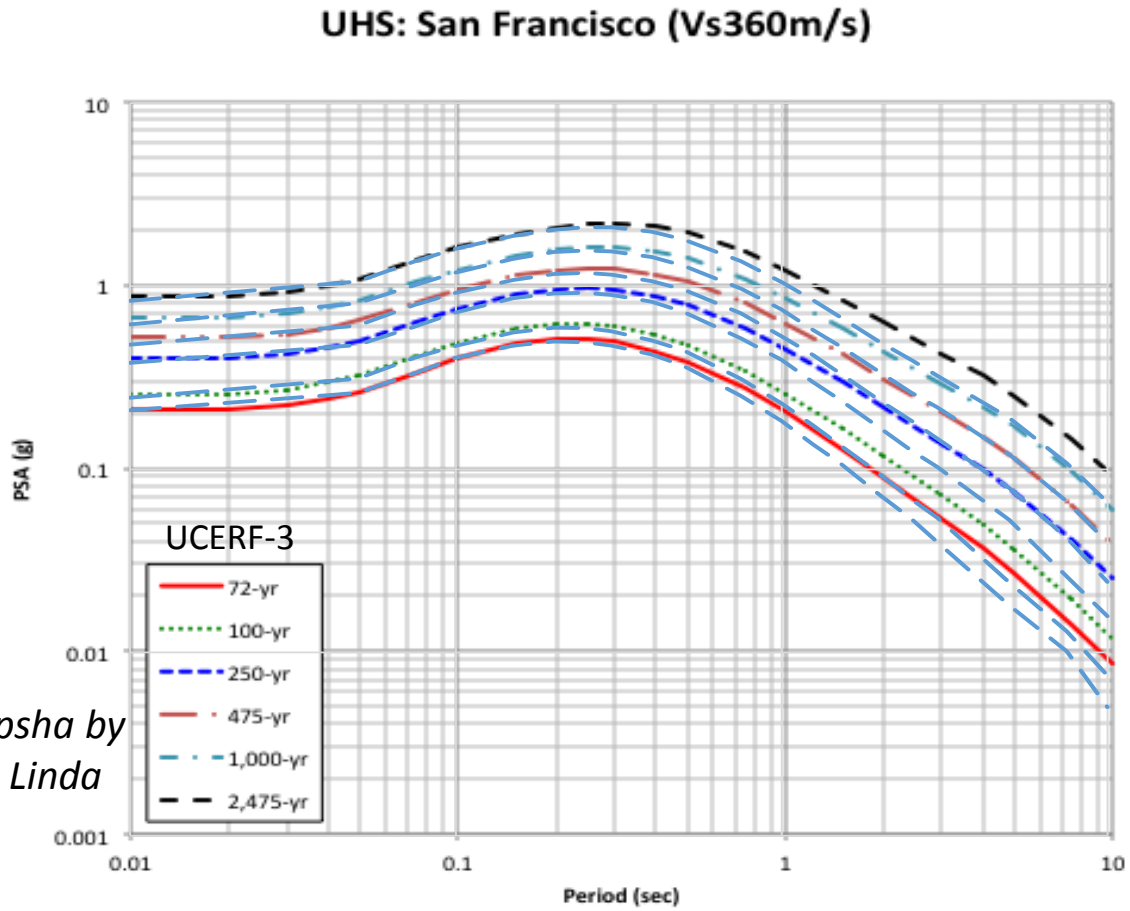


Quick psha by Nick & Linda

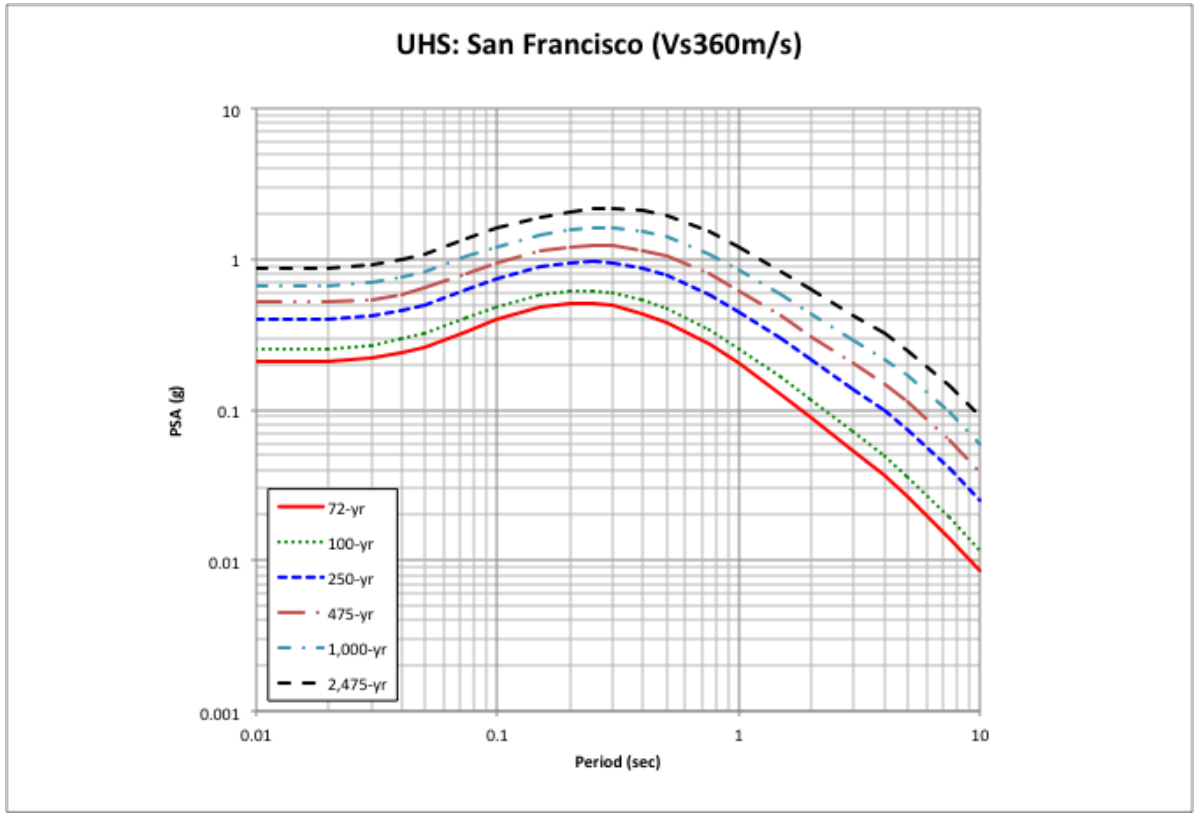
UCERF-2

- SFO_VS360, RP:72
- SFO_VS360, RP:100
- SFO_VS360, RP:1000
- SFO_VS360, RP:250
- SFO_VS360, RP:475
- SFO_VS360, RP:2475

Quick psha by Silvia

5. Define Uniform-Hazard Spectra

- Determine hazard levels considered, Return Period:
  - RP: 100,250,475,1000,2475



- Will be discussed in detail by Nick and Linda

PANEL DISCUSSION:

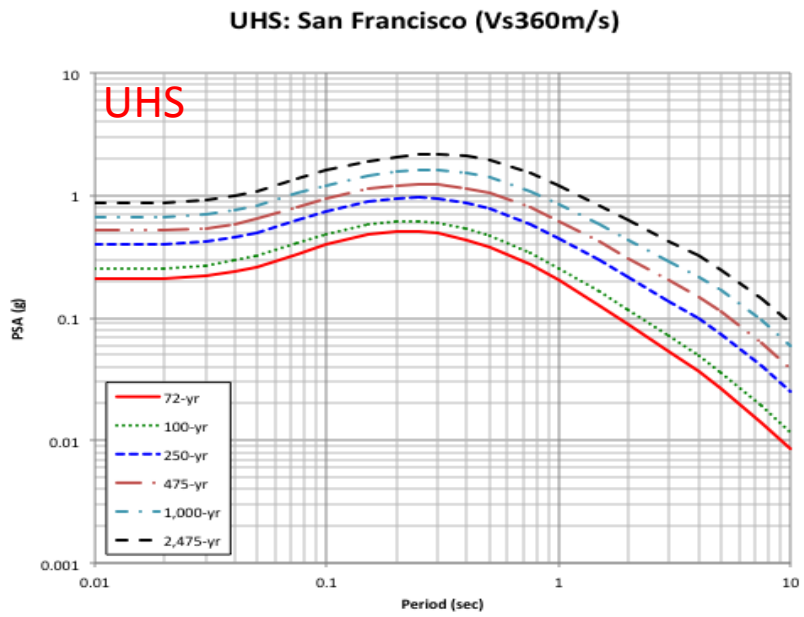
- Approve Hazard Levels: RP: 100,250,475,1000,2475

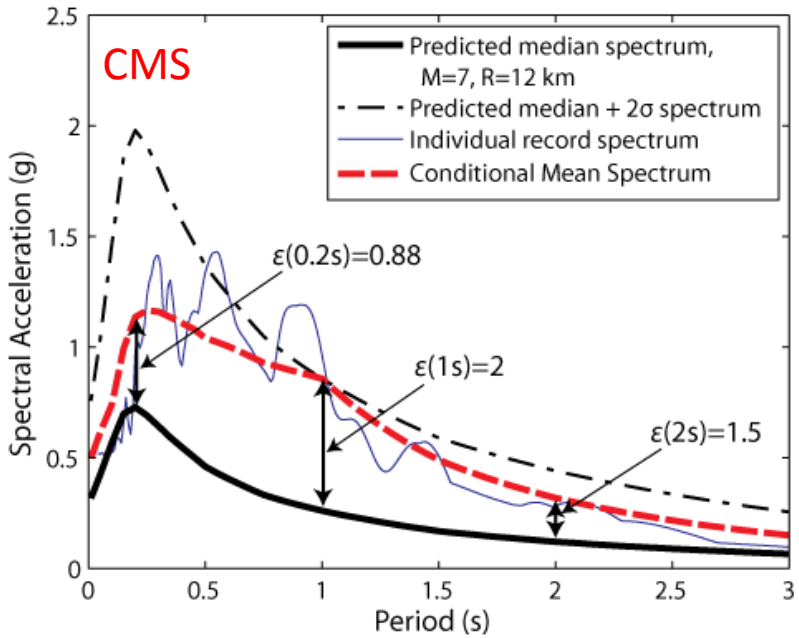
6. Define Target Spectra

- Deterministic Spectrum
  - Simple Magnitude and Distance spectrum
- Uniform-Hazard Spectrum
  - Series of hazard spectra: RP: 72,100,250,475,1000,2475
  - Advantage: one spectrum per hazard level
- Conditional Spectra
  - Conditioning Period
    - Number of Periods
    - Value of Periods
  - Epsilon0 values
  - Advantage: more realistic representation of ground motions
  - Disadvantage: one spectrum per hazard level + conditioning period

PANEL DISCUSSION:

- Approve no Deterministic
- UHS vs CMS
- If CMS:
  - Tconditioning
  - Epsilon0



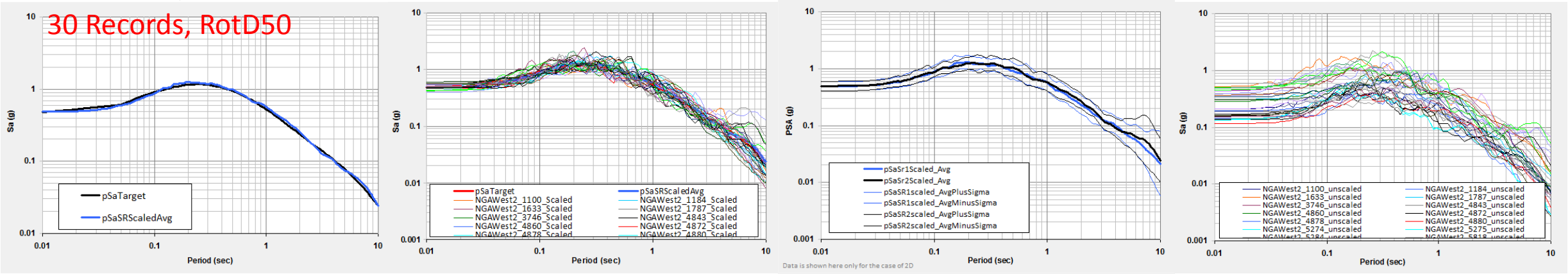


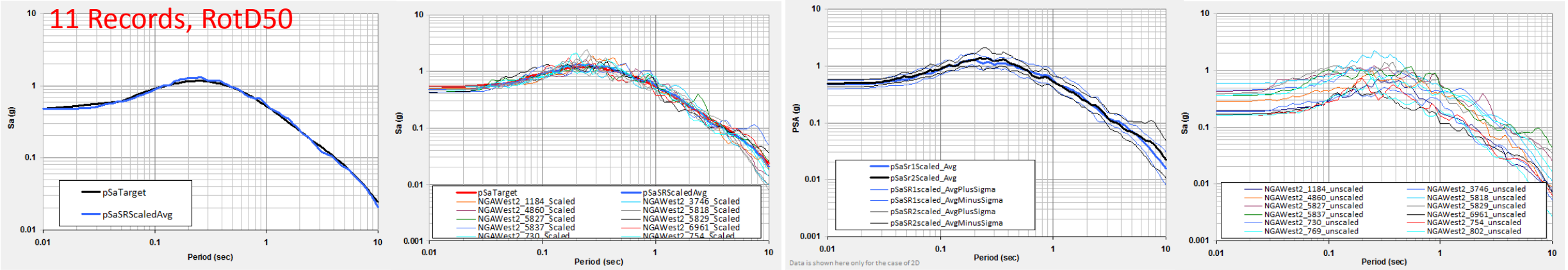
7. Number of Ground Motions in Each Suite

- Use of Suite:
  - Fragility Curves for analysis, larger suite
  - Experimental, limited suite
- Variability

PANEL DISCUSSION:

- Set limits on number of records per suite



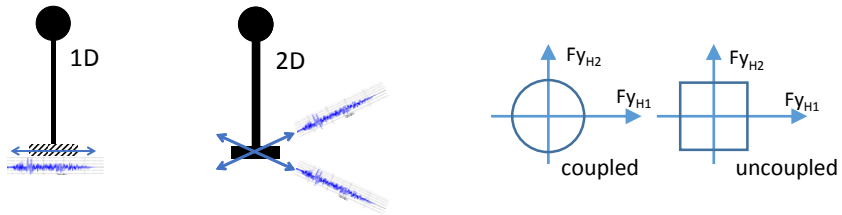


Suite Average rotD50 | Scaled rotD50 | H1,H2 | Unscaled rotD50

8. Record Dimensions & Directionality

The target spectrum (UHS or CMS) is in terms of RotD50

- 1D
  - Ground Motion:
    - Use H1 and H2 records individually
    - Spectrum Modification (tight or mean) makes most sense in 1D
  - Analysis Model:
    - 1D hysteretic model
- 2D
  - Ground Motion:
    - RotD50 or SRSS
    - If you modify a record, you should recalculate RotD50
    - Can use a proxy for modification, it should work well
  - Analysis Model
    - 2D coupled model
      - Most equivalent to a SDOF system
      - Independent of rotation, need a single analysis
    - 2D uncoupled model
      - Can use 1D model for analysis of each ground motion separately
      - Need to analyze all rotations
  - Record Application
    - Apply H1 & H2
    - Measure H1 and H2 response, or Maximum, Geomean, or RotD50?
    - Do we look at the maximum of both directions?



Discussion Topics

- **Which is more realistic?**
- **Which is more informative?**
- **Which are most practical for fragility curves?**

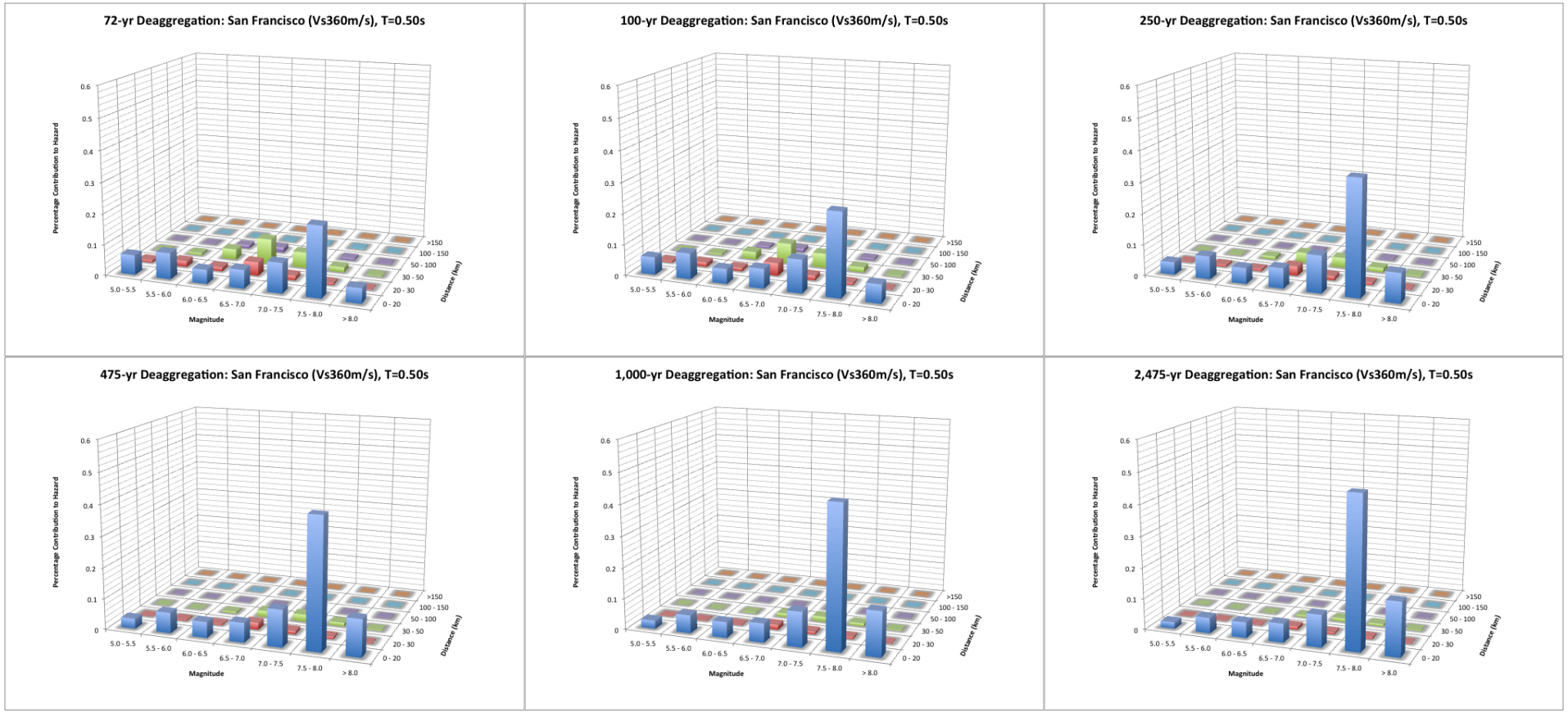
PANEL DISCUSSION:

- Dimension: 2D or 1D
- If 2D:
  - Spectrum Resultant (rotD50?)
  - Analysis model, coupled or uncoupled
  - Measure H1, H2, max(H1,H2), rotD50, Geomean, resultant?

9. Search Records

PANEL DISCUSSION

- limit on number of records per event



10. Synthetic Records

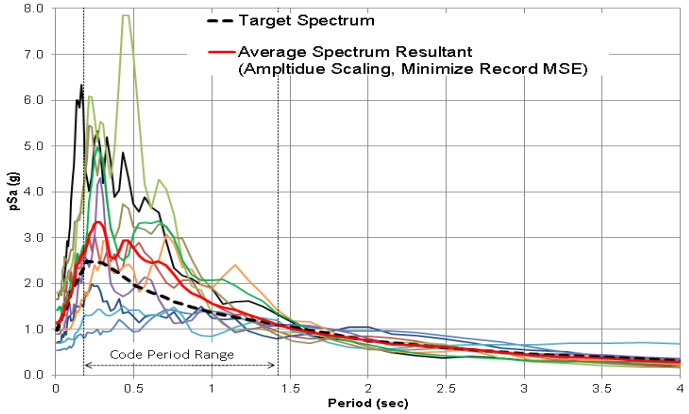
- Simulated synthetic ground-motion database
  - These synthetic records were generated as parts of the NGA-West1 and NGA-West2 projects
  - Combine with recorded motions
  - Demonstrate that they are reliable and applicable
- Compensate for cases where recorded ground motions are not available
- If still insufficient, recommendations for generating new synthetic ground motions will be made to the CEA
- Generation of new synthetic records is outside the scope of this project

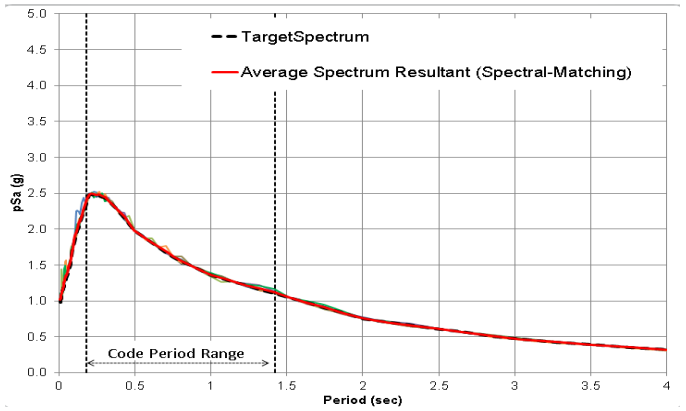
PANEL DISCUSSION:

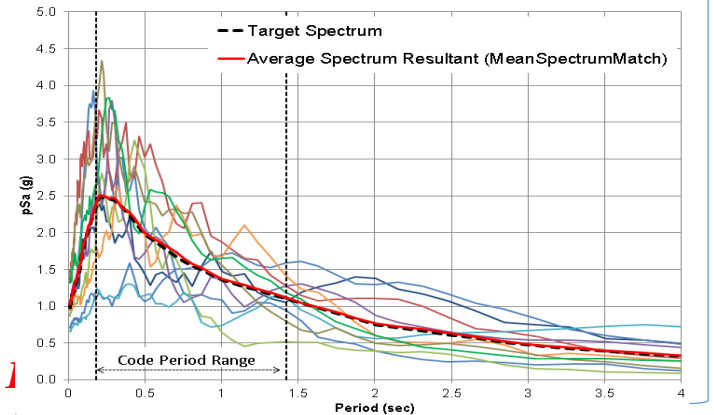
- Do we need them?

11.Ground-Motion Scaling & Modification

- **Amplitude Scaling**
  - Apply scalar scale factor to record
  - The same scale factor is applied to both components in a pair
  - No frequency-content modification to record
  - Maintain record-to-record variability
  - Maintain variability along periods (peaks and valleys)
  - Maintain characteristic period
- **Spectral Matching**
  - Modify frequency content of each record to match that of the target spectrum
  - Ground-motion modification is performed in the time domain
  - No record-to-record variability
  - No variability along periods (no peaks and valleys)
  - Controls amplification of higher modes
- **Mean-Spectrum Modification**
  - Modify frequency content of each record such that the average of the suite matches the target spectrum
  - Minimal modification to record
  - Maintain record-to-record variability
  - Maintain variability along periods (peaks and valleys)







Need a proxy for rotD50

11.Ground-Motion Scaling & Modification

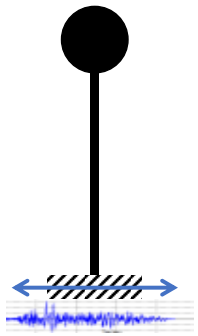
PANEL DISCUSSION

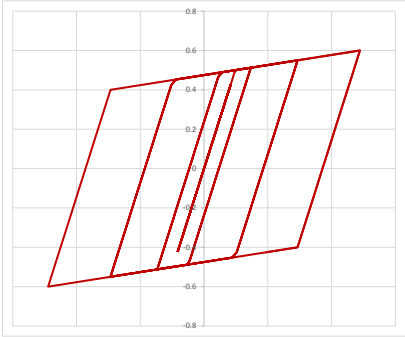
- Which methods to consider
  - Amplitude Scaling
    - No frequency-content modification to record
    - Maintain record-to-record variability
  - Spectral Matching
    - Control Spectrum shape
    - No record-to-record variability
  - Mean-Spectrum Modification
    - Minimal modification to record
    - Maintain record-to-record variability
    - Maintain variability along periods (peaks and valleys)

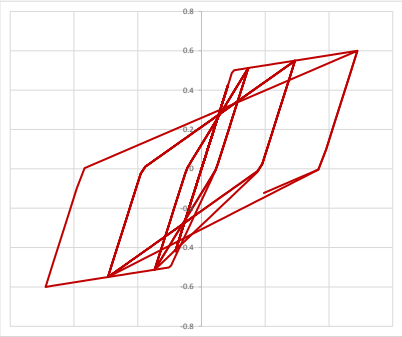
- In 2D analysis, modification can change results, we need to consider a proxy and check it. How do we reconcile the rotD50.
  - Need 2D modification, or proxy

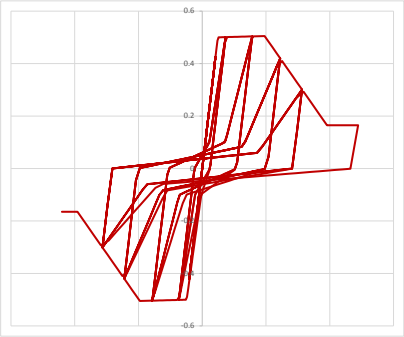
12. Inelastic Spectra

- Determine "DAMAGE POTENTIAL" by computing inelastic spectra of selected and scaled ground motions
- Define characteristic hysteretic behavior to represent different types of structures
  - Represent critical characteristics of wood frame houses with and without deficient cripple walls



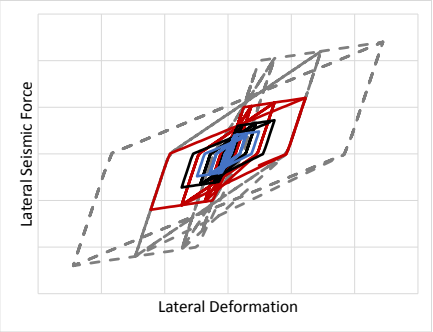


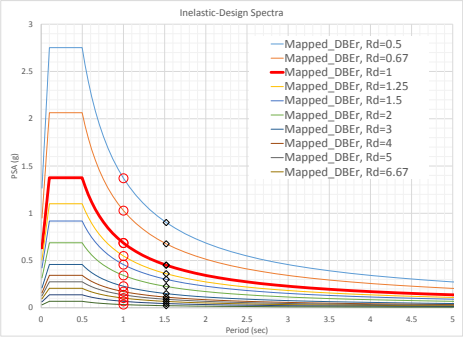


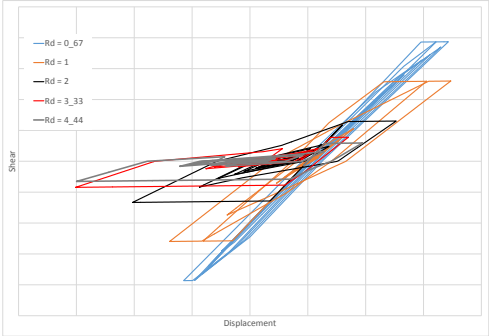


PANEL DISCUSSION
Confirm inelastic models are consistent with those used by the analyst

- Define different levels of strength to represent different levels of retrofit:
  - Retrofit vs. unretrofit







- Determine characteristics of ground motions which affect the inelastic response of unretroffited homes

13. Delivery

- All ground-motion suites will be scaled and modified before being delivered to analysts

PANEL DISCUSSION

- Any additional considerations?

14. Variability & Uncertainty

- Investigate Variability and Uncertainty of ground motions
  - Characterize sources of variability and uncertainty
  - Characterize amount of variability and uncertainty
- Investigate impact of variability and uncertainty on the elastic and inelastic response of SDOF models
- Interpret results to determine effects on wood frame house with and without deficient cripple walls
- Variability is considered in the PSHA

- Record-to-Record Variability
- Period-to-Period Variability (peaks and valleys)

PANEL DISCUSSION

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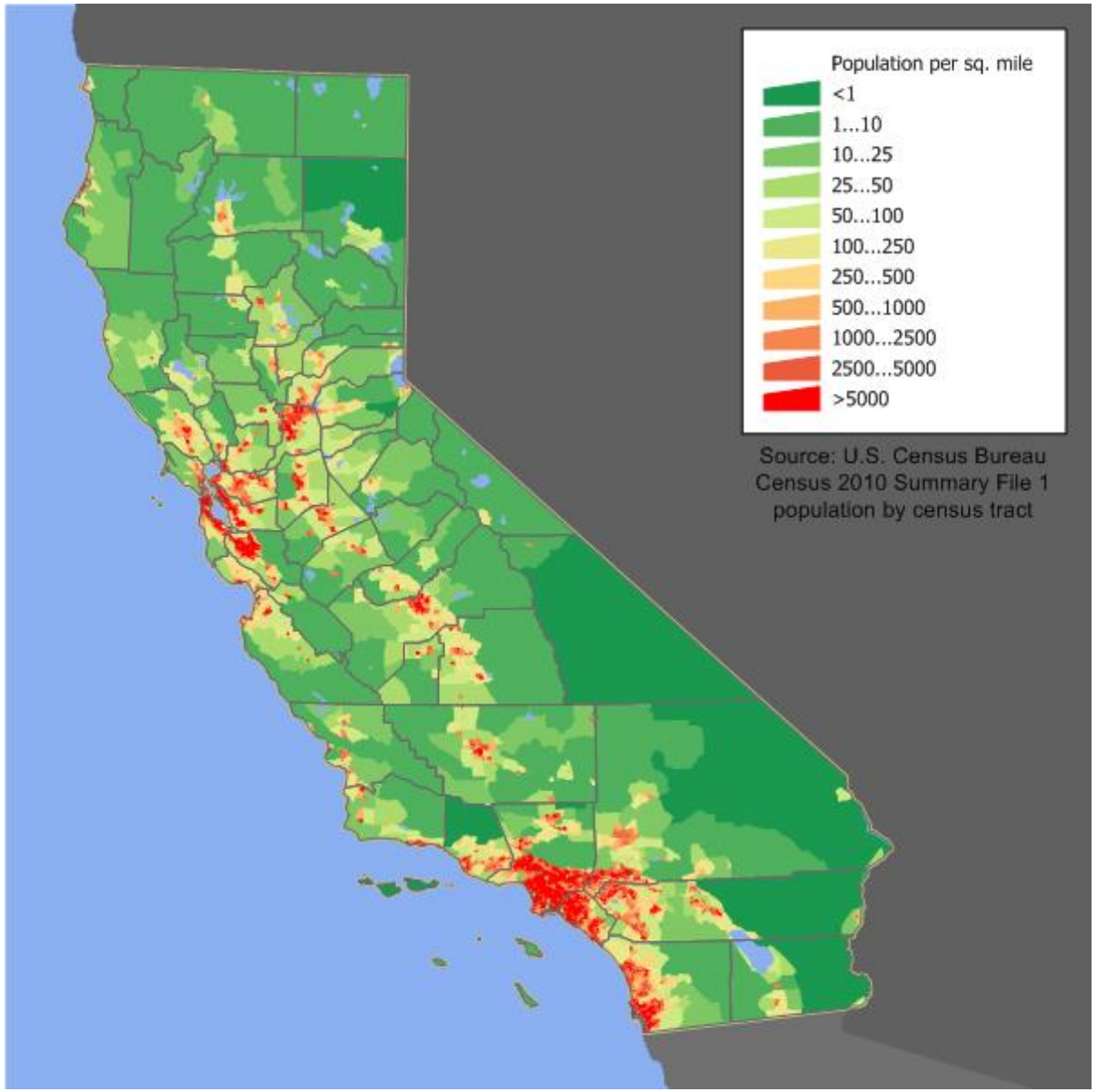
Site Selection

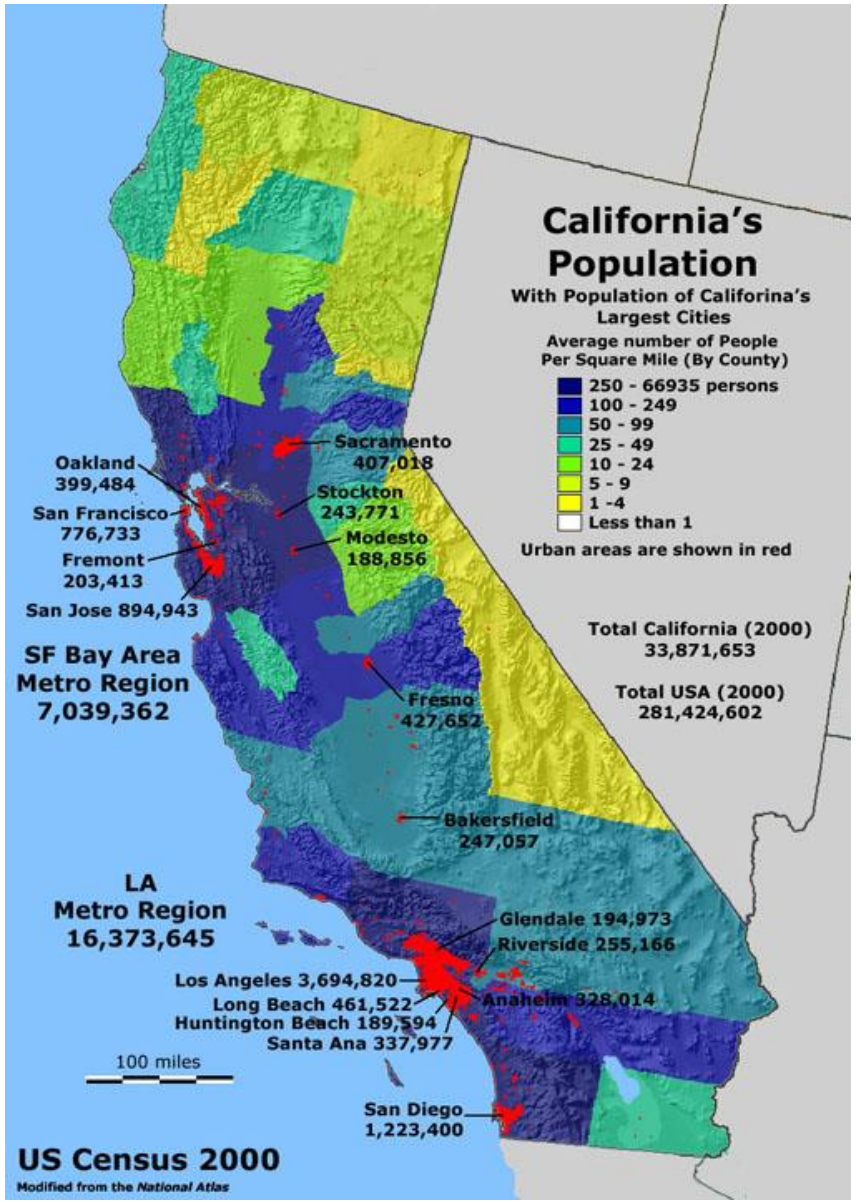
	City	Population	Pop. Rank
1.	Los Angeles	3,971,883	1
2.	San Diego	1,394,928	2
3.	San Jose	1,026,908	3
4.	San Francisco	864,816	4
5.	Sacramento	490,712	6
6.	Long Beach	474,140	7
7.	Oakland	419,267	8
8.	Bakersfield	373,640	9
9.	San Bernardino	216,108	17
10.	San Fernando	24,931	300

Considered Set:

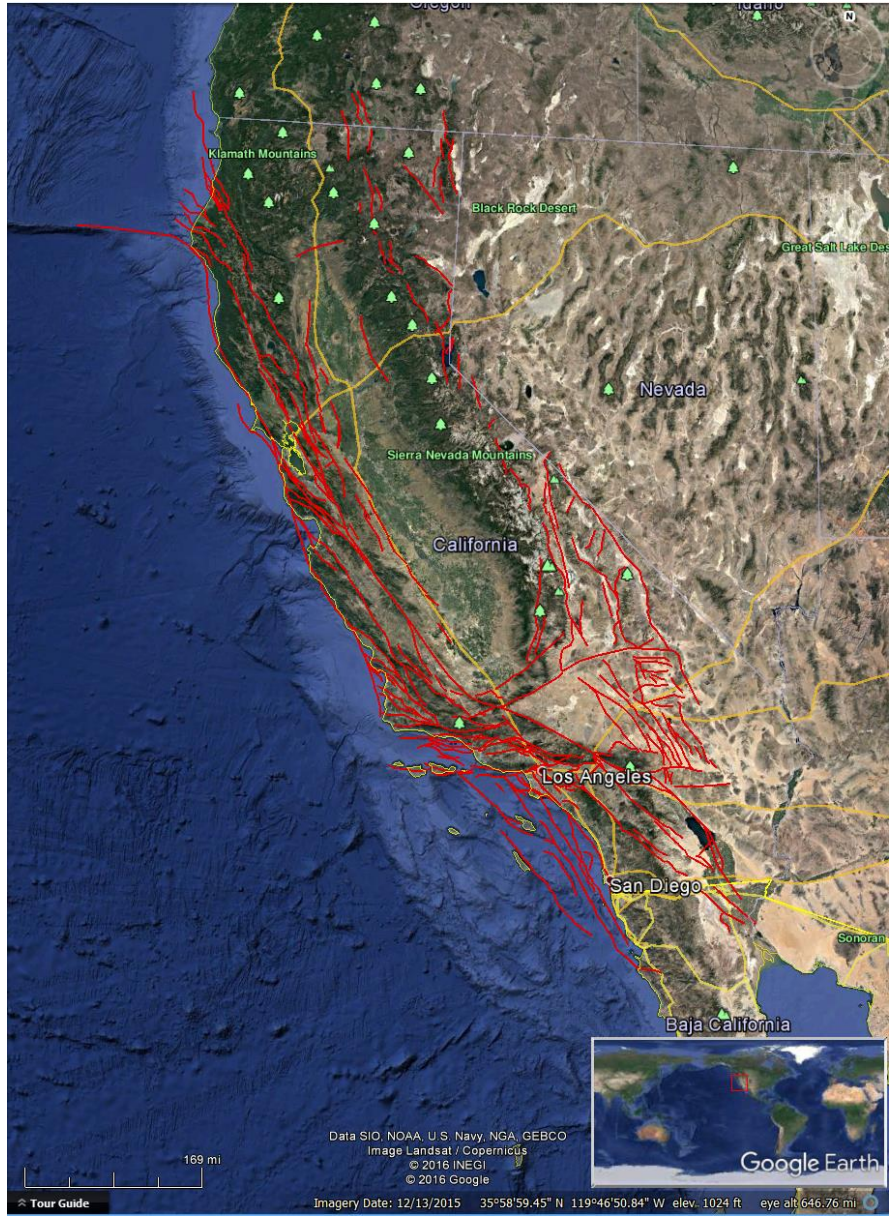
City	Population	Population Rank	Notes/recommended
• Los Angeles	3,971,883	1	*
• San Diego	1,394,928	2	*
• San Jose	1,026,908	3	*
• San Francisco	864,816	4	*
• Fresno	520,052	5	Expected similar PSHA results to Sacramento
• Sacramento	490,712	6	*
• Long Beach	474,140	7	*
• Oakland	419,267	8	*
• Bakersfield	373,640	9	*
• Anaheim	350,742	10	
• Santa Ana	335,400	11	
• Riverside	322,424	12	
• Stockton	305,658	13	Expected similar PSHA results to Sacramento
• Chula Vista	265,757	14	
• Irvine	256,927	15	
• Fremont	232,206	16	
• San Bernardino	216,108	17	*
• Modesto	211,266	18	Expected similar PSHA results to Sacramento
• Fontana	207,460	19	
• Oxnard	207,254	20	
• Santa Monica	93,220	81	
• San Fernando	24,931	300	Selected for Site in San Fernando Valley*
• Napa	76,915		
• Walnut Creek	66,900		
• San Mateo	103,536	70	
• Golden Gate Park	864,816		
• Milbrae	22,424		

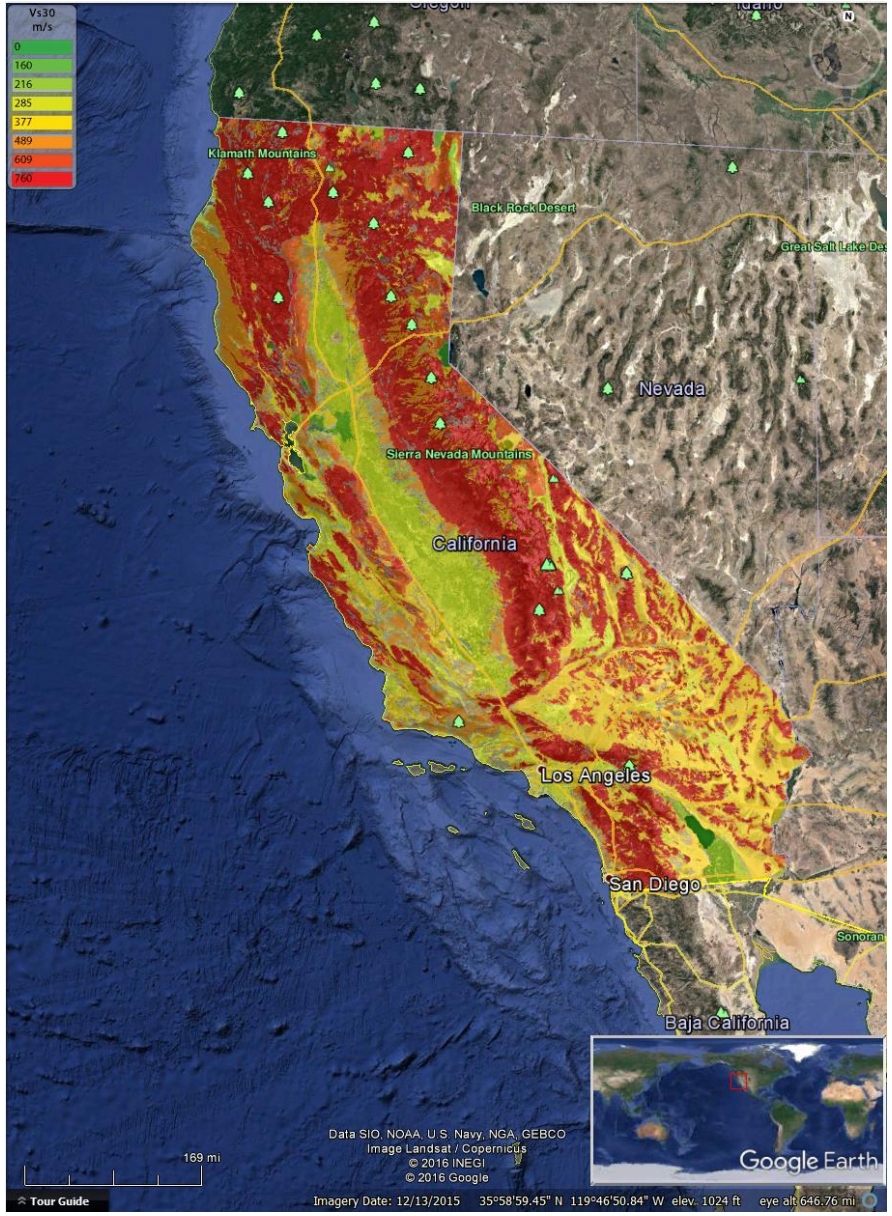
CA Population Densities





UCERF-3, Vs30


Klamath Mountains
Black Rock Desert
Great Salt Lake Des
Nevada
Sierra Nevada Mountains
California
Los Angeles
San Diego
Sonoran
Baja California
169 mi
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image Landsat / Copernicus
© 2016 INEGI
© 2016 Google
Google Earth
Tour Guide
Imagery Date: 12/13/2015 35°58'59.45" N 119°46'50.84" W elev. 1024 ft eye alt 646.76 mi


Vs30
m/s
0
160
216
285
377
489
609
760
Klamath Mountains
Black Rock Desert
Great Salt Lake Des
Nevada
Sierra Nevada Mountains
California
Los Angeles
San Diego
Sonoran
Baja California
169 mi
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
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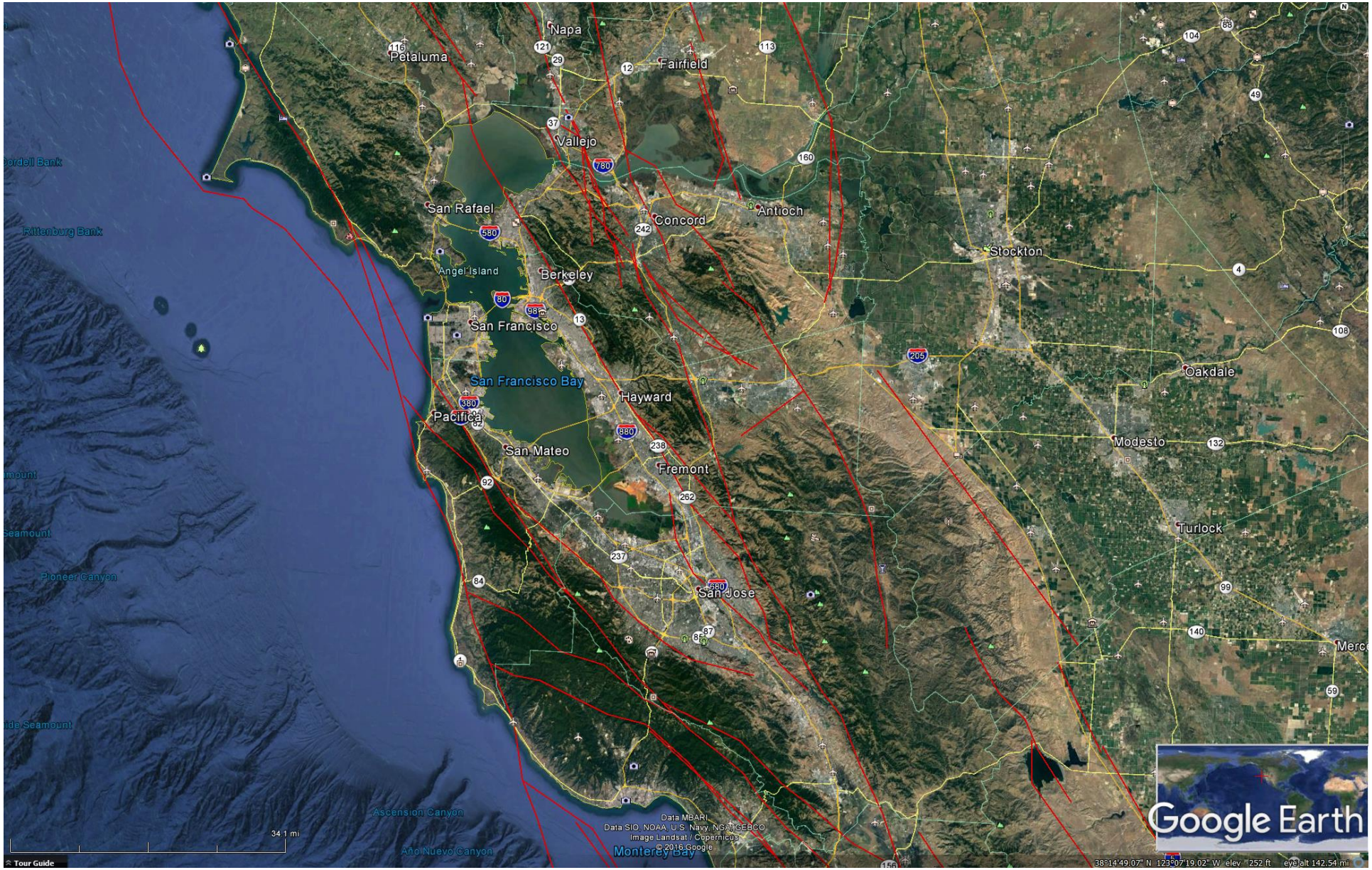
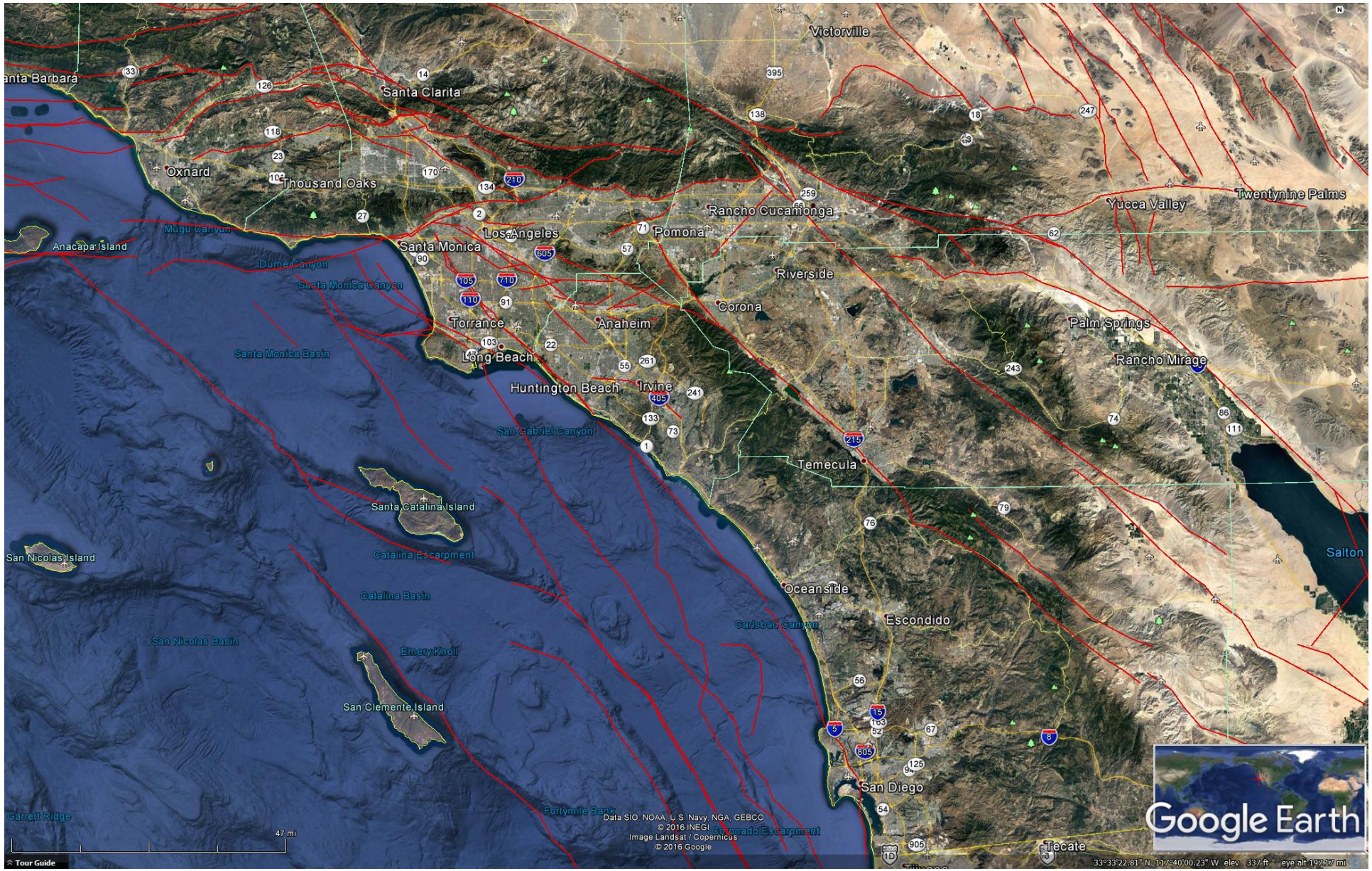
Google Earth
Tour Guide
Imagery Date: 12/13/2015 35°58'59.45" N 119°46'50.84" W elev. 1024 ft eye alt 646.76 mi

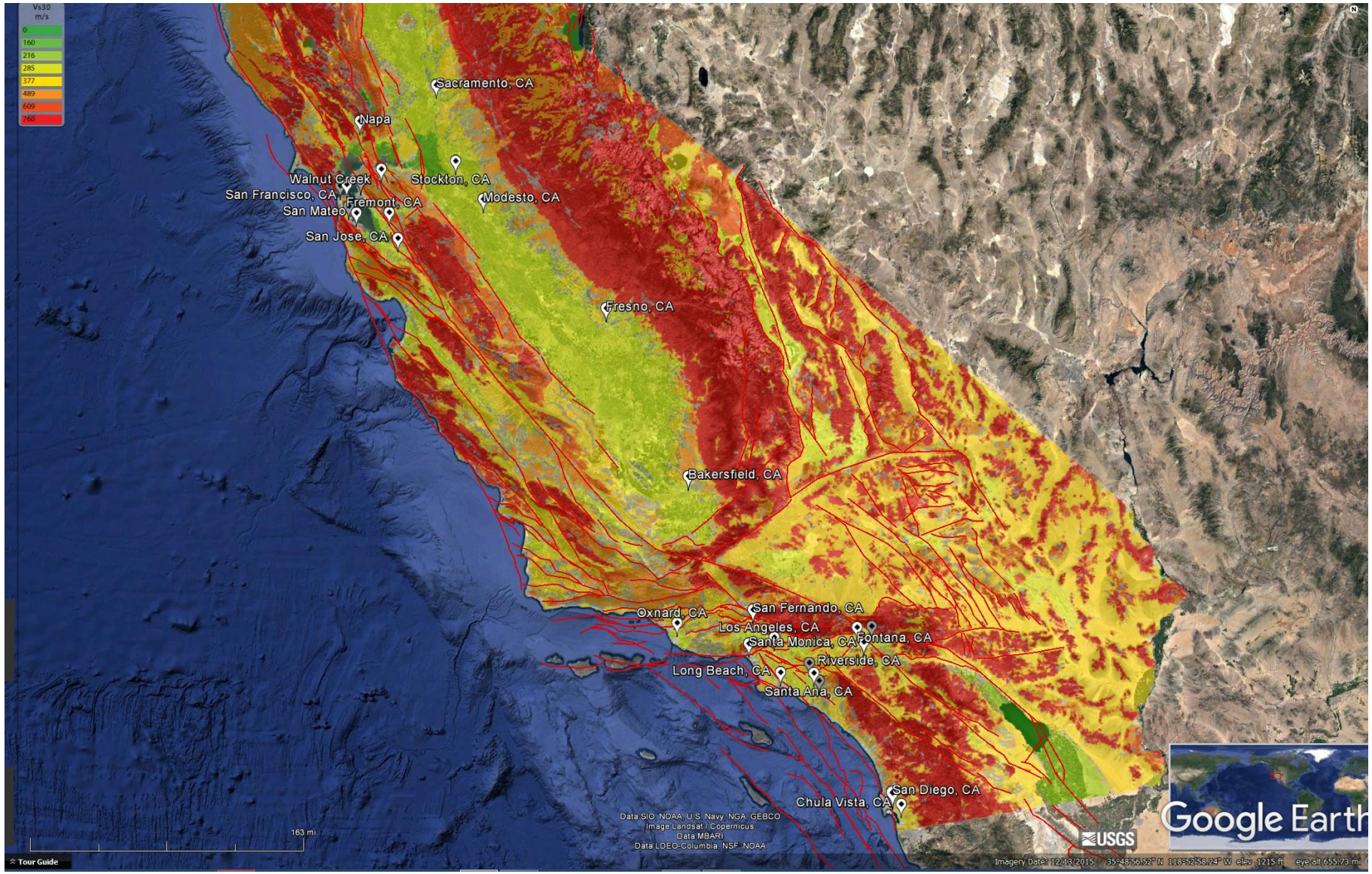
UCERF-3, NorCal



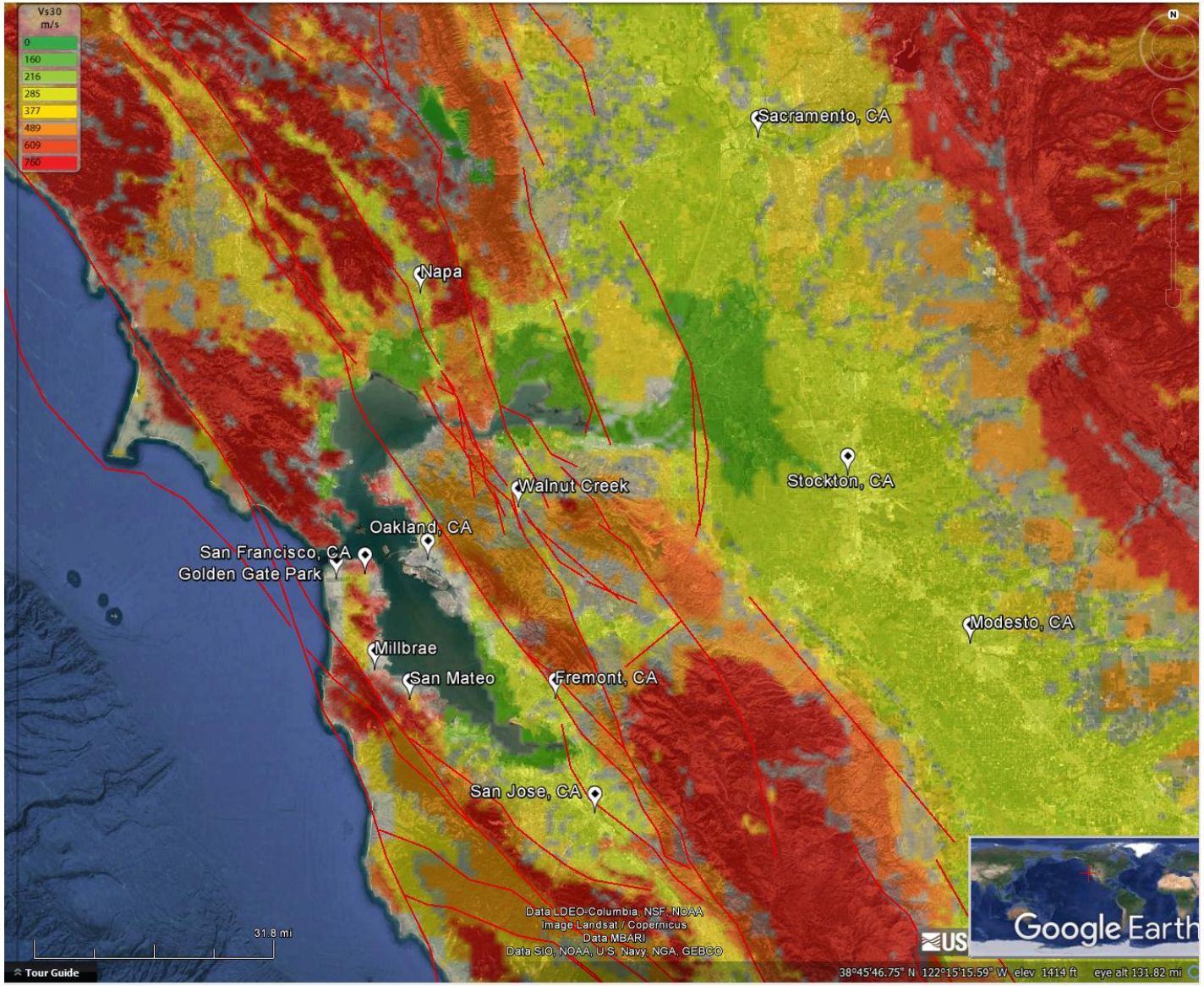
UCERF-3, SoCal



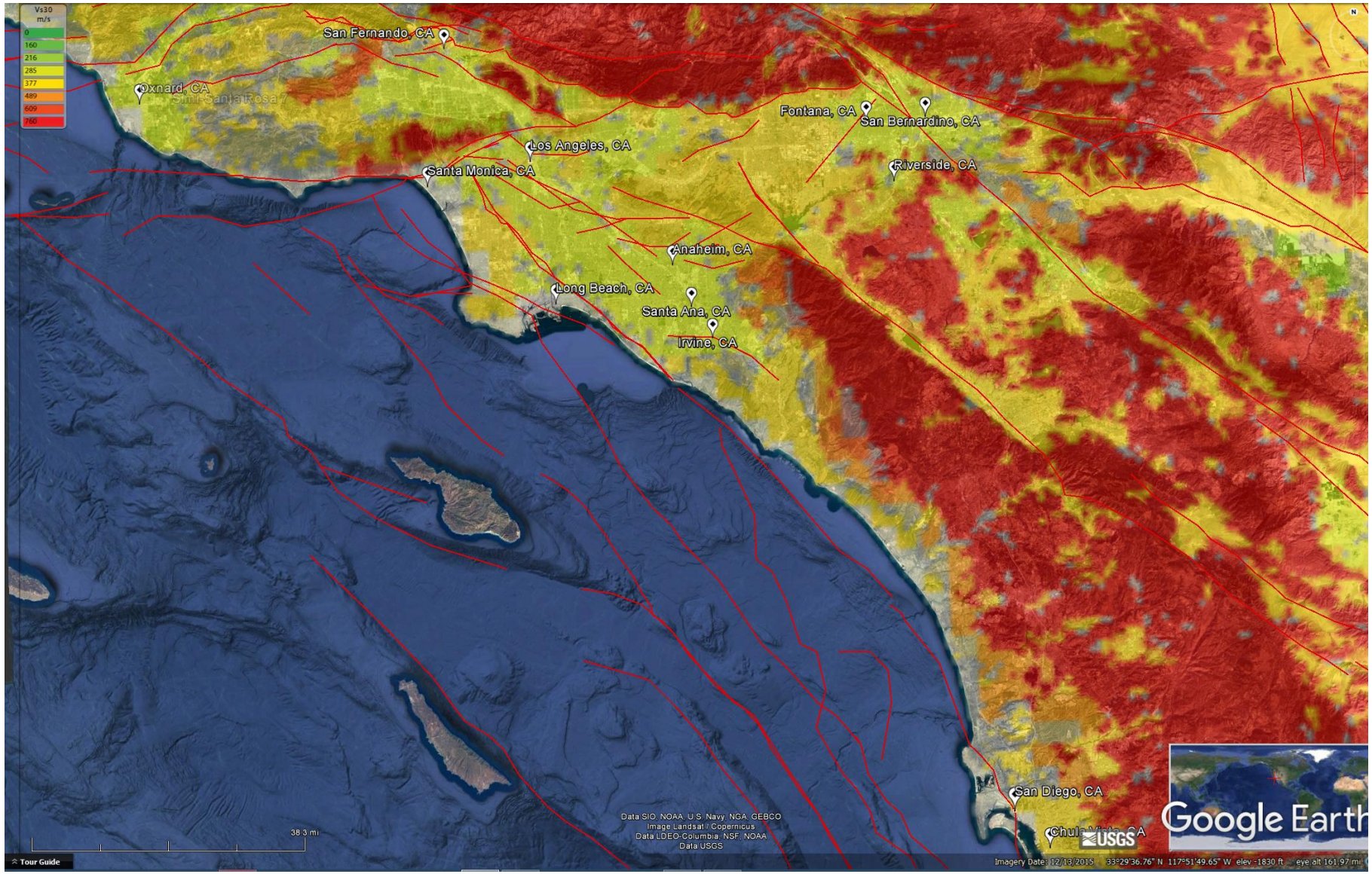
Considered Sites:



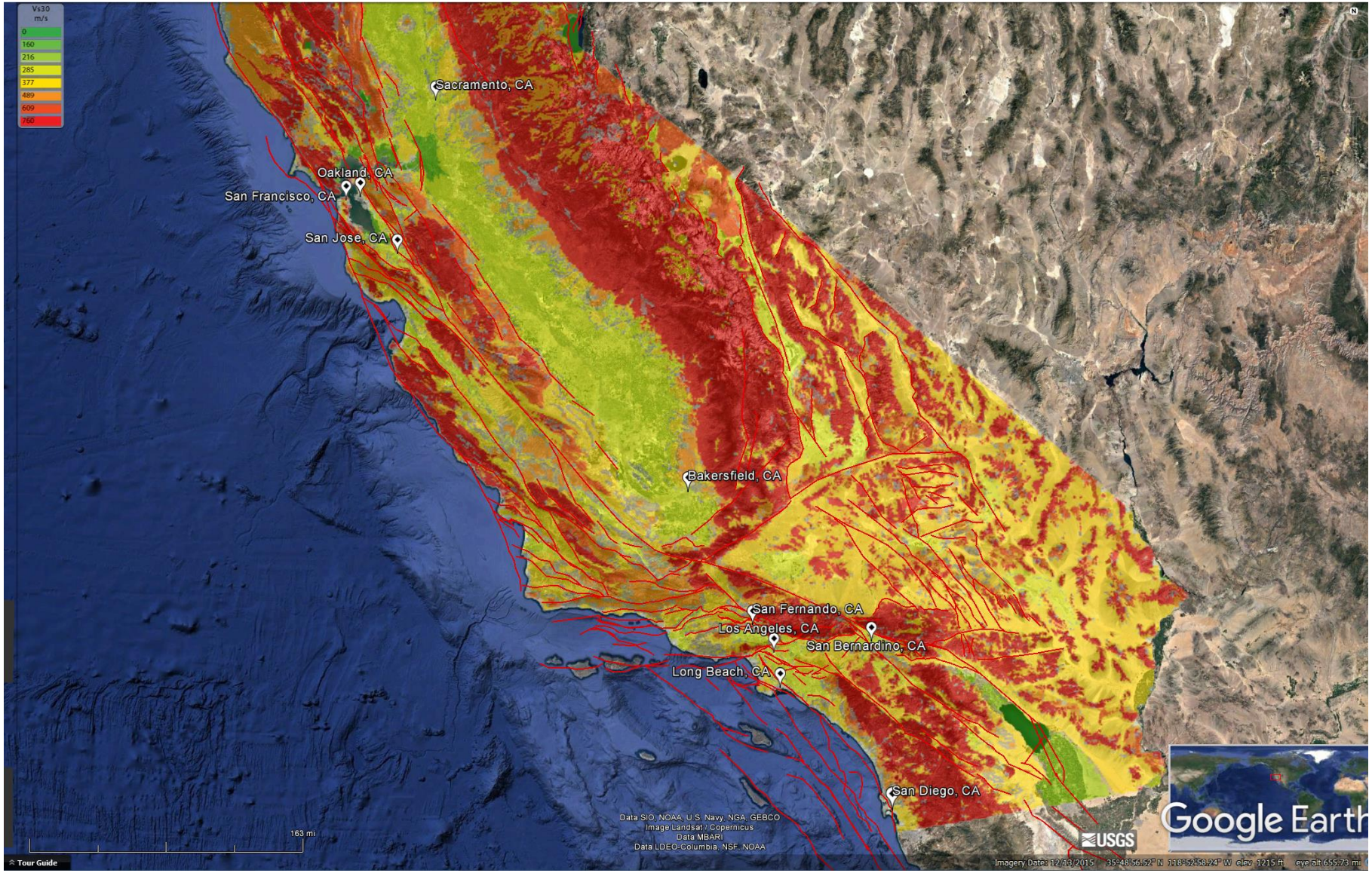
Considered Sites, NorCal



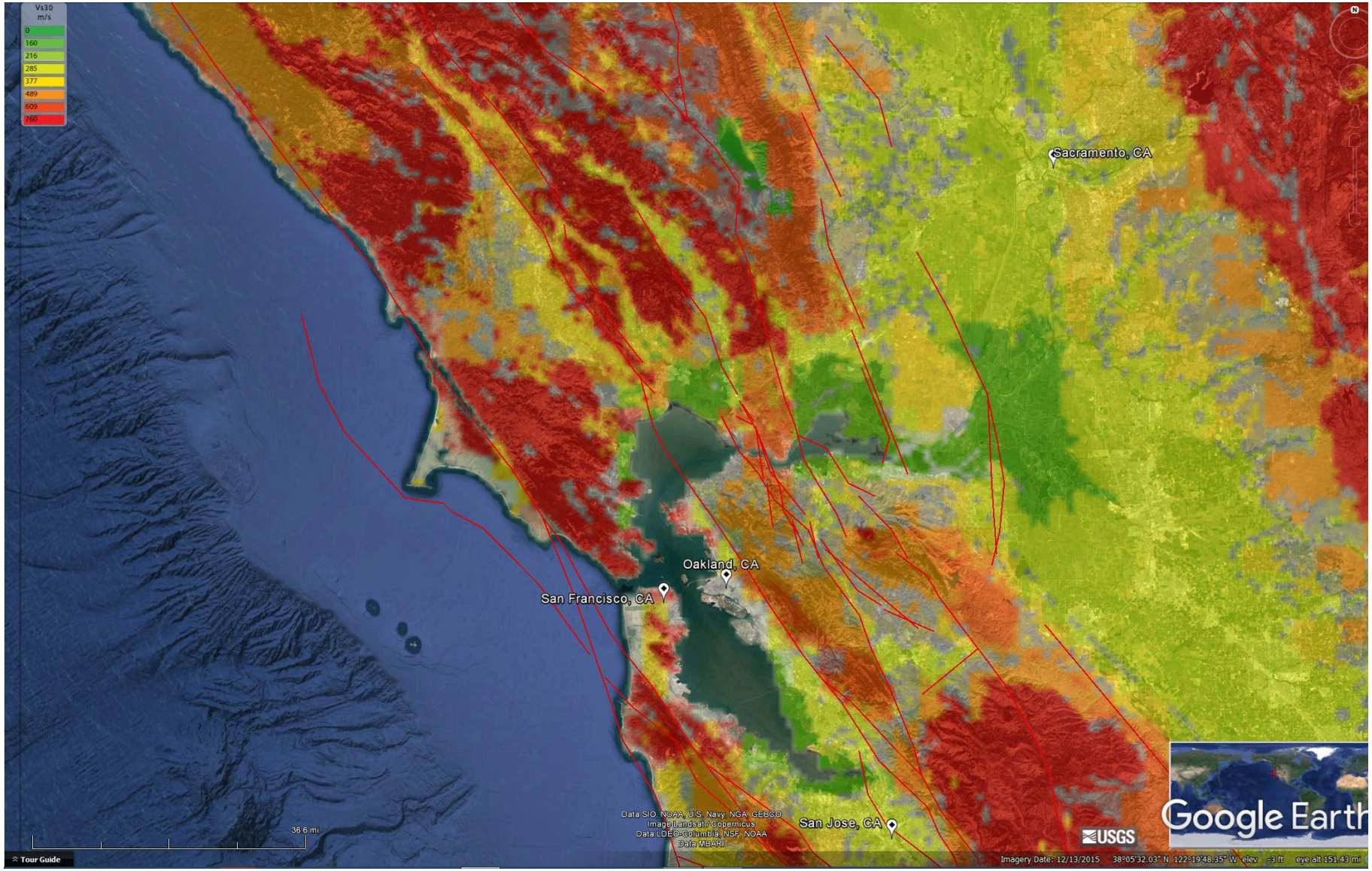
Considered Sites, SoCal



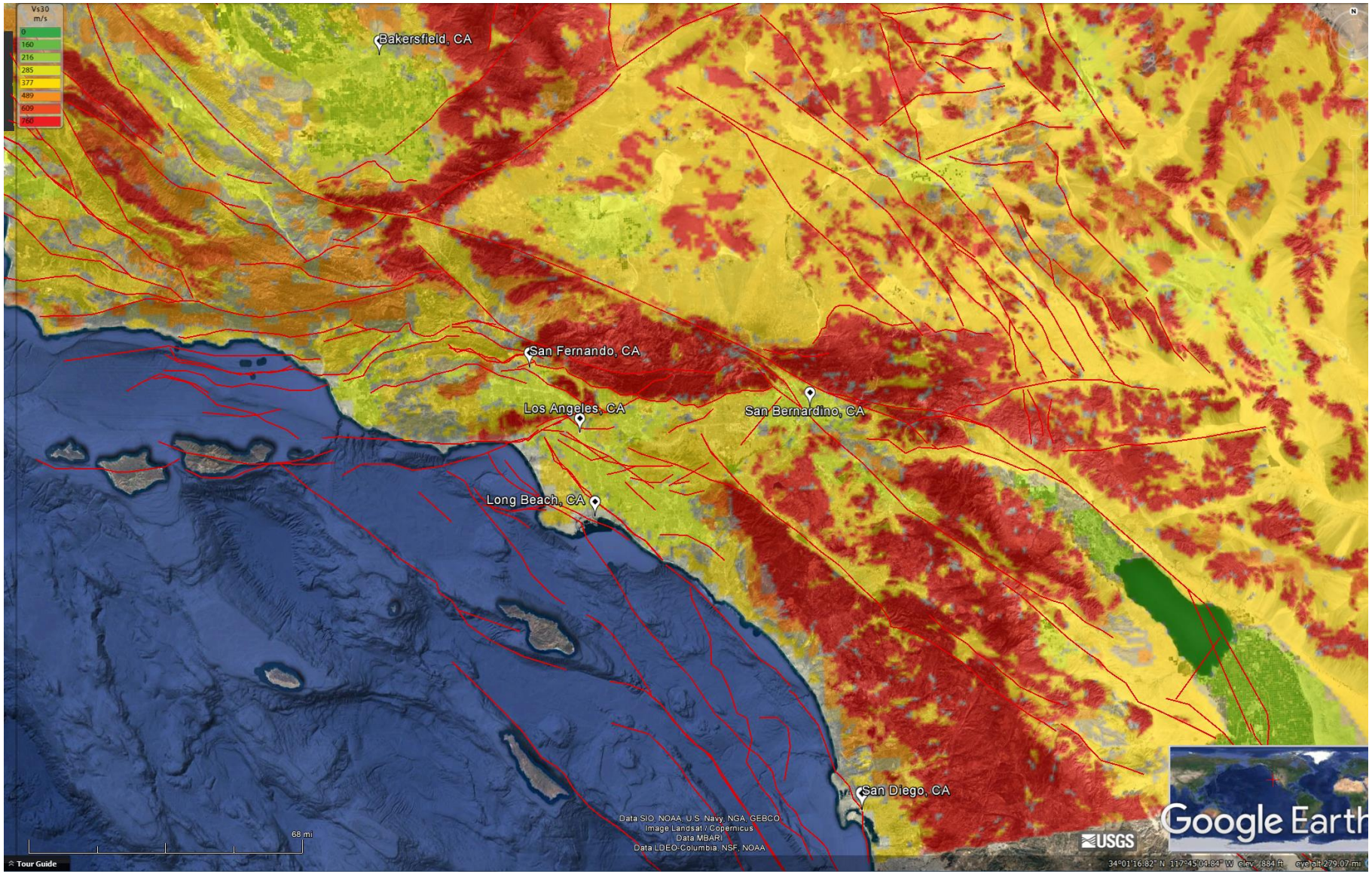
Selected Sites (10)



Selected Sites, NorCal (4)



Selected Sites, SoCal (6)



Selected Sites, Vs30

Label	Latitude	Longitude	Vs30 (m/sec)	Soil Class
Los Angeles, CA	34.053527	-118.2429	363	D
San Diego, CA	32.71815	-117.1643	392	C
San Jose, CA	37.337848	-121.8861	263	D
San Francisco, CA	37.77926	-122.4193	396	C
Sacramento, CA	38.581892	-121.4935	235	D
Long Beach, CA	33.768036	-118.1956	302	D
Oakland, CA	37.805305	-122.2725	223	D
Bakersfield, CA	35.37368	-119.0205	218	D
San Bernardino, CA	34.104571	-117.2928	328	D
San Fernando, CA	34.284096	-118.4389	347	D
		average	307	D

http://earthquake.usgs.gov/hazards/apps/vs30/

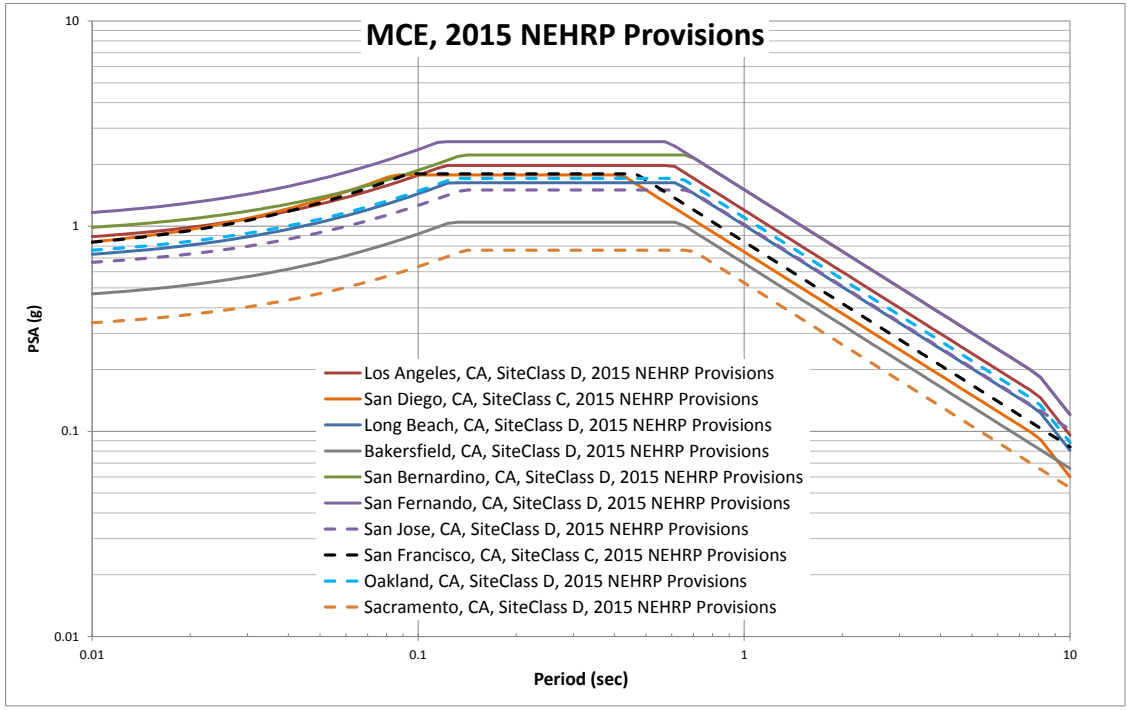
Nearest Fault

1	SiteLabel	siteLongitude	siteLatitude	parentSectionName	FaultTraceName	ClosestDistanceK
2	San Diego	-117.1642655	32.7181497	Rose Canyon	Rose Canyon 6	0.13
3	San Fernando	-118.4388955	34.284096	Sierra Madre (San Fernando)	Sierra Madre (San Fernando) 3	1.29
4	San Jose	-121.8861262	37.3378484	Silver Creek 2011 CFM	Silver Creek 2011 CFM 6	1.63
5	Los Angeles	-118.2429316	34.0535267	Elysian Park (Upper)	Elysian Park (Upper) 2	1.72
6	Long Beach	-118.1956387	33.7680362	Compton	Compton 2	1.98
7	San Bernardino	-117.2927641	34.1045714	San Jacinto (San Bernardino)	San Jacinto (San Bernardino) 4	2.53
8	Oakland	-122.2725459	37.8053046	Hayward (No) 2011 CFM	Hayward (No) 2011 CFM 1	5.90
9	San Francisco	-122.4192646	37.7792597	San Andreas (Peninsula) 2011 CFM	San Andreas (Peninsula) 2011 CFM 13	12.67
10	Bakersfield	-119.020492	35.3736802	White Wolf	White Wolf 5	31.04
11	Sacramento	-121.4935297	38.5818918	Great Valley 03a Dunnigan Hills	Great Valley 03a Dunnigan Hills 1	33.73

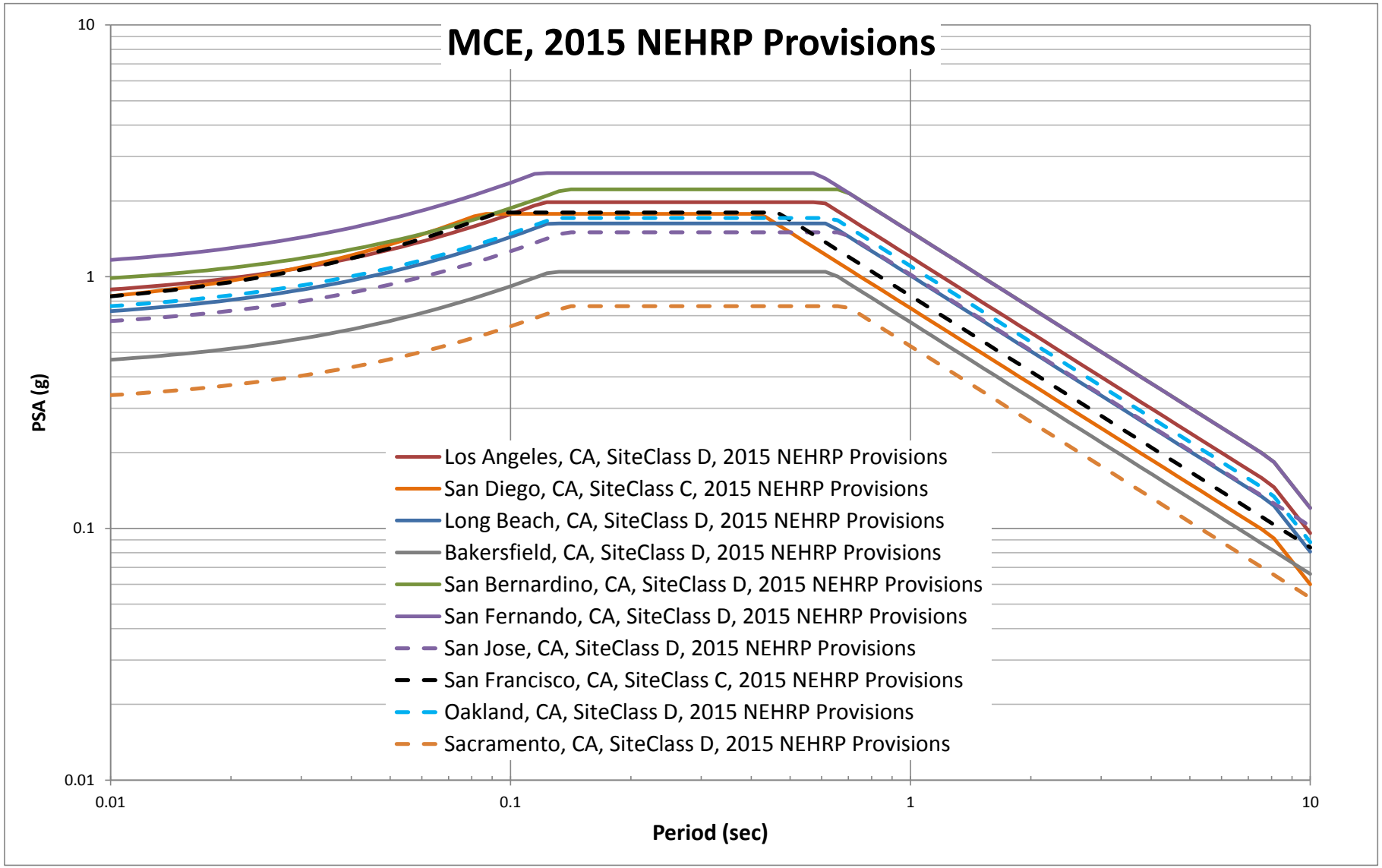
- Building Prototype: Single-Story Wood-Frame Structures
- Period Range of Interest: 0.01-1sec

2015 NEHRP, MCE

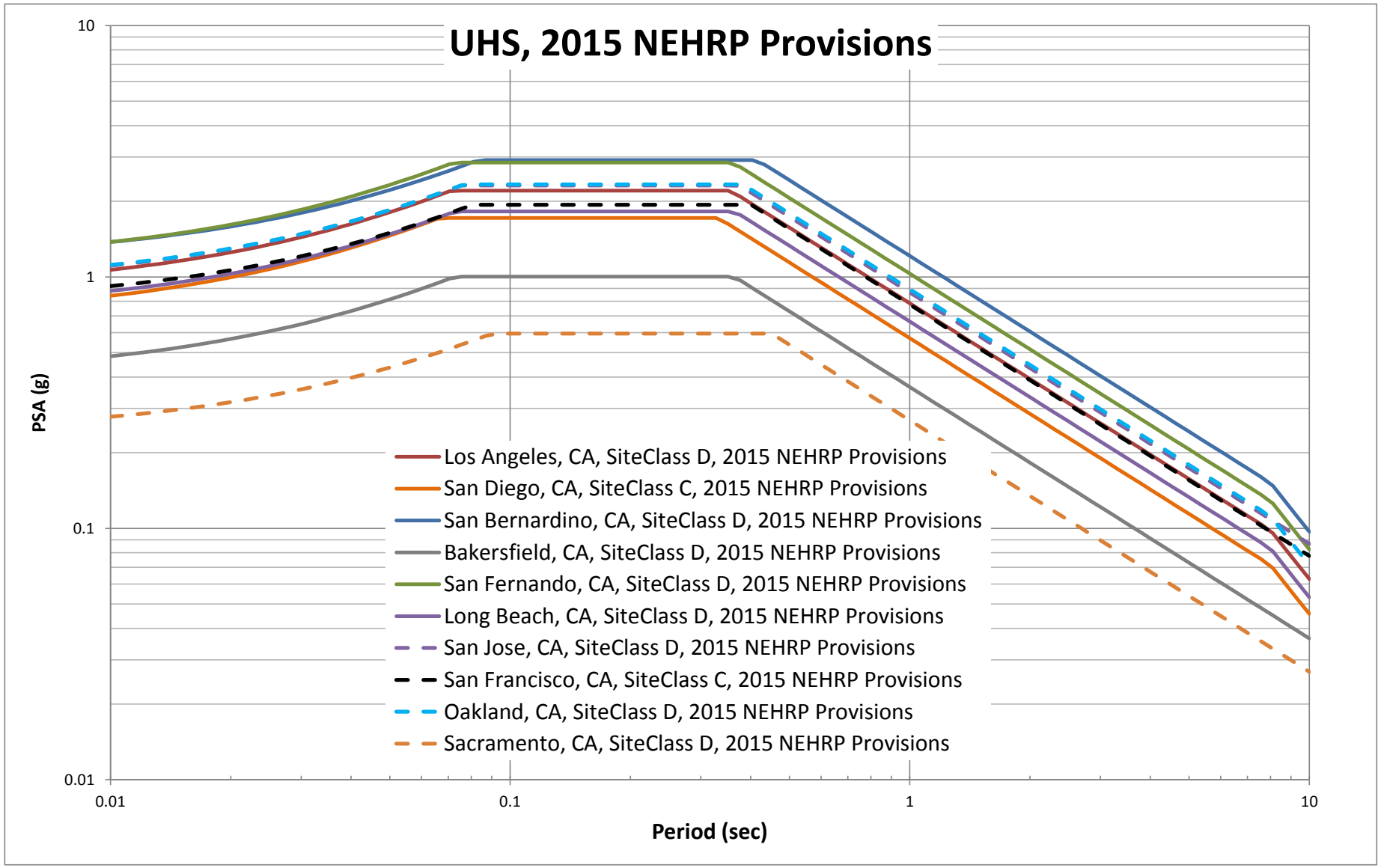
					2015 NEHRP Provisions														
Label	Latitude	Longitude	Vs30 (m/sec)	Soil Class	Ss	S1	SMS	SM1	SDS	SD1	CRS	CR1	Suh	S1uh	Ssd	S1d	Fa	Fv	TL
Los Angeles, CA	34.053527	-118.2429	363	D	1.978	0.705	1.978	1.198	1.318	0.799	0.897	0.897	2.205	0.786	2.475	0.784	1	1.7	8
San Diego, CA	32.71815	-117.1643	392	C	1.482	0.5	1.778	0.75	1.185	0.5	0.863	0.876	1.717	0.571	2.264	0.797	1.2	1.5	8
San Jose, CA	37.337848	-121.8861	263	D	1.5	0.6	1.5	1.02	1	0.68	0.956	0.932	2.311	0.868	1.5	0.6	1	1.7	12
San Francisco, CA	37.77926	-122.4193	396	C	1.5	0.6	1.8	0.84	1.2	0.56	0.926	0.907	1.936	0.777	1.5	0.6	1.2	1.4	12
Sacramento, CA	38.581892	-121.4935	235	D	0.567	0.253	0.763	0.53	0.509	0.353	0.951	0.941	0.596	0.269	1.5	0.6	1.346	2.094	12
Long Beach, CA	33.768036	-118.1956	302	D	1.628	0.592	1.628	1.011	1.085	0.674	0.893	0.891	1.824	0.665	2.125	0.766	1	1.708	8
Oakland, CA	37.805305	-122.2725	223	D	1.711	0.648	1.711	1.102	1.141	0.735	0.922	0.907	2.334	0.894	1.711	0.648	1	1.7	8
Bakersfield, CA	35.37368	-119.0205	218	D	0.926	0.335	1.046	0.659	0.697	0.439	0.923	0.919	1.003	0.365	1.5	0.6	1.13	1.965	12
San Bernardino, CA	34.104571	-117.2928	328	D	2.222	0.887	2.222	1.508	1.482	1.005	0.915	0.889	2.916	1.213	2.222	0.887	1	1.7	8
San Fernando, CA	34.284096	-118.4389	347	D	2.583	0.886	2.583	1.507	1.722	1.005	0.906	0.891	2.853	1.031	2.72	0.886	1	1.7	8



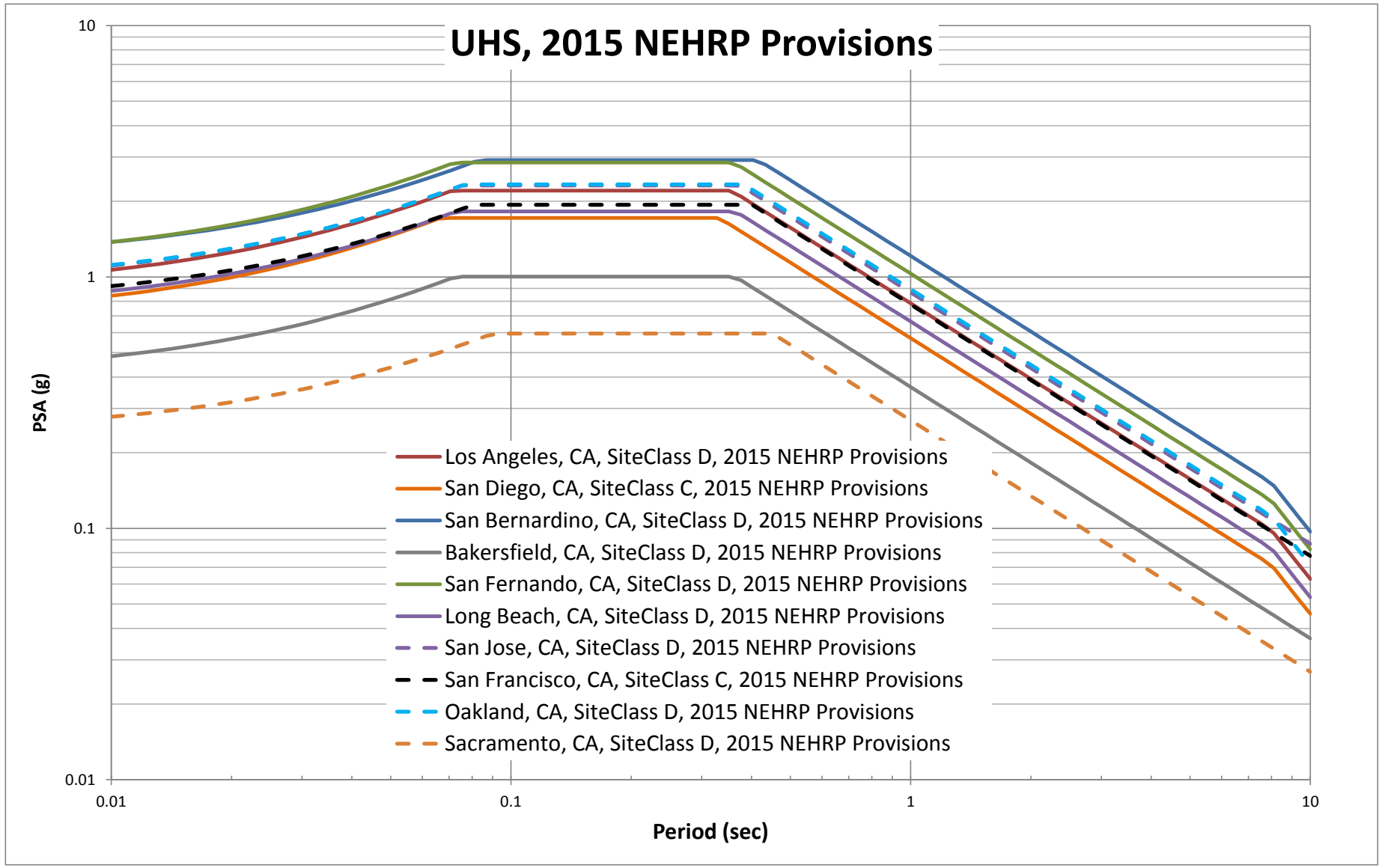
2015 NEHRP, MCE



2015 NEHRP, UHS (Suh,S1uh)



2015 NEHRP, DET (Ssd,S1d)



Methodology

A. Ground motions for analysis

1. Determine objective of ground motions: Fragility-Curve Development
2. Select number of ground-motion suites per site
3. Select Sites & Site
4. Perform Seismic H
5. Define Uniform-H
6. Define Target Spe
   - UHS – one Target
   - CMS – one Target
7. Determine numbe
8. Determine dimen
   - 2D
     - The Targe
     - How do y
   - 1D
     - How do y
     - Decision b
9. Search records ba
10. Consider Syntheti
11. Scale records base
12. Compute inelastic
13. Deliver Records to analyst

B. Ground Motions for experimental testing

1. Define objective of ground motions
2. Select Records based on the objectives and results

sis

h researchers

Topics

Uncertainty

PEER-CEA Woodframe Project: Ground Motion Development

Nick Gregor and Linda Al Atik

March 13th, 2017

PEER-CEA Woodframe Project

PEER-CEA Woodframe Project: Ground Motion Development

Nick Gregor and Linda Al Atik

March 13th, 2017

PEER-CEA Woodframe Project

Outline

- Seismic Source Model (UCERF3)
- Ground Motion Prediction Equations (NGA West2)
  - Vs30 site conditions
- PSHA
  - Representative site locations
  - Return periods
  - Deaggregation
- Time History Development

UCERF3 Seismic Source Model

- 1,440 branches for logic tree (UCERF2=480 branches)
- Inversion based on geodetic, geologic, creep estimates, seismicity, and slip rate data
- Developed for use with OpenSHA
- Available from OpenSHA/UCERF3 Web sites
- Binary Based Files
- Additional data extracted from modification of OpenSHA program (e.g., gridded seismicity fault mechanism weighting factors)

UCERF3 Seismic Source Model - Faults

FM 3.1 Source Model

- 3,065 Fault Segments
- 930,563 Rupture Scenarios

FM 3.2 Source Model

- 3,122 Fault Segments
- 1,128,358 Rupture Scenarios

FM Mean Source Model

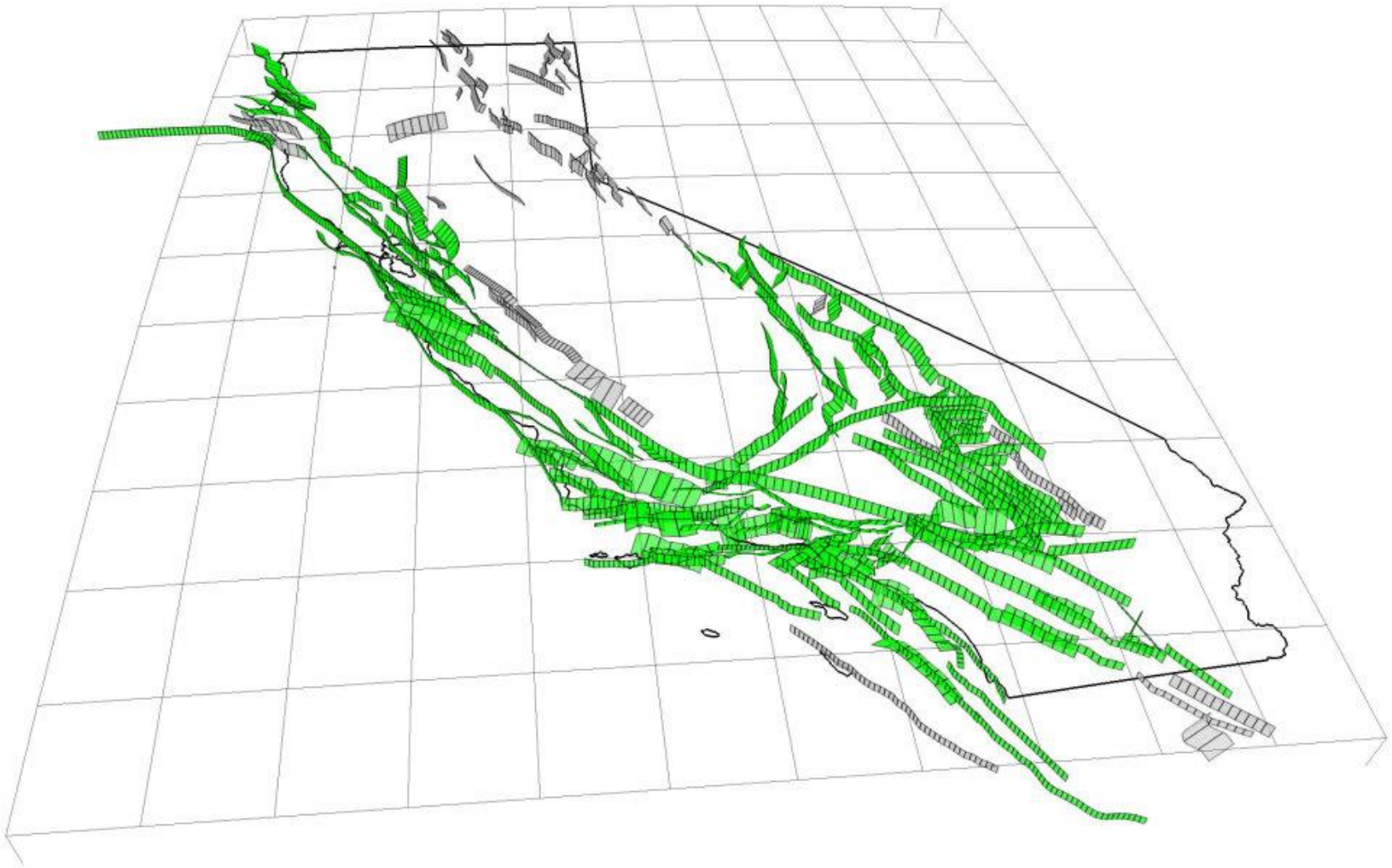
- **3,412 Individual Fault Segments**
- **1,634,466 Rupture Scenarios**

UCERF3 Seismic Source Model - Faults

- Scenarios defined as ruptures of two or more fault segments
  - Potential for very long rupture lengths
  - Scenarios can happen on continuous or disconnected fault segments (about 20% of scenarios have stepovers)
  - It is assumed that one rupture occurs per scenario (no floating of rupture areas along the fault or downdip)
  - Segments within about 5 km area allowed to rupture together

- Magnitude, rake, rate, area defined for each scenario
  - Dip angle, ZtoR defined based on the stitching of the fault segments

UCERF3 Seismic Source Model - Faults



USGS (2013), FM3.1

UCERF3 Seismic Source Model – Grid

- Updated seismicity catalog from UCERF2
- Grid Points Based on Smoothed Seismicity
- UCERF2 smoothing approach and adaptive smoothing approaches in UCERF3
- Fault Mechanism Classification weights (extracted from OpenSHA program)
  - Strike-slip
  - Reverse
  - Normal
- Virtual Faults for distance adjustments
  - Vertical Strike-slip
  - Dipping reverse and normal for footwall and hanging wall

UCERF3 Implementation Issues

- Fault scenarios:
  - Aseismic slip factor
  - Fault stitching
- Gridded seismicity:
  - Minimum Rjb distance
  - Virtual faults implementation
- These implementation issues/choices were modified in HAZ45 PSHA program and different than USGS implementation

GMPE Models

- Four NGA West2 GMPE (equally weighted)
  - ASK
  - BSSA
  - CB
  - CY
- Idriss not valid for Vs30 < 450 m/s
- Spectral period range T~<0.5 sec
  - No basin effects
  - No directivity
- Al Atik and Youngs (2014) epistemic model

PSHA

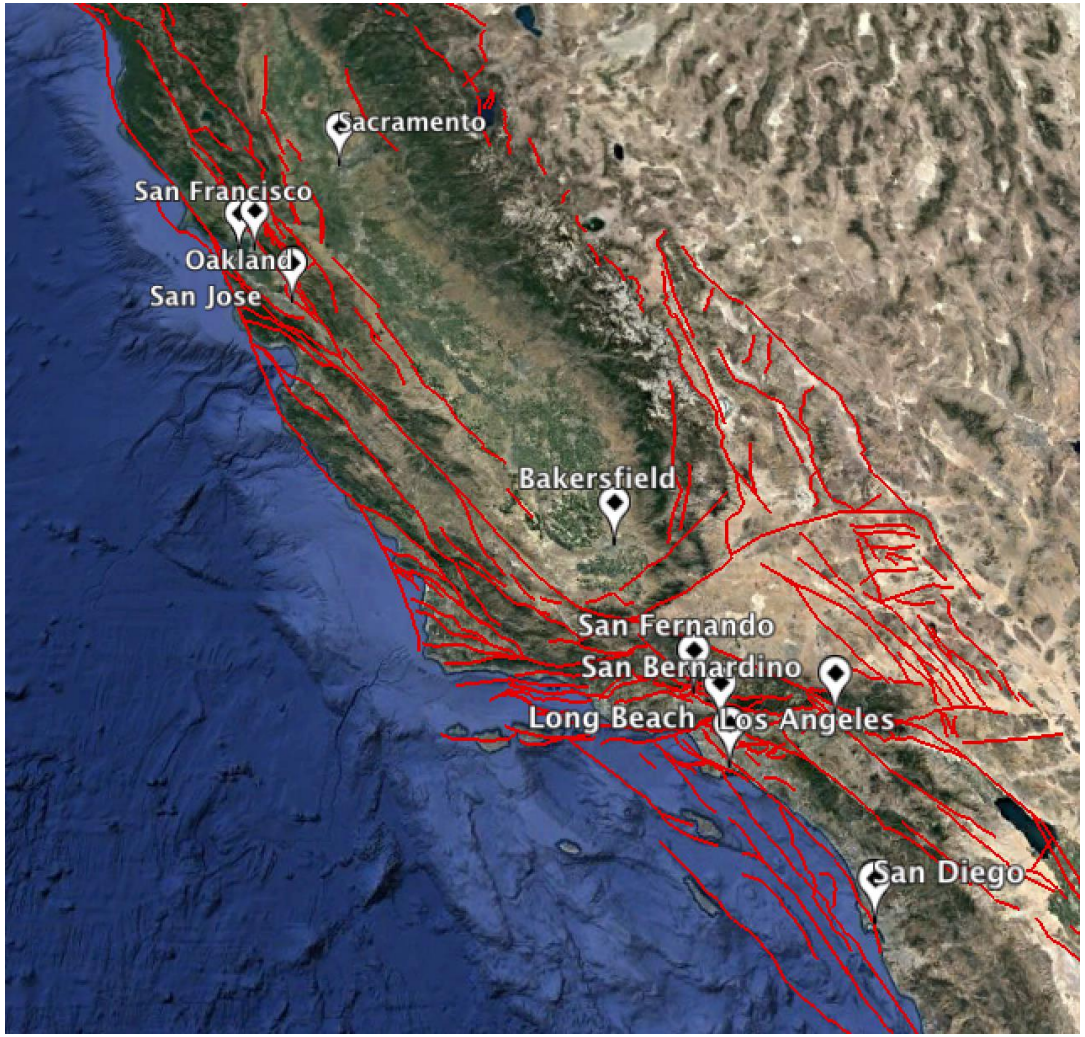
- UHS for full 0.01 – 10.0 sec spectral period
- Return periods:
  - 72, 100, 250, 475, 1000, and 2475 years
- Deaggregation
- UCERF3 SSC (no Cascadia source)
- NGA West2 GMPEs
- Representative sites (~5-10) within California
- Representative Vs30 condition

PSHA – Potential Sites

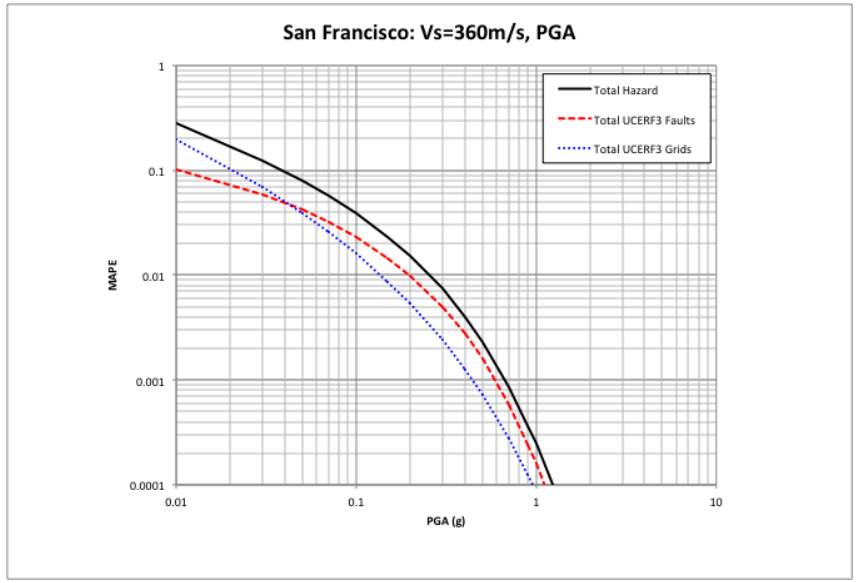
- City Hall location
- Selection process
  - City population
  - Distribution around the state
  - Sites both near and away from active fault sources
  - Sites with empirical data from past earthquakes
  - Sites variety of contributing seismic sources for the hazard

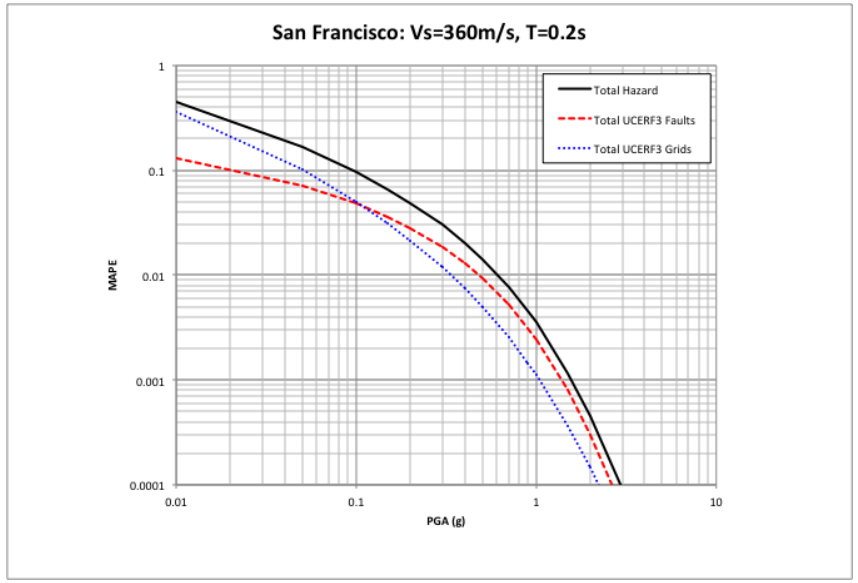
PSHA – Potential Sites

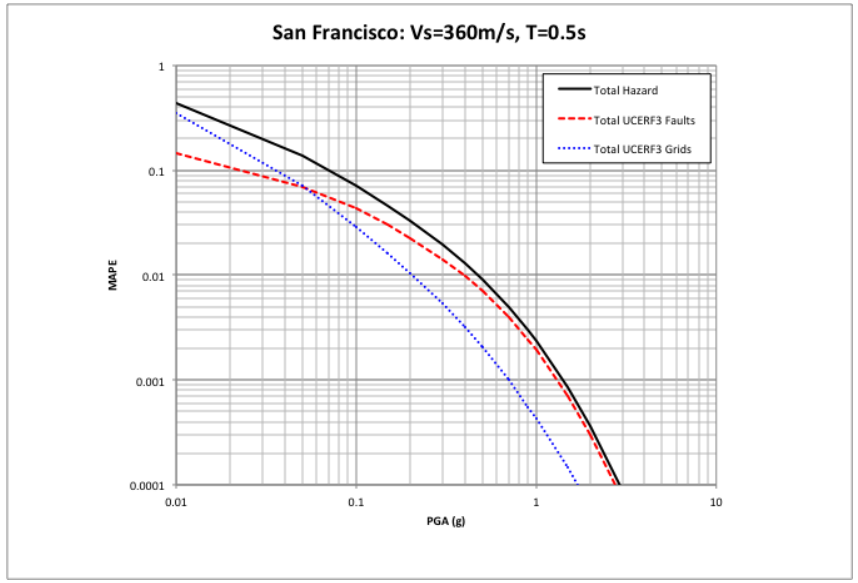
- San Francisco (C)
- Oakland (D)
- San Jose (D)
- Sacramento (D)
- Bakersfield (D)
- San Fernando (D)
- Los Angeles (D)
- Long Beach (D)
- San Bernardino (D)
- San Diego (C)

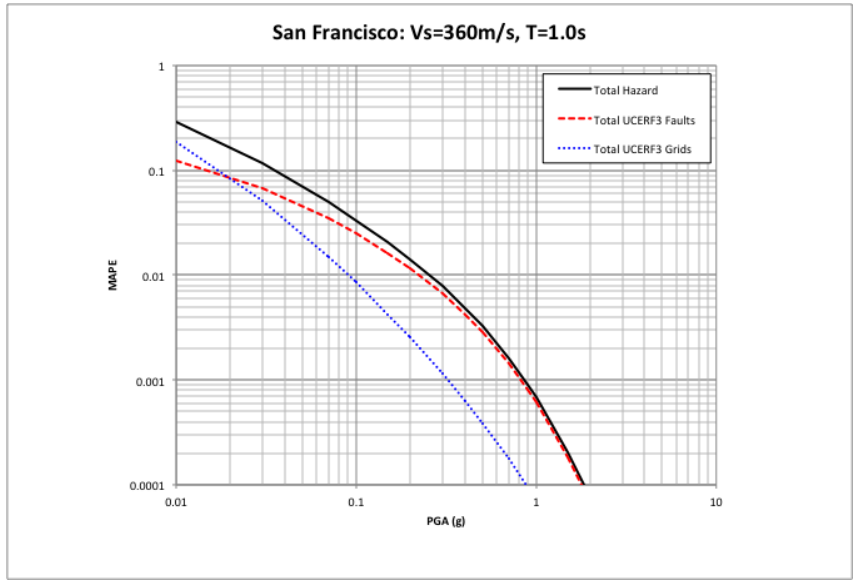


PSHA – San Francisco

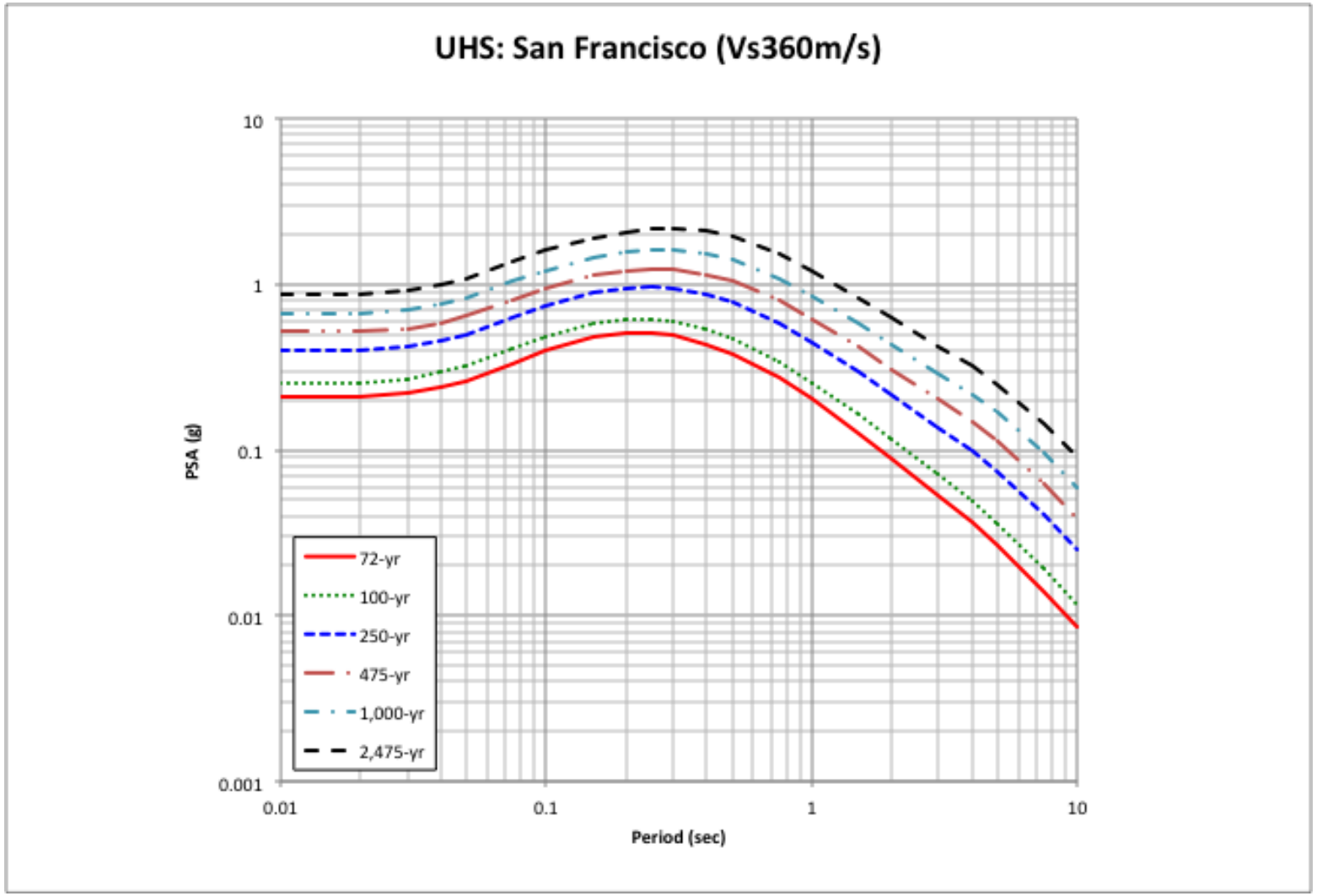




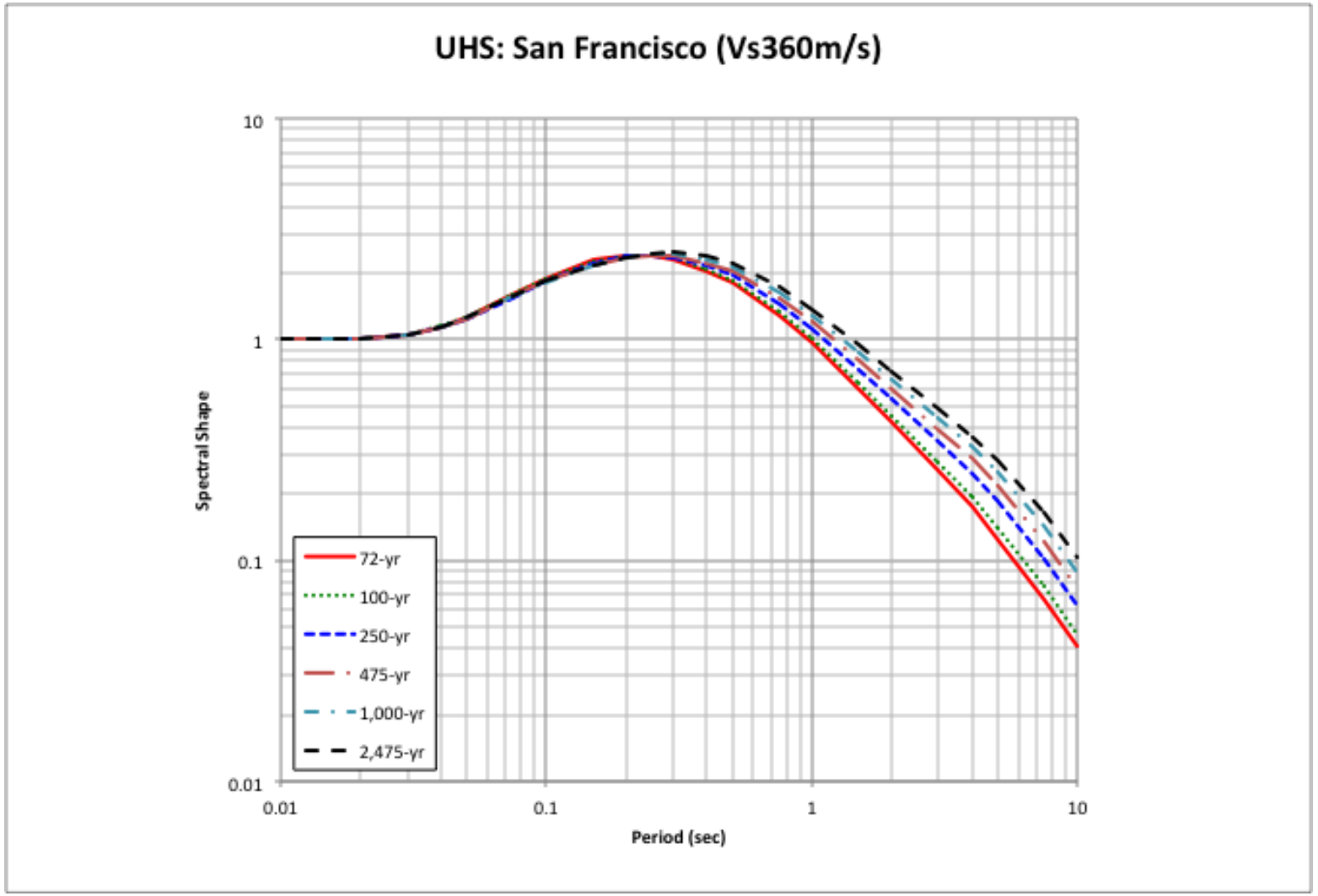




PSHA – San Francisco



PSHA – San Francisco



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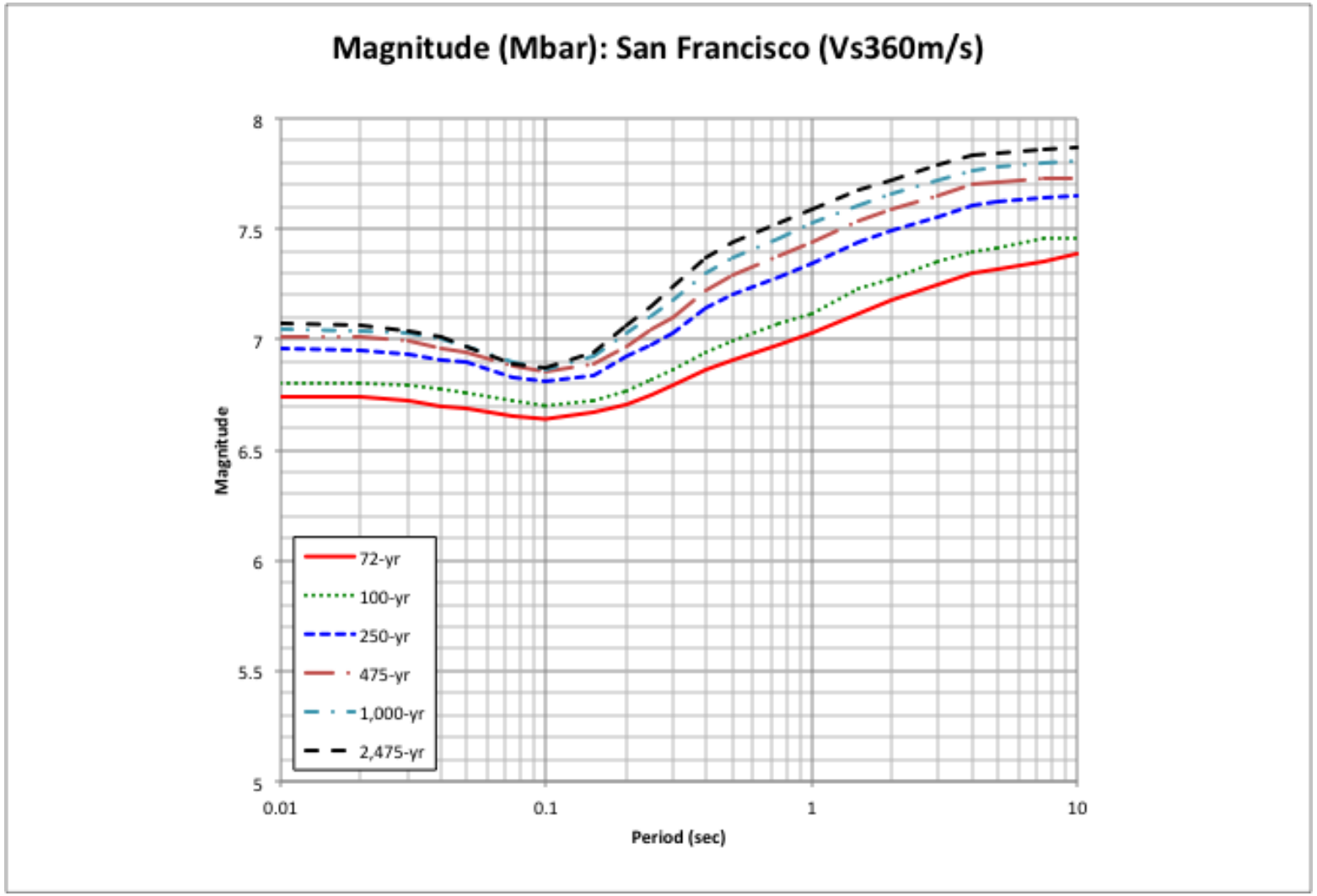

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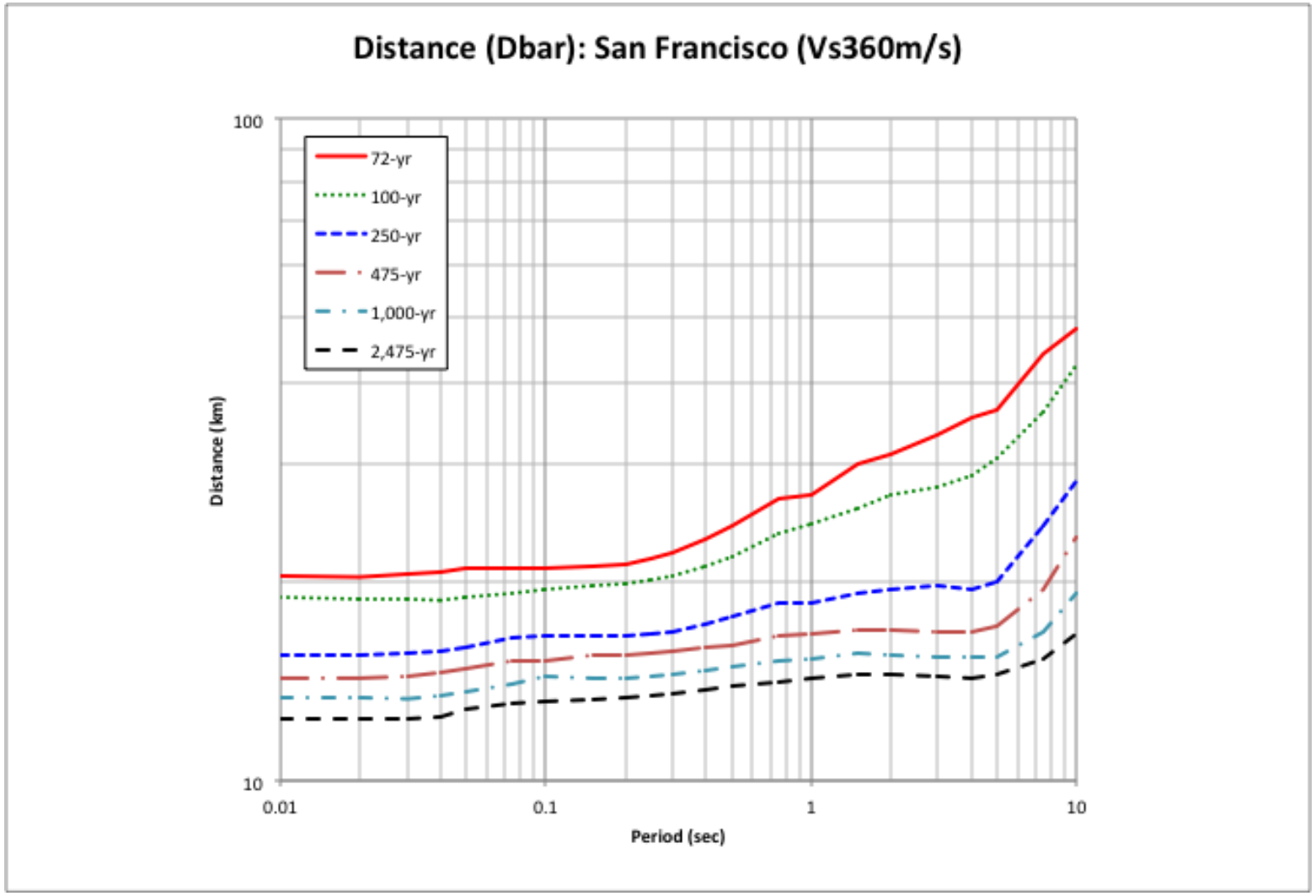

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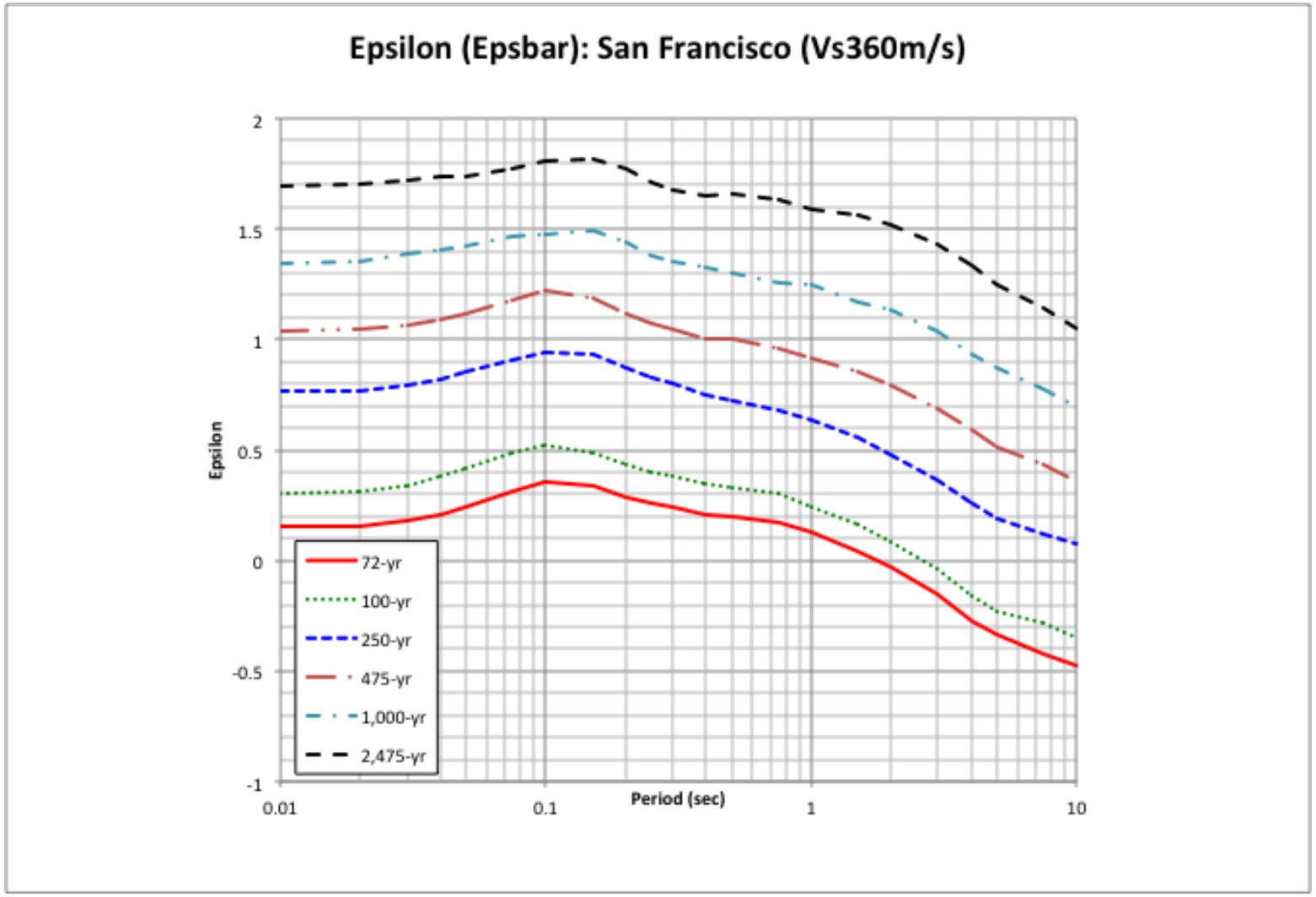
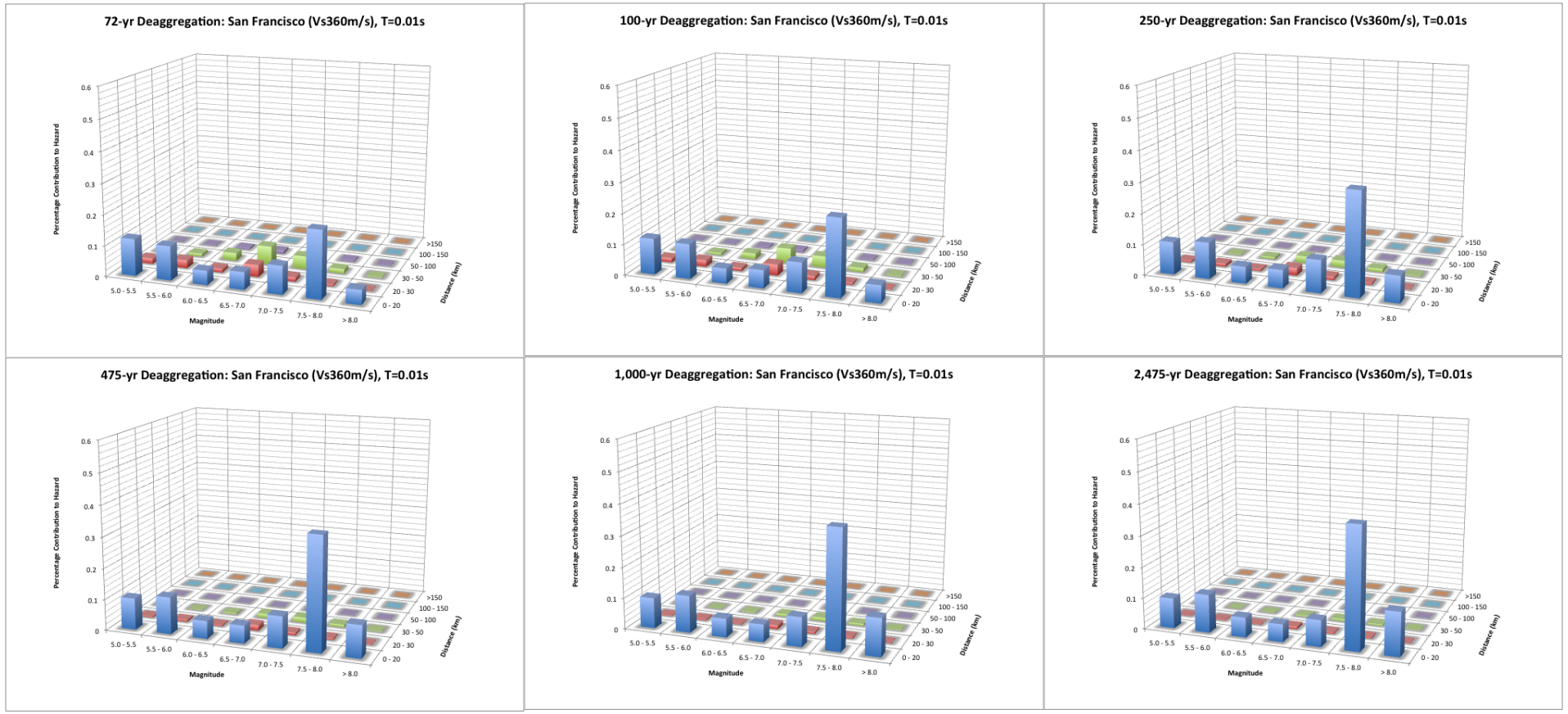
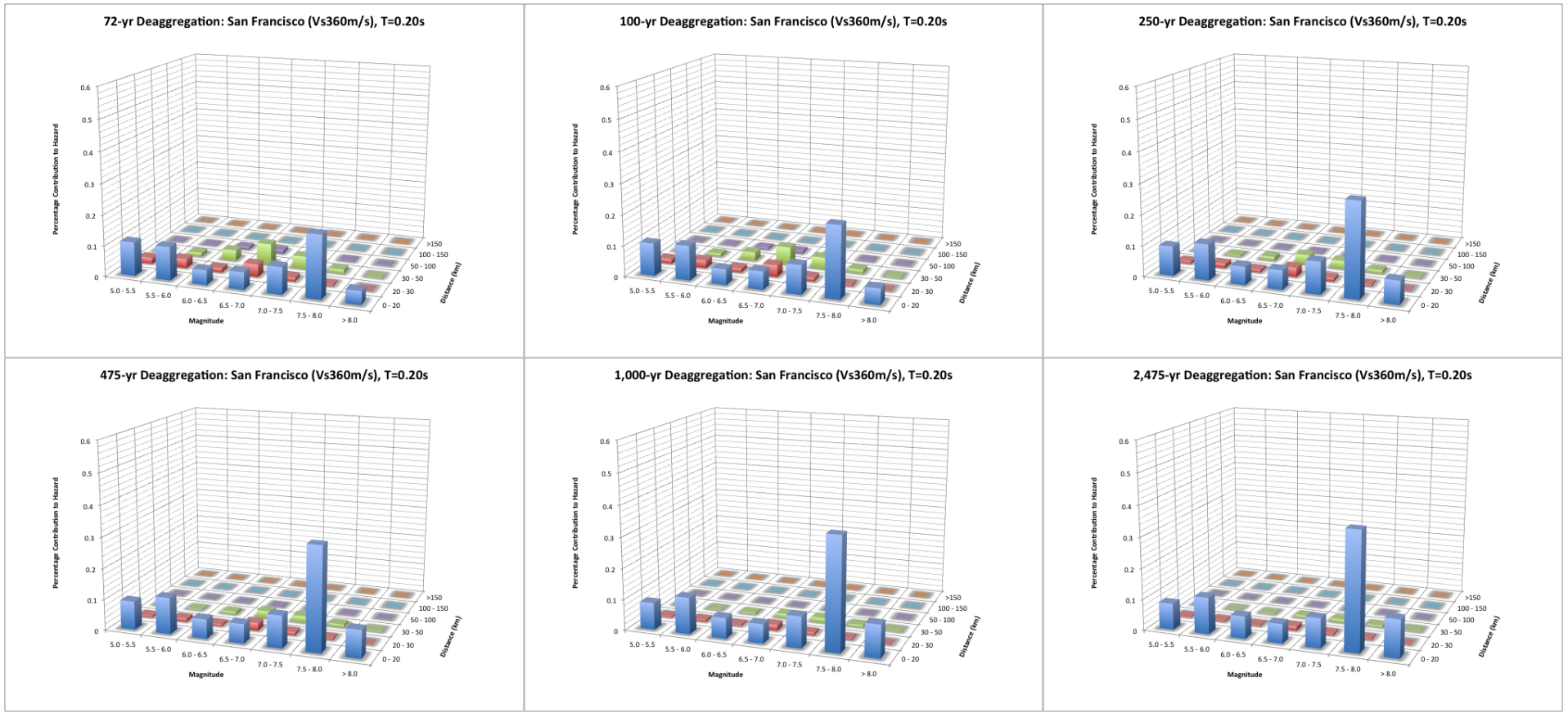


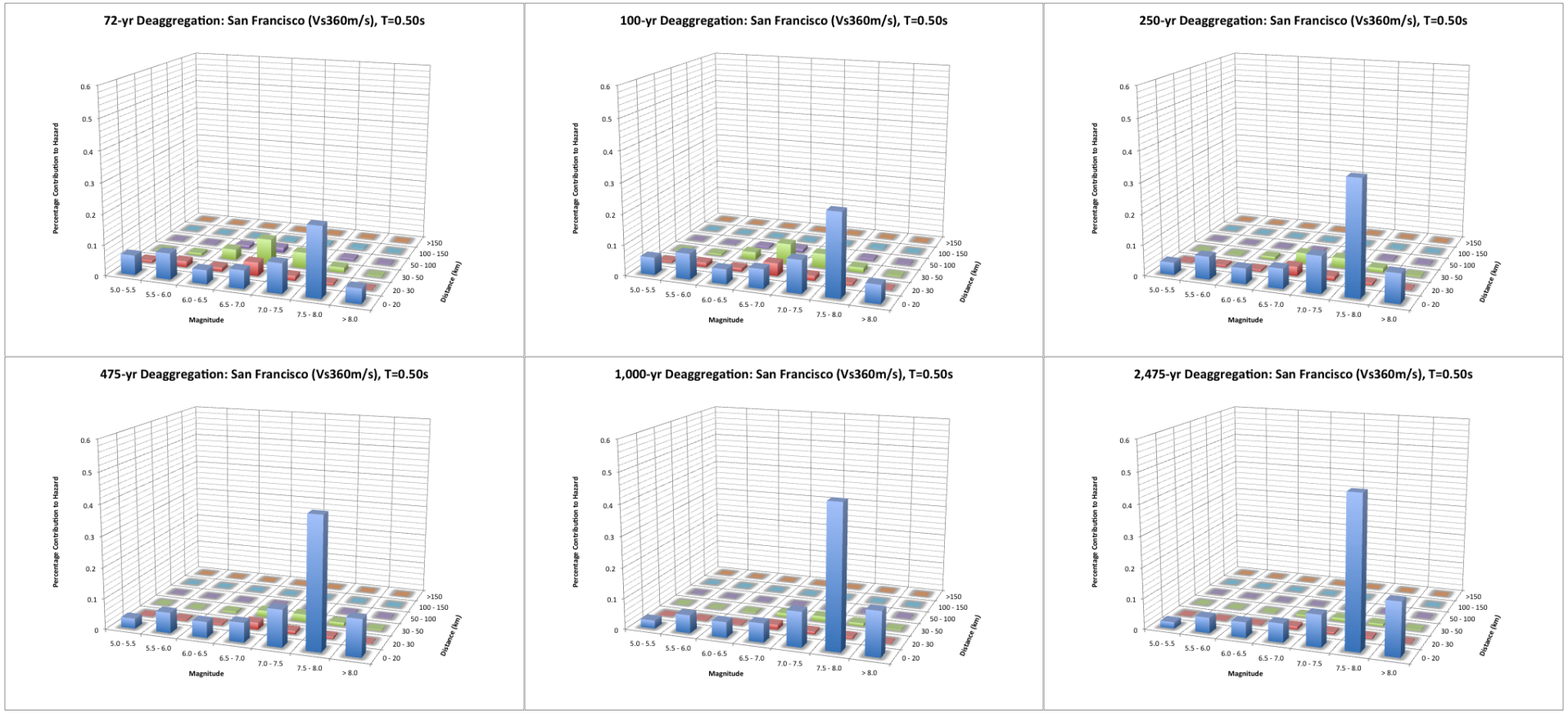
PSHA – San Francisco, PGA



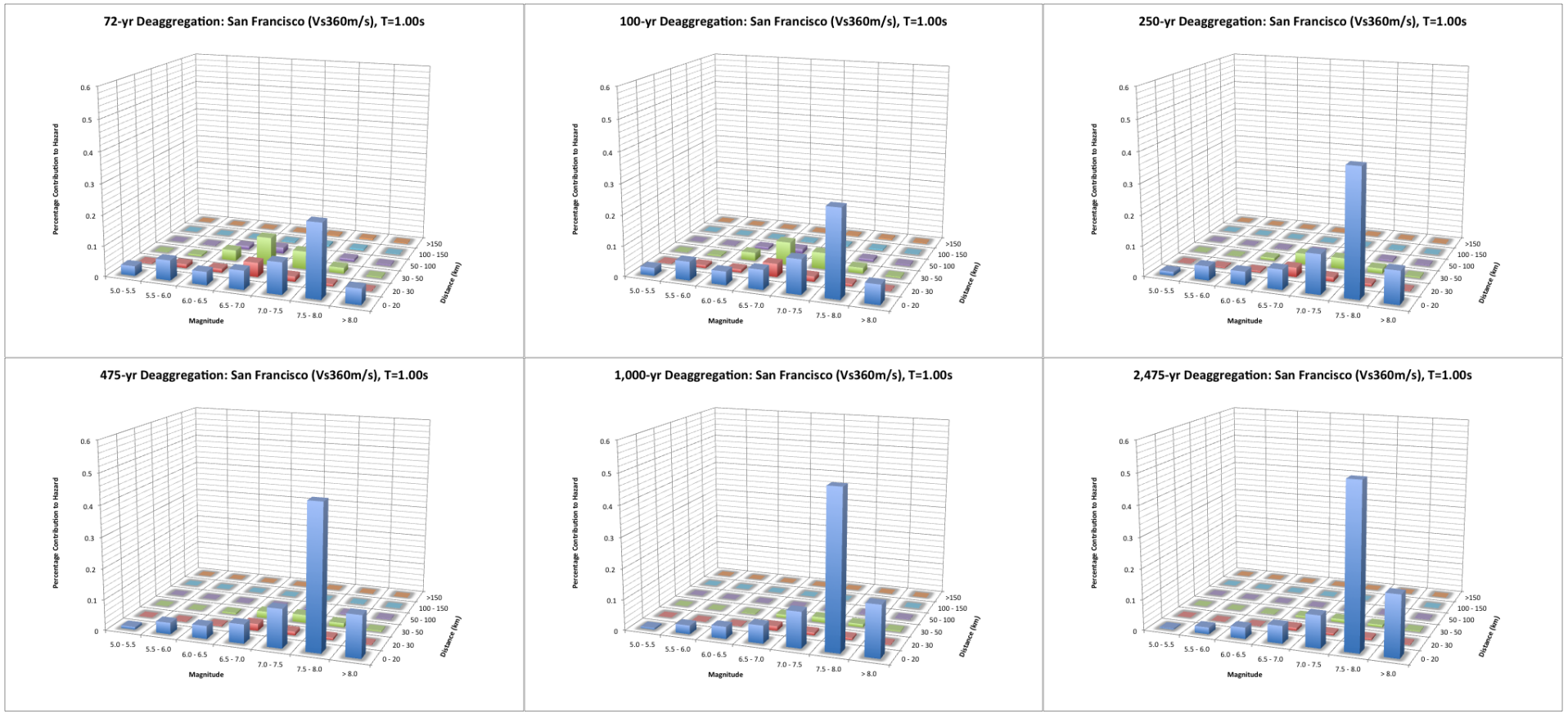
PSHA – San Francisco, T=0.2Hz



PSHA – San Francisco, T=0.5Hz



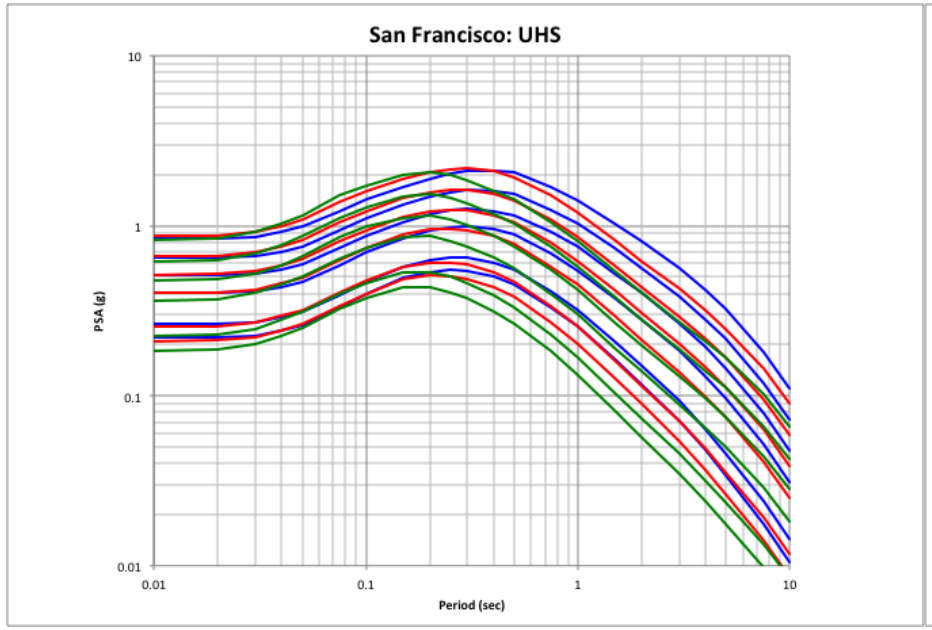
PSHA – San Francisco, T=1.0Hz

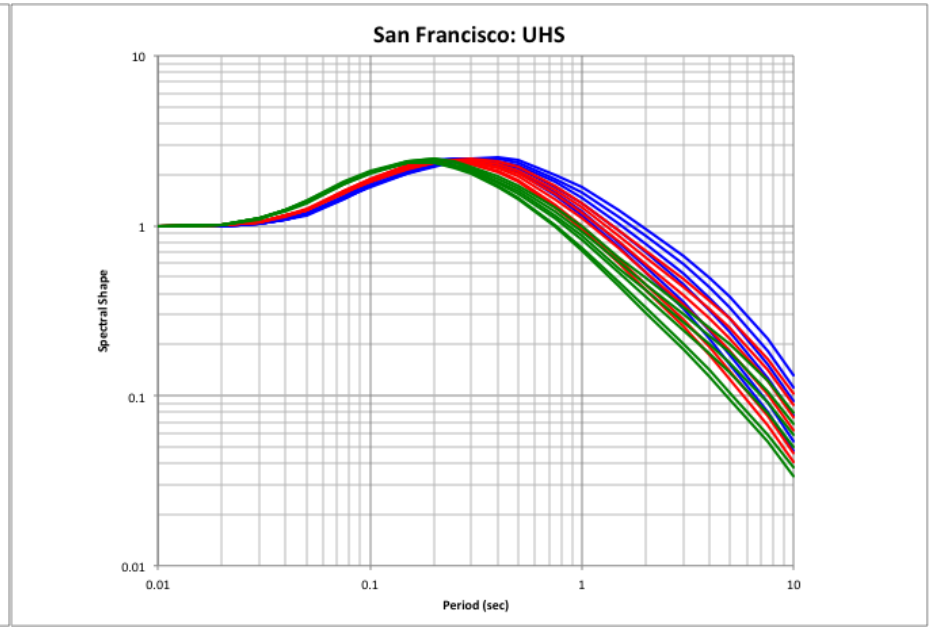


mazzoni@berkeley.edu

Nick Gregor and Linda Al Atik

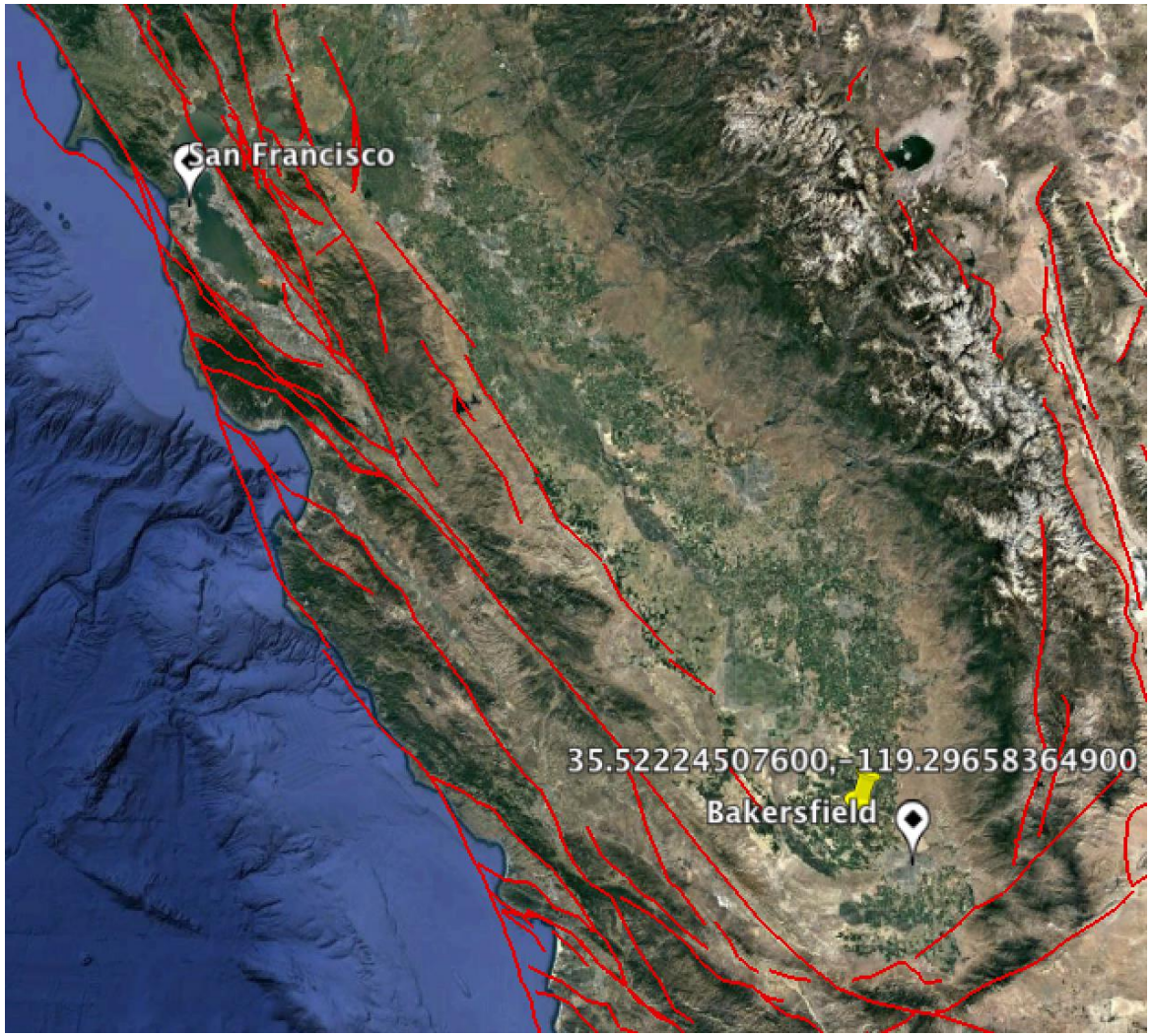
PSHA – San Francisco





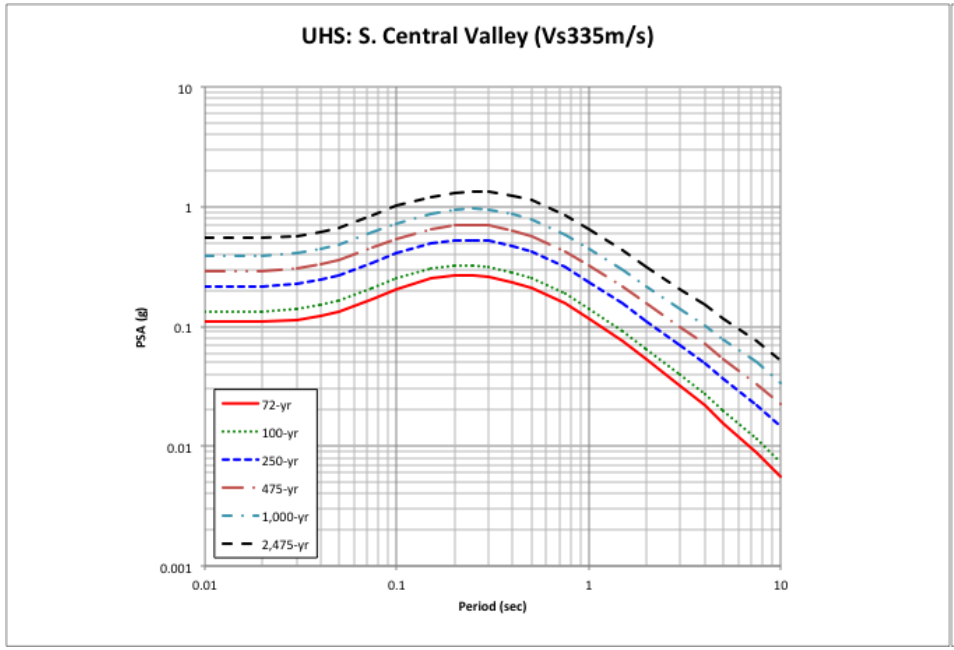
Vs30 = 270 (blue)
Vs30 = 360 (red)
Vs30 = 560 (green)

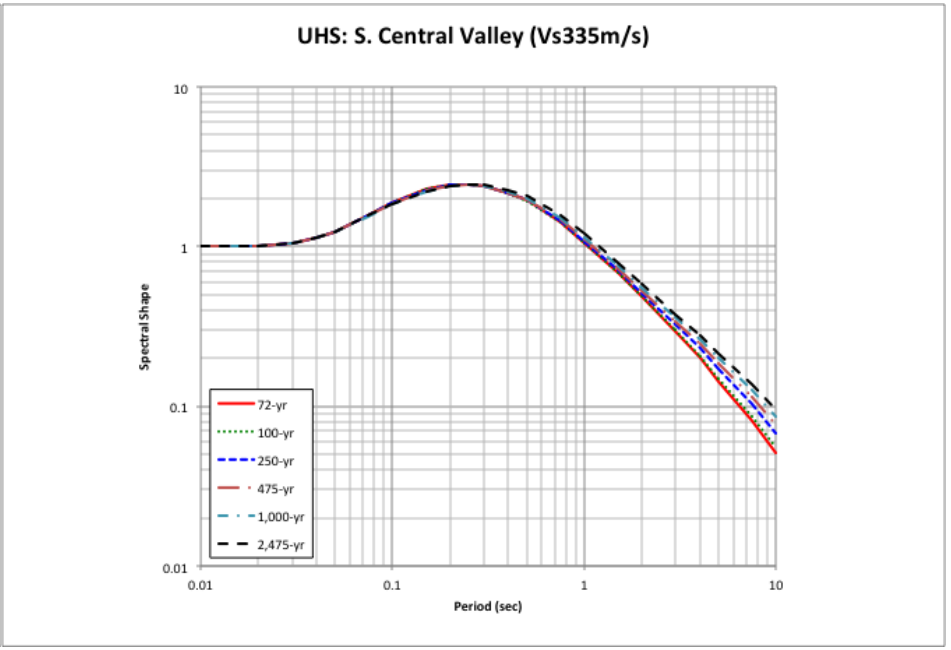
PSHA – San Francisco and Southern Central Valley



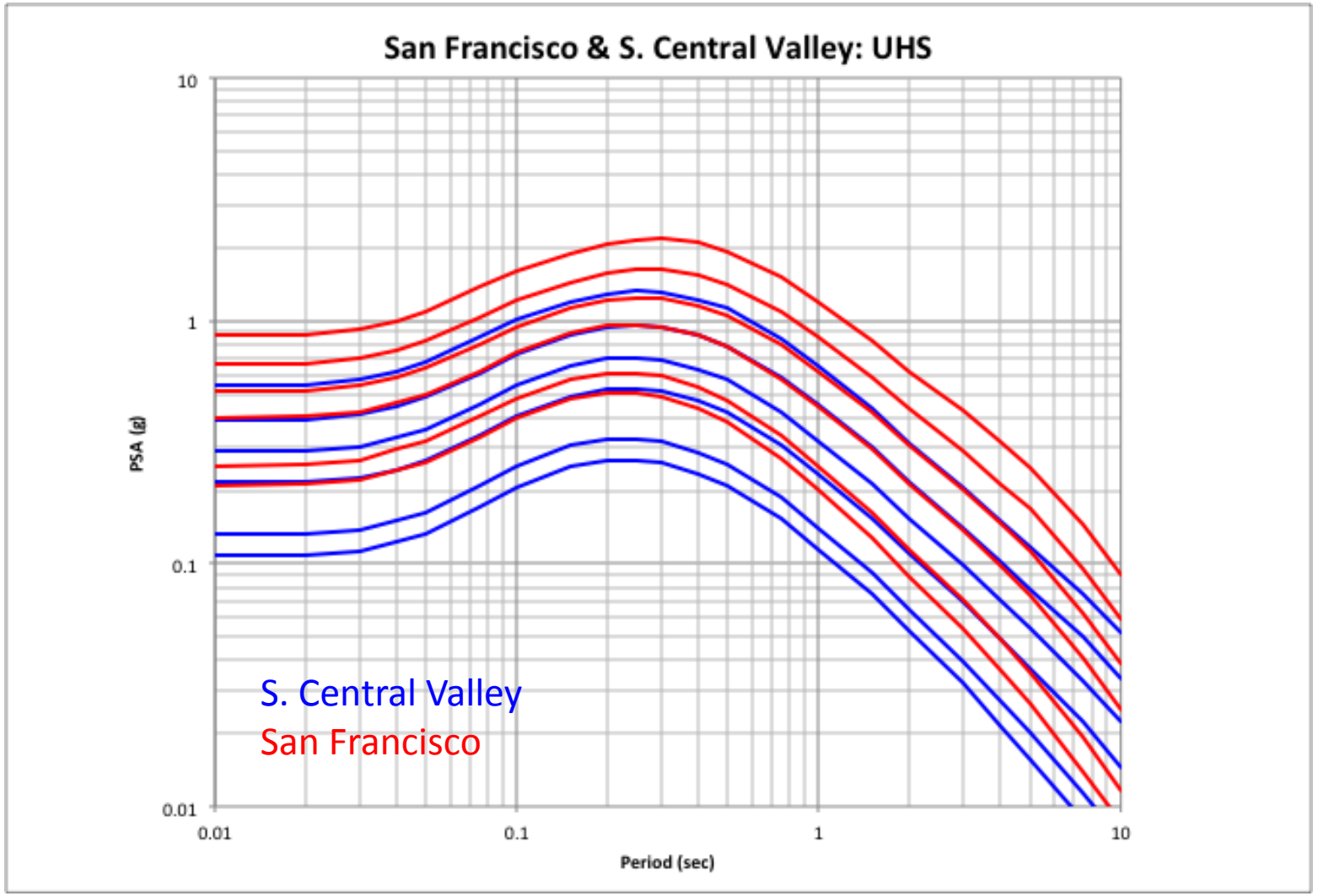
Southern Central Valley Site:
Vs30=335m/s

PSHA –S. Central Valley (Vs30=335 m/s)

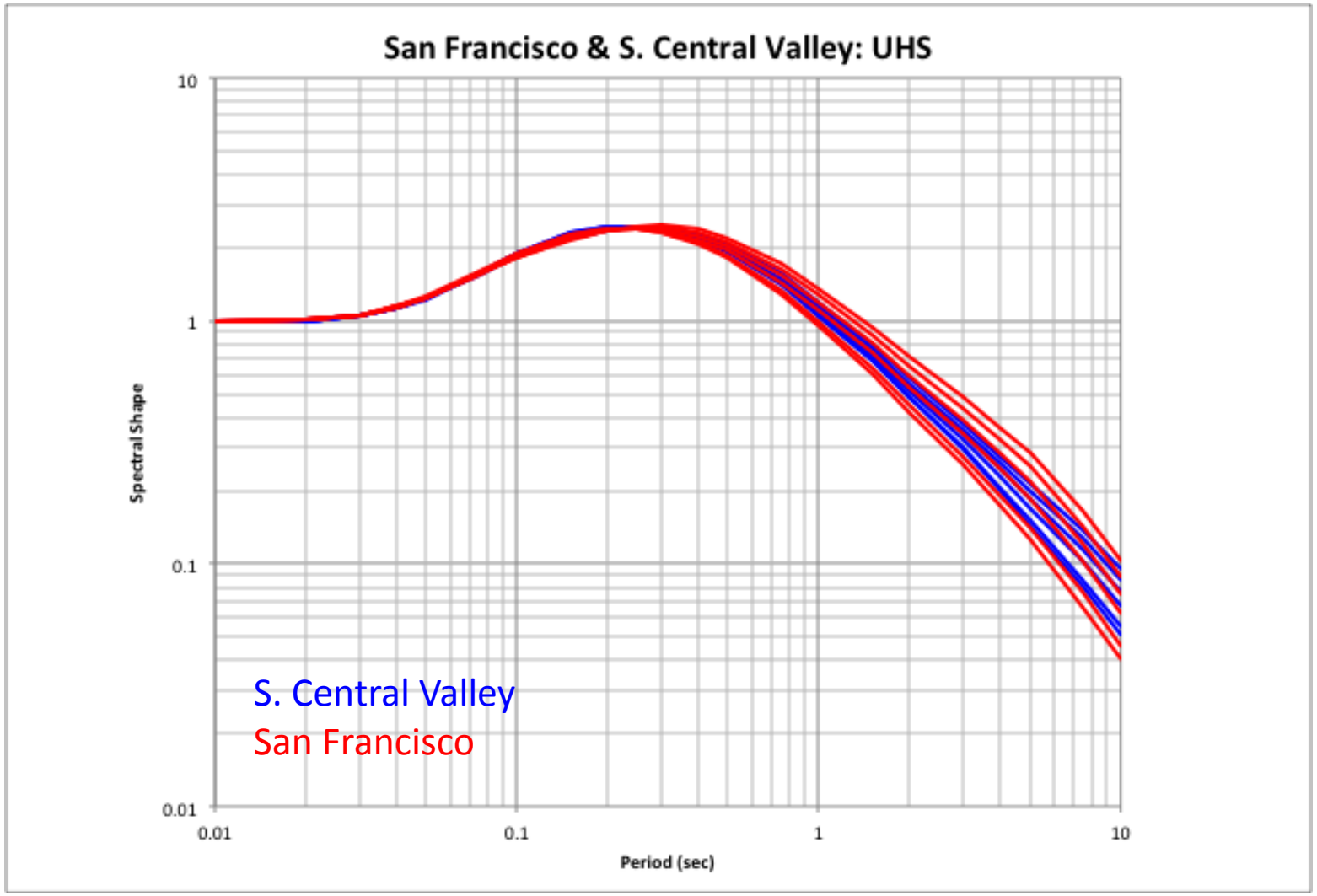




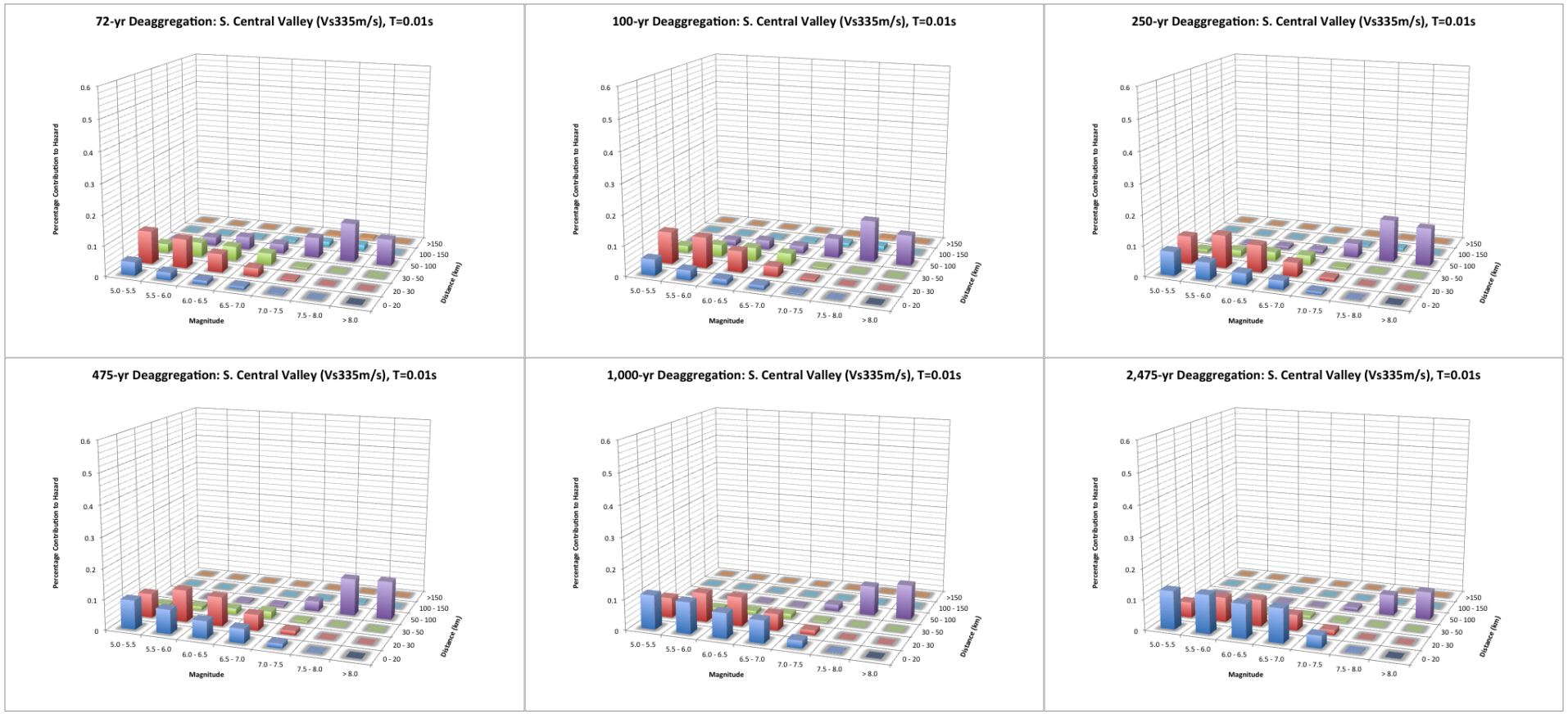
PSHA – San Francisco and Southern Central Valley



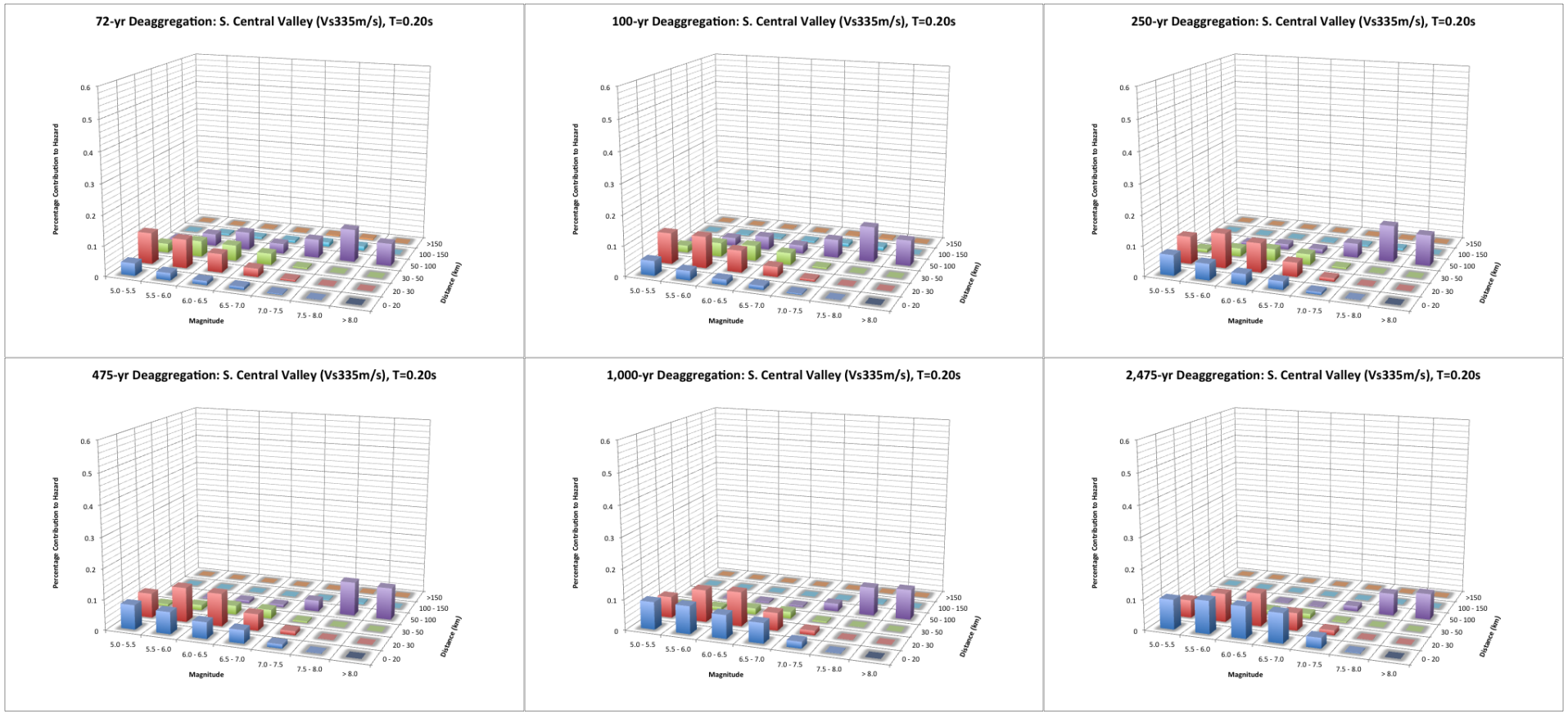
PSHA – San Francisco and Southern Central Valley



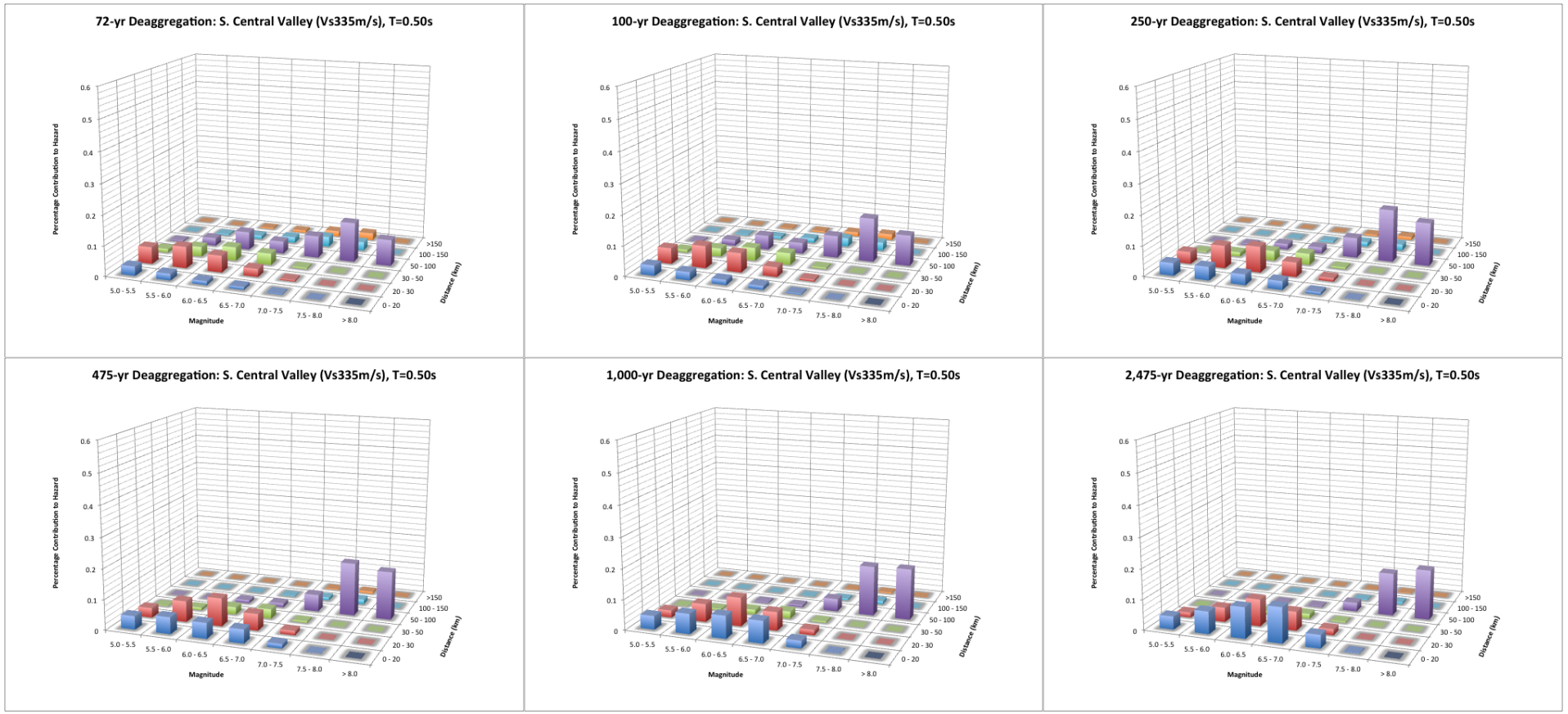
PSHA – S. Central Valley, PGA



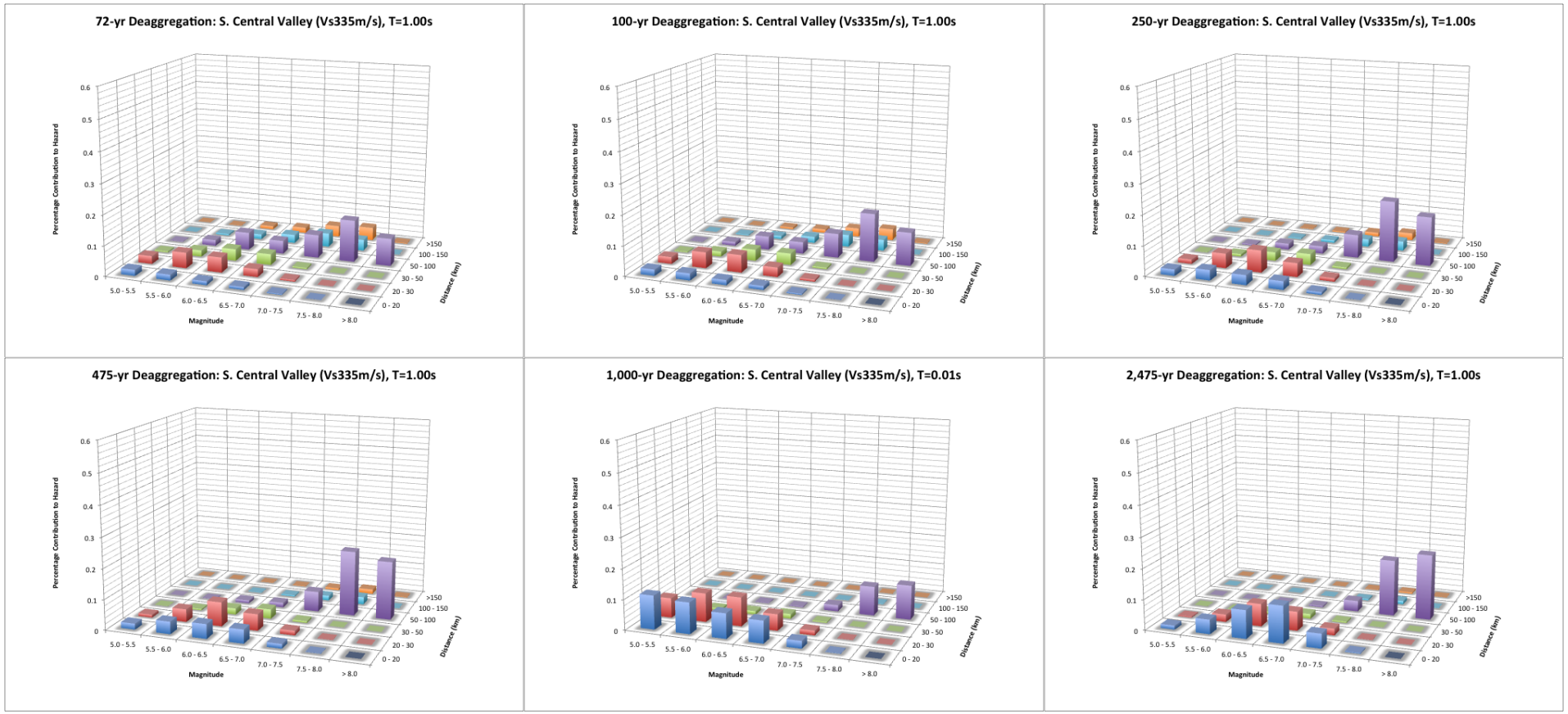
PSHA – S. Central Valley, T=0.2Hz



PSHA – S. Central Valley, T=0.5Hz

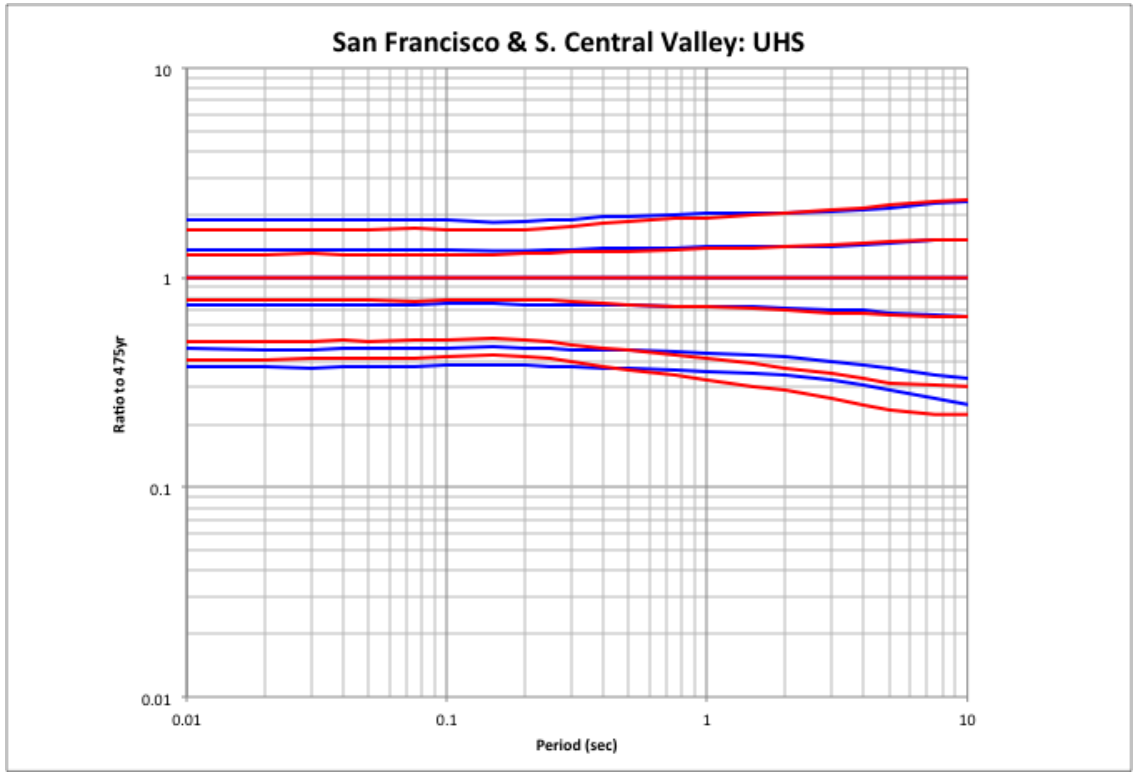


PSHA – S. Central Valley, T=1.0Hz



Time Histories

- Spectral Scaling vs. Spectral Matching
- Period range of interest (T~<0.5sec)
- Single horizontal component vs. three component time histories
- Cross correlation requirements
- 7, 11 or more sets of time histories
- Selection of near fault recordings

Discussion

- Acceptability of ~5 or less sites for PSHA
- Acceptable Vs30 value of ~360 m/s
- Spectral matching to 475 yr spectrum
  - Scale time histories for other hazard levels
- Development of time histories