Drift Scaling for ELF and MRSA when ASCE 7-22 Eq. 12.8-7 Governs

By
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To HBSB – SNSR Committee
7/29/2026

Department of Health Care Access and Information

Outline of Presentation

- *Motivation for the study*
- *Background research for current drift scaling requirements for long period buildings when S1 >= 0.6*
- *Impact of drift scaling on hospital construction – A Case study*
- *Additional Studies showing impact of the change for near fault and non near fault sites*
- *Recommendations from the committee*

Requirements in ASCE 7 for Base Shear Calculation

12.8 EQUIVALENT LATERAL FORCE (ELF) PROCEDURE

12.8.1 Seismic Base Shear The seismic base shear, V, in a given direction shall be determined in accordance with the following equation:

$$V = C_s W \qquad (12.8\text{-}1)$$

where

C_s = The seismic response coefficient determined in accordance with Section 12.8.1.1, and
W = The effective seismic weight per Section 12.7.2.

Method 2.

Method 1: The seismic response coefficient, C_s, shall be determined in accordance with Equation (12.8-2).

$$C_s = \frac{S_a}{\left(\frac{R}{I_e}\right)} \qquad (12.8\text{-}2)$$

where

be used.

Method 2: The seismic response coefficient, C_s, shall be determined in accordance with the following:

$$C_s = \frac{S_{DS}}{\left(\frac{R}{I_e}\right)} \qquad (12.8\text{-}3)$$

for $T \le T_L$,

$$C_s = \frac{S_{D1}}{T\left(\frac{R}{I_e}\right)} \qquad (12.8\text{-}4)$$

and for $T > T_L$,

$$C_s = \frac{S_{D1} T_L}{T^2\left(\frac{R}{I_e}\right)} \qquad (12.8\text{-}5)$$

where I_e and R are as defined in this section;

S_{D1} = Design spectral response acceleration parameter at a period of 1.0 s, as determined from Section 11.4.5 or 11.4.6;
T = Fundamental period of the structure(s) determined in Section 12.8.2; and
T_L = Long-period transition period(s) determined in Section 11.4.6.

Lower Bounds for C_s for Both Methods: C_s shall not be less than

$$C_s = 0.044 S_{DS} I_e \ge 0.01 \qquad (12.8\text{-}6)$$

In addition, for structures located where S_1 is equal to or greater than 0.6, C_s shall not be less than

$$C_s = 0.5 S_1/(R/I_e) \qquad (12.8\text{-}7)$$

Period (T) for calculating Base Shear

substantiated analysis. The fundamental period, T, shall not exceed the product of the coefficient for upper limit on calculated period, C_u, from Table 12.8-1 and the approximate fundamental period, T_a, determined in accordance with Section 12.8.2.1. As an alternative to performing an analysis to determine the fundamental period, T, it is permitted to use the approximate building period, T_a, calculated in accordance with Section 12.8.2.1, directly.

$$C_s = \frac{S_{D1}}{T\left(\frac{R}{I_e}\right)} \quad (12.8\text{-}4)$$

12.8.2.1 Approximate Fundamental Period The approximate fundamental period (T_a), in seconds, shall be determined from the following equation:

$$T_a = C_t h_n^x \quad (12.8\text{-}8)$$

where h_n is the structural height as defined in Section 11.2, and the coefficients C_t and x are determined from Table 12.8-2.

Table 12.8-1. Coefficient for Upper Limit on Calculated Period.

Design Spectral Response Acceleration Parameter at 1 s, S_{D1}	Coefficient C_u
≥ 0.4	1.4
0.3	1.4
0.2	1.5
0.15	1.6
≤ 0.1	1.7

Period for Calculating Drift

12.8.6.2 Period for Computing Displacement and Drift For determining displacements and drifts, it is permitted to determine the elastic displacements, δ_e, using seismic design forces based on the computed fundamental period of the structure without the upper limit, $C_u T_a$, specified in Section 12.8.2.

Scaling of Drift - ELF

C12.8.6.1 Minimum Base Shear and Load Combination for Computing Displacement and Drift Except for period limits (as described in Section C12.8.6.2), all of the requirements of Section 12.8 must be satisfied when computing drift for an ELF analysis, except that the minimum base shear determined from applying Equation (12.8-6) does not need to be considered. This equation represents a minimum strength that needs to be provided to a system (Section C12.8.1.1). Equation (12.8-7) needs to be considered, when triggered, because it represents the increase in the response spectrum in the long-period range from near-fault effects.

Scaling of Drift - MRSA

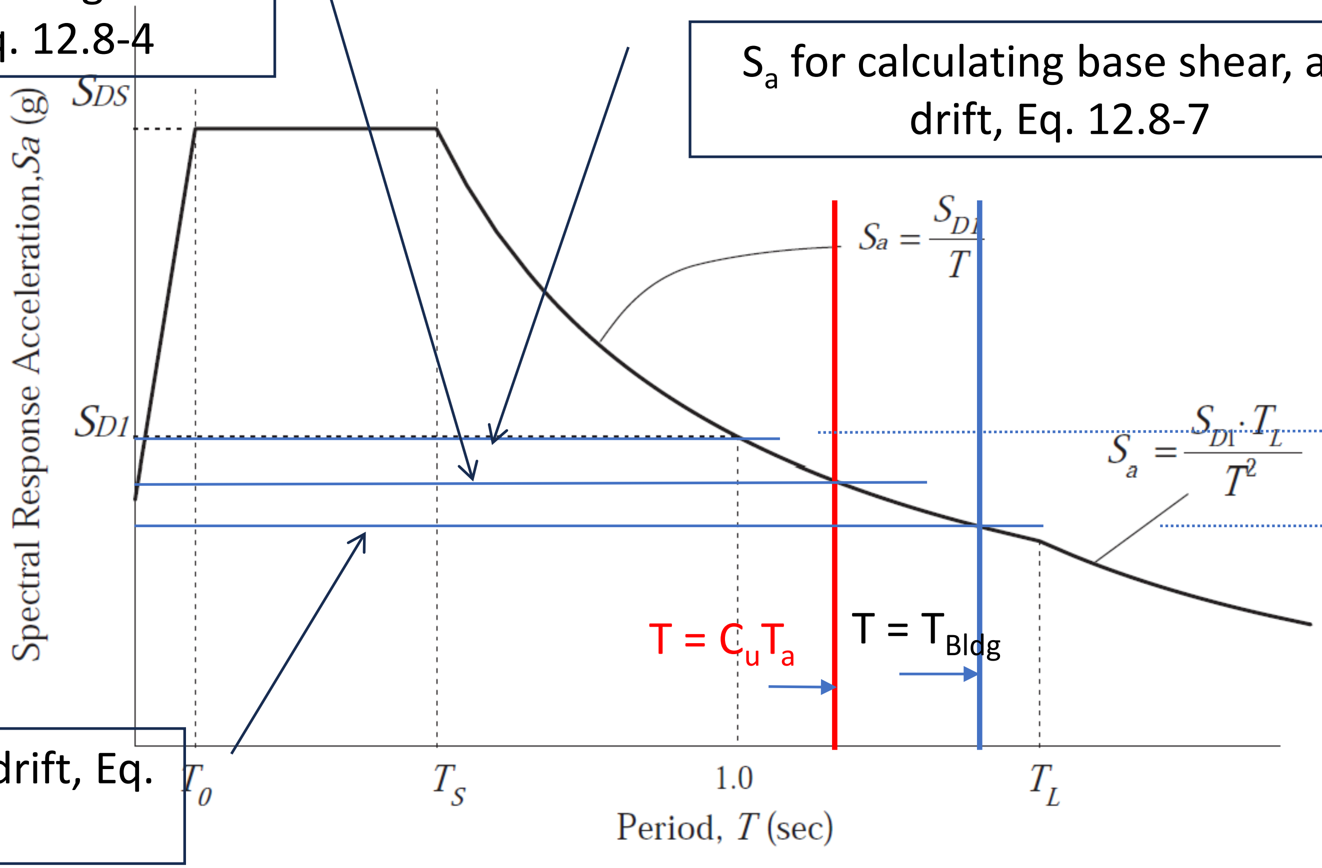
C12.9.1.4.2 Scaling of Drifts Displacements from the modal response spectrum are only scaled to the ELF base shear where V_t is less than $C_s W$ and C_s is determined based on Equation (12.8-7). For all other situations, the displacements need not be scaled, because the use of an overly flexible model will result in conservative estimates of displacement that need not be further scaled. The reason for requiring scaling when Equation (12.8-7) controls the minimum base shear is to be consistent with the requirements for designs based on the ELF procedure.

S_a for Calculating Base Shear & Drift ($T_s < T < T_L$)

S_a for calculating base shear, Eq. 12.8-4

S_a for calculating base shear, and drift, Eq. 12.8-7

Increase in demand when drift scaling not reqd.



S_a for calculating drift, Eq. 12.8-4

$$C_s = \frac{S_{D1}}{T\left(\frac{R}{I_e}\right)} \qquad (12.8\text{-}4)$$

$$C_s = 0.5S_1/(R/I_e) \qquad (12.8\text{-}7)$$

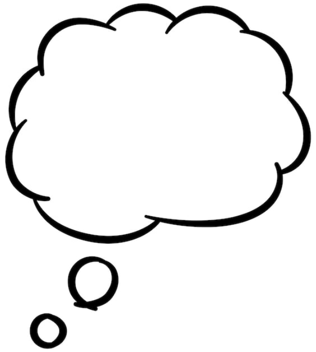
Figure 11.4-1. Two-period design response spectrum.

Genesis of Eq. 12.8-7

- Eq. 12.8-7 is pegged to sites where S_1 >= 0.6. This limit was selected to address spectral shapes from near fault records including the Sylmar Converter Station (1971), Jensen Filtration plant (1994) and Newhall Fire Station (1994) records. Similar records were seen in Kobe (1995) and El Centro (1979). (source:- Ron Hamburger)

Is Spectral Shape for drift scaling dependent on Site Class for near fault effects?

- For buildings in the long period range ($T_s < T < T_L$), is drift scaling intended more for buildings in Site Class D and E soils because of the elongated spectra, or in Site Class A, B and C soils?



- Drift scaling is independent of Site Class?

Is Drift Scaling per Eq. 12.8-7 Still Required?

- When Eq 12.8-7 governs the design base shear, is drift scaling still required given the advances made to the design response spectrum. This equation was introduced in the 2000 NEHRP provisions which required F_a and F_v multipliers to estimate the response spectrum. Since then, there have been revisions to how S_{D1} is derived from a response spectrum. This has resulted in S_{D1} being larger than S_{DS} for many site class D and E sites.

Background regarding 1997 UBC Eq. 30-7 and Drift

Many significant investigations of the effects of near field pulses had been undertaken especially those by Heaton and Hall of CalTech in the late 1990s. These investigations confirmed the earlier work of the SEAOC Seismology's Strong Ground Motion Subcommittee that in the near field of large earthquakes, tall structures need to be stiffer as well as stronger if they were to safely withstand the near field pulse effects of large earthquakes. One way to achieve this objective is to require that the minimum base shear of formula 30-7 be used when calculating drift. (Source: Kircher et.al.)

Background regarding 1997 UBC Eq. 30-7 and Drift

1630.2.1 Design base shear. The total design base shear in a given direction shall be determined from the following formula:

$$V = \frac{C_v I}{R T} W \qquad (30\text{-}4)$$

The total design base shear need not exceed the following:

$$V = \frac{2.5\ C_a\ I}{R} W \qquad (30\text{-}5)$$

The total design base shear shall not be less than the following:

$$V = 0.11\ C_a\ I\ W \qquad (30\text{-}6)$$

In addition, for Seismic Zone 4, the total base shear shall also not be less than the following:

$$V = \frac{0.8\ ZN_v\ I}{R} W \qquad (30\text{-}7)$$

TABLE 16-I—SEISMIC ZONE FACTOR *Z*

ZONE	1	2A	2B	3	4
Z	0.075	0.15	0.20	0.30	0.40

NOTE: The zone shall be determined from the seismic zone map in Figure 16-2.

TABLE 16-R—SEISMIC COEFFICIENT C_v

SOIL PROFILE TYPE	SEISMIC ZONE FACTOR, Z				
	Z = 0.075	Z = 0.15	Z = 0.2	Z = 0.3	Z = 0.4
S_A	0.06	0.12	0.16	0.24	$0.32N_v$
S_B	0.08	0.15	0.20	0.30	$0.40N_v$
S_C	0.13	0.25	0.32	0.45	$0.56N_v$
S_D	0.18	0.32	0.40	0.54	$0.64N_v$
S_E	0.26	0.50	0.64	0.84	$0.96N_v$
S_F	See Footnote 1				

[1]Site-specific geotechnical investigation and dynamic site response analysis shall be performed to determine seismic coefficients for Soil Profile Type S_F.

TABLE 16-T—NEAR-SOURCE FACTOR N_v[1]

SEISMIC SOURCE TYPE	CLOSEST DISTANCE TO KNOWN SEISMIC SOURCE[2,3]			
	≤ 2 km	5 km	10 km	≥ 15 km
A	2.0	1.6	1.2	1.0
B	1.6	1.2	1.0	1.0
C	1.0	1.0	1.0	1.0

[1]The Near-Source Factor may be based on the linear interpolation of values for distances other than those shown in the table.
[2]The location and type of seismic sources to be used for design shall be established based on approved geotechnical data (e.g., most recent mapping of active faults by the United States Geological Survey or the California Division of Mines and Geology).
[3]The closest distance to seismic source shall be taken as the minimum distance between the site and the area described by the vertical projection of the source on the surface (i.e., surface projection of fault plane). The surface projection need not include portions of the source at depths of 10 km or greater. The largest value of the

TABLE 16-U—SEISMIC SOURCE TYPE[1]

SEISMIC SOURCE TYPE	SEISMIC SOURCE DESCRIPTION	SEISMIC SOURCE DEFINITION[2]	
		Maximum Moment Magnitude, M	Slip Rate, SR (mm/year)
A	Faults that are capable of producing large magnitude events and that have a high rate of seismic activity	$M \geq 7.0$	$SR \geq 5$
B	All faults other than Types A and C	$M \geq 7.0$ $M < 7.0$ $M \geq 6.5$	$SR < 5$ $SR > 2$ $SR < 2$
C	Faults that are not capable of producing large magnitude earthquakes and that have a relatively low rate of seismic activity	$M < 6.5$	$SR \leq 2$

[1]Subduction sources shall be evaluated on a site-specific basis.
[2]Both maximum moment magnitude and slip rate conditions must be satisfied concurrently when determining the seismic source type.

Background regarding 1997 UBC Eq. 30-7 and Drift

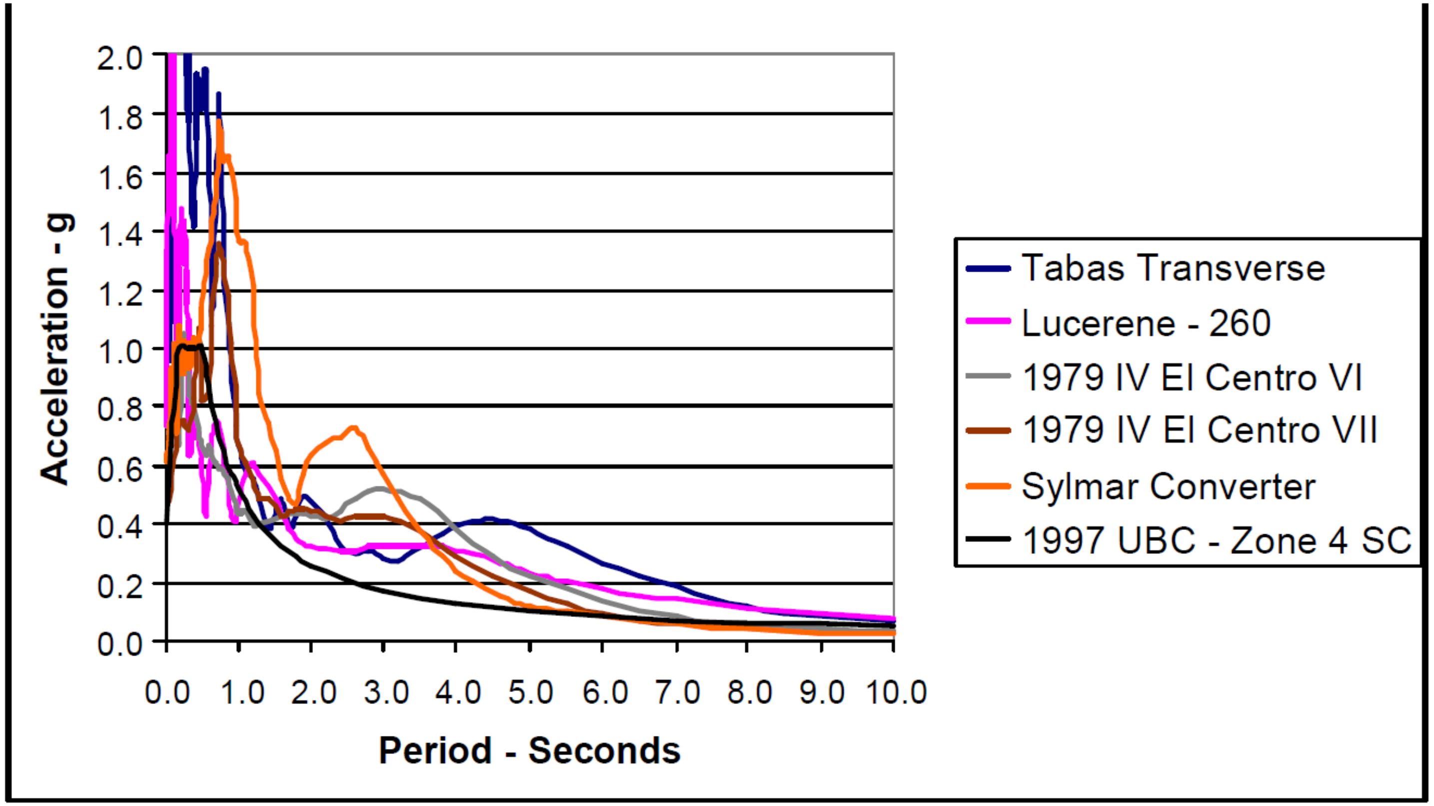


Figure 1 – Comparison of Near Fault Records and 1997 UBC Zone 4 Acceleration Response Spectrum

Background regarding 1997 UBC Eq. 30-7 and Drift

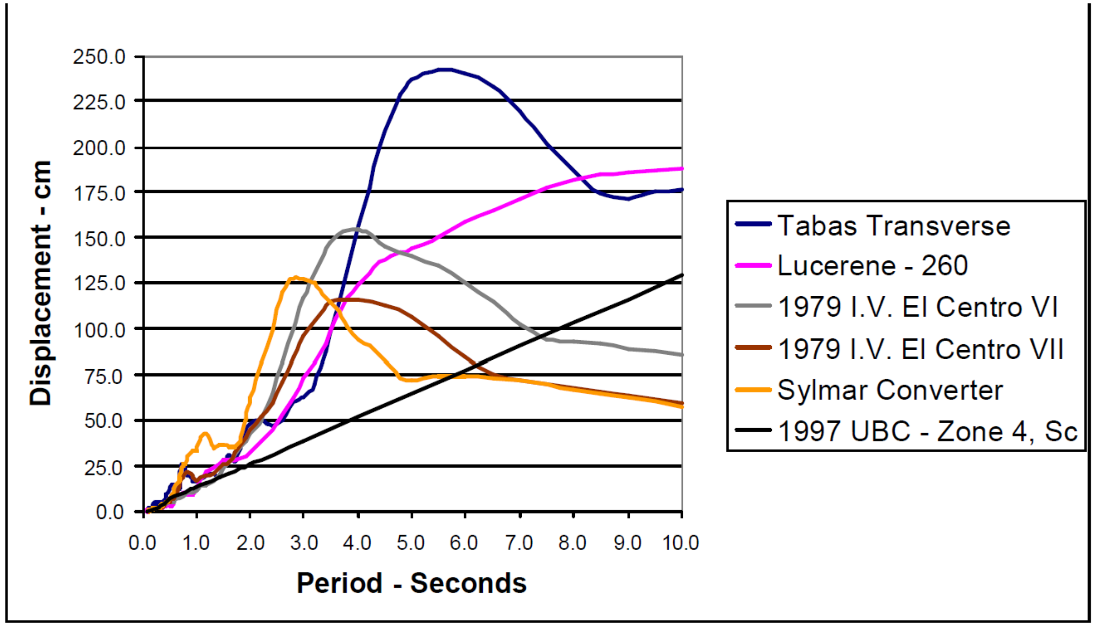


Figure 2 – Comparison of Near Fault Records and 1997 UBC Zone 4 – Displacement Response Spectrum

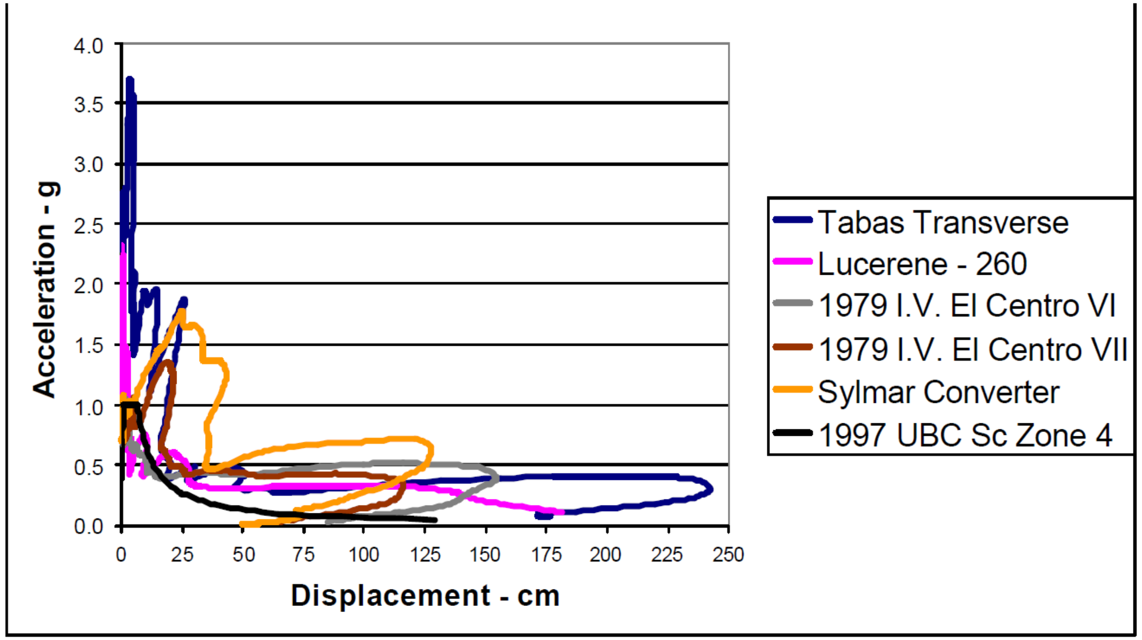
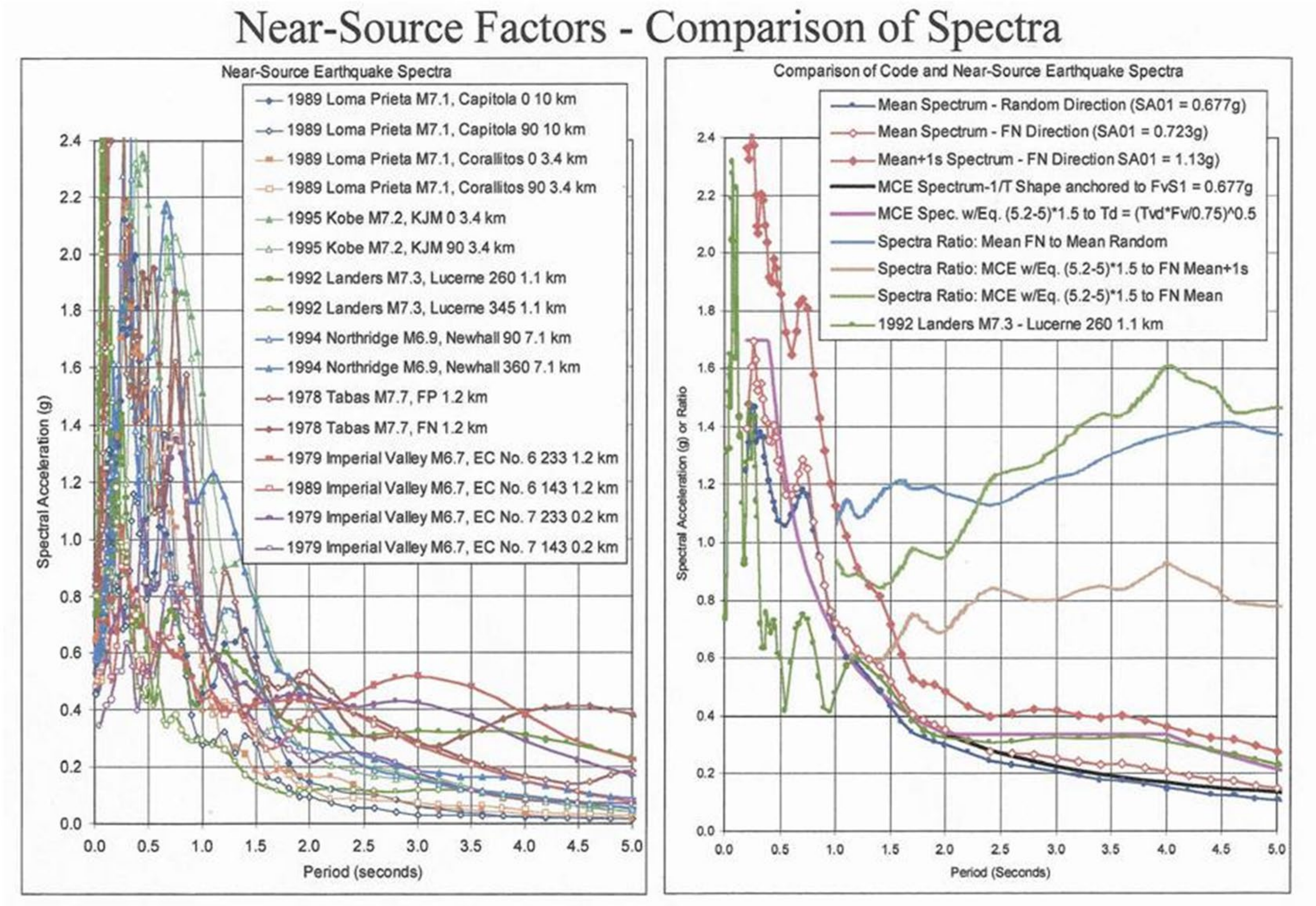


Figure 3 – Comparison of Near Fault Records and 1997 UBC Zone Spectrum in Acceleration – Displacement (ADRS) format

Near Source Factors – Comparison of Spectra

Kircher & Associates
Consulting Engineers

Near-Source Ground Motions
April 2003



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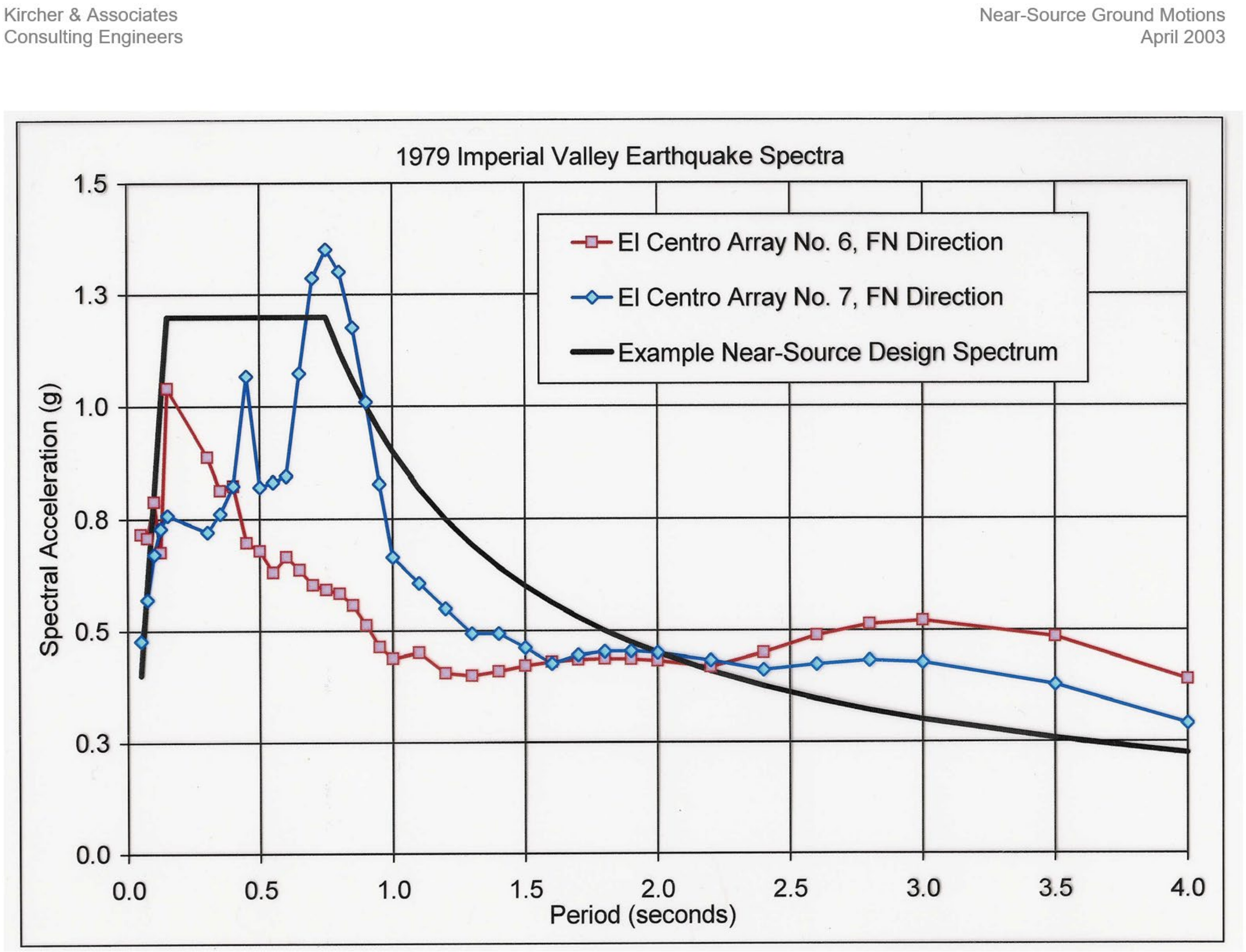
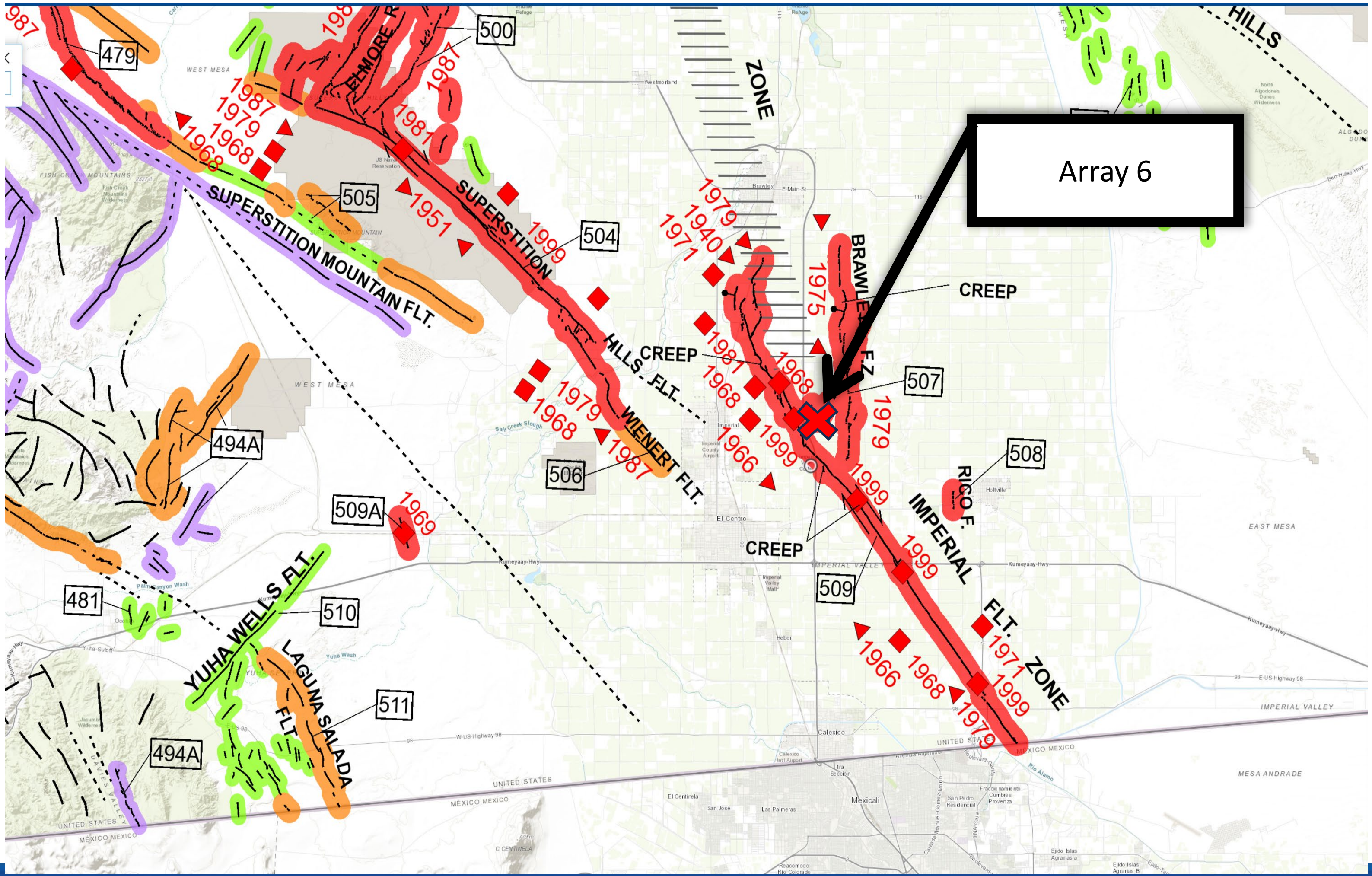
1979 Imperial Valley – Comparison of Spectra



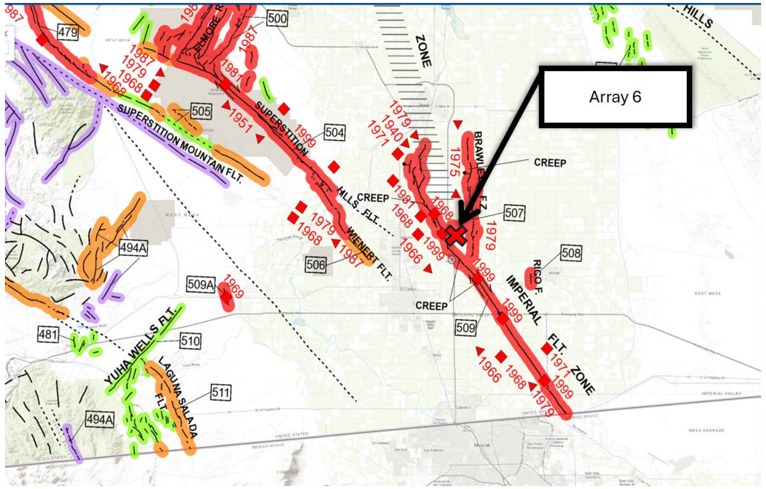
1979 Imperial Valley – Array 6

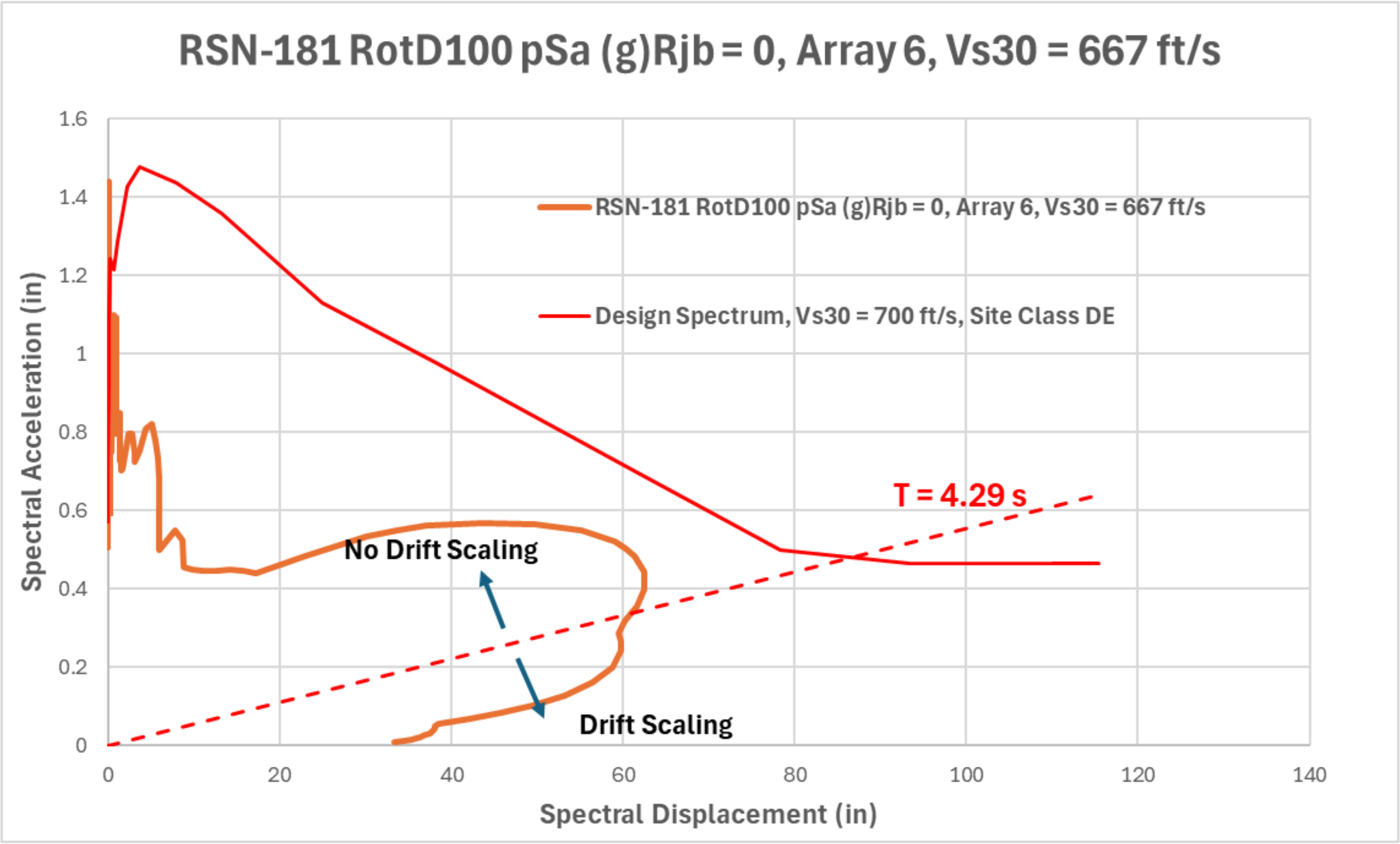


1979 Imperial Valley – Array 6
Comparison with ASCE 7-22 Design Spectrum

- $S_1 = 0.93$ g
- $S_{Ds} = 1.25$ g
- $S_{D1} = 2.12$ g

- T ≥ 4.29 s Drift Scaling Required





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Comparison with ASCE 7-22 Design Spectrum

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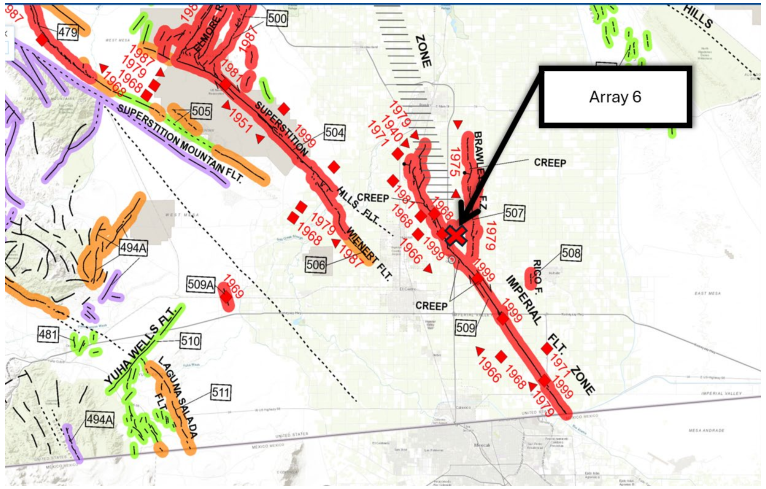
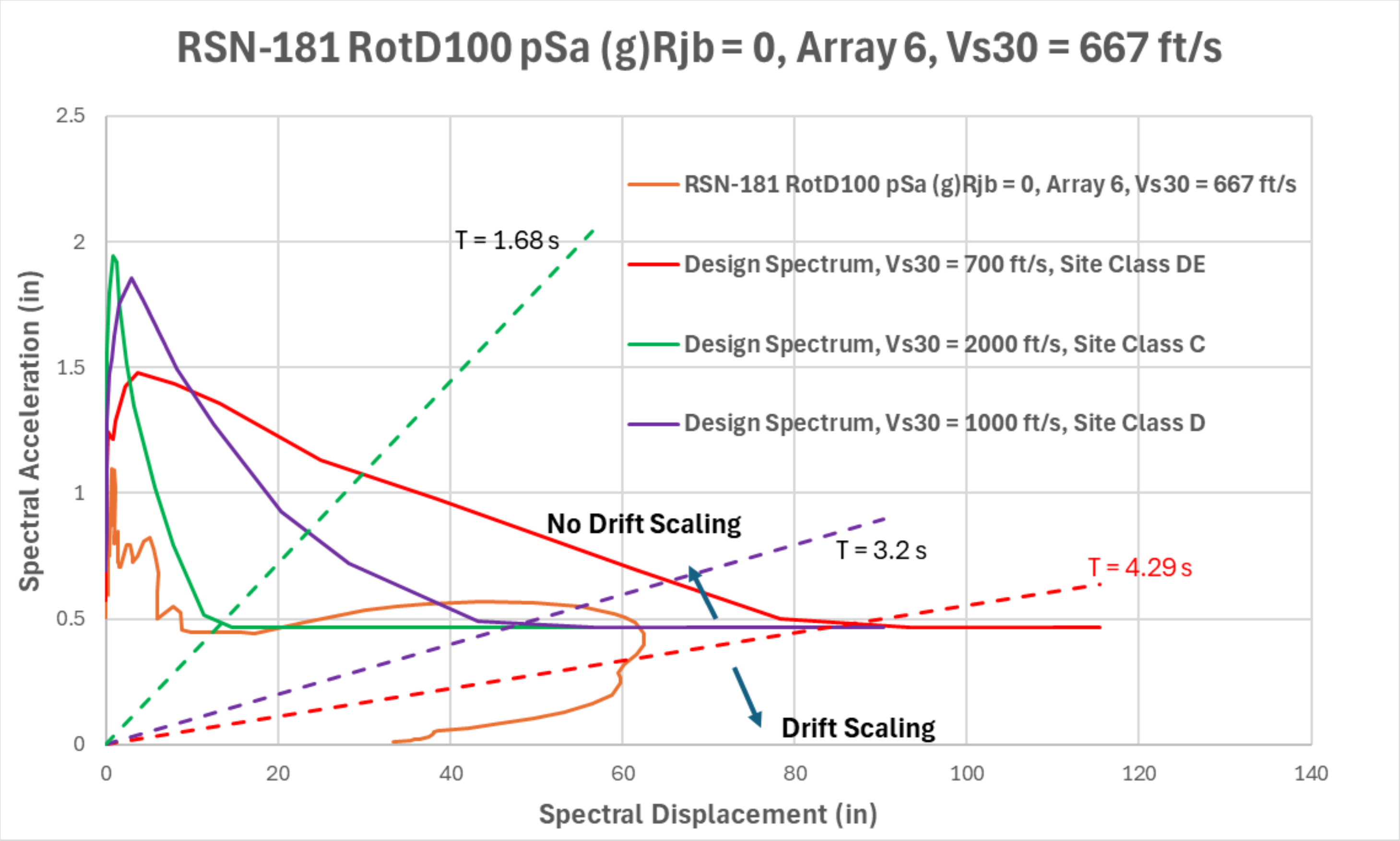
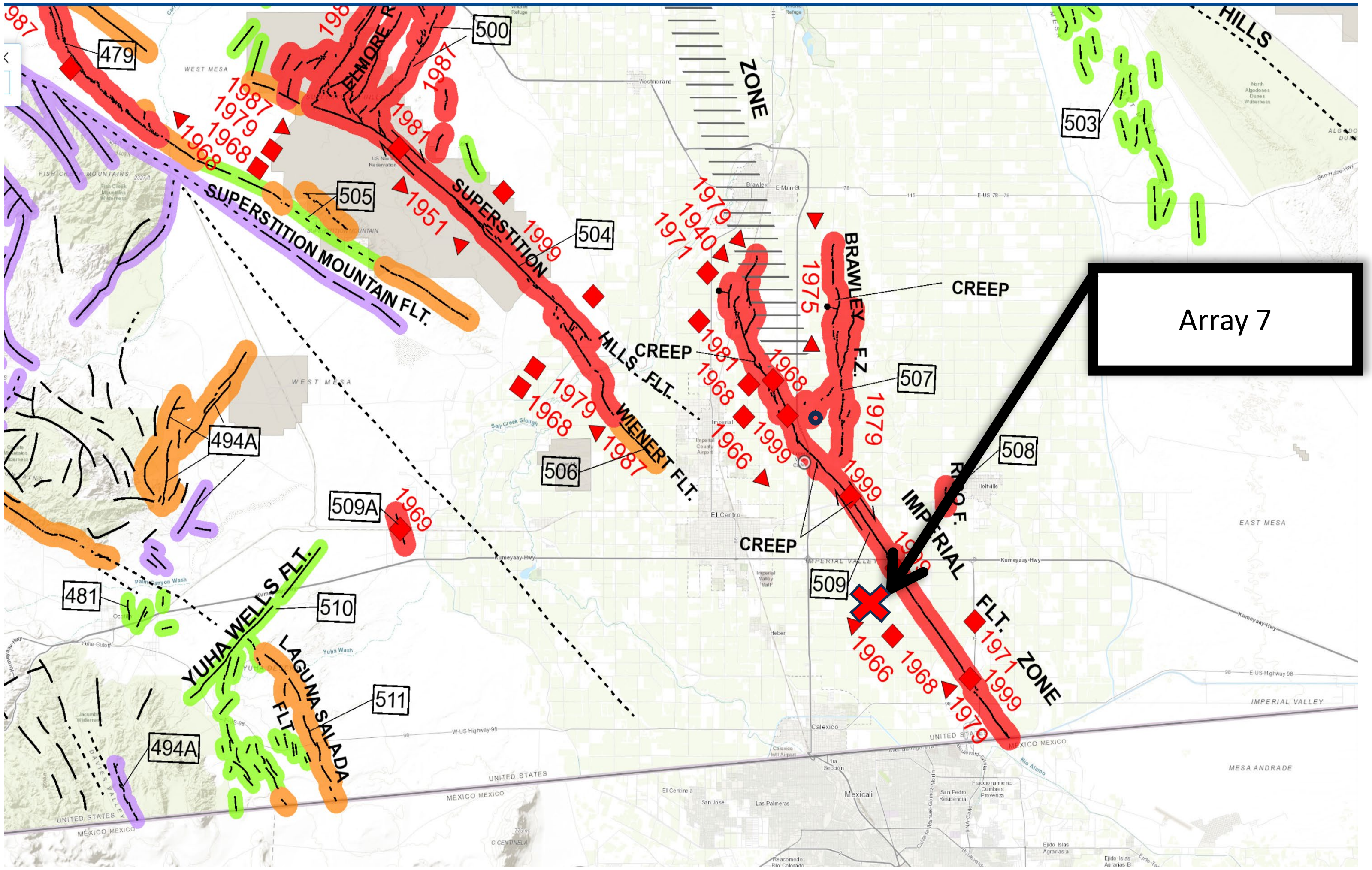
- $C_uT_a \geq 4.29$ s Drift Scaling Required





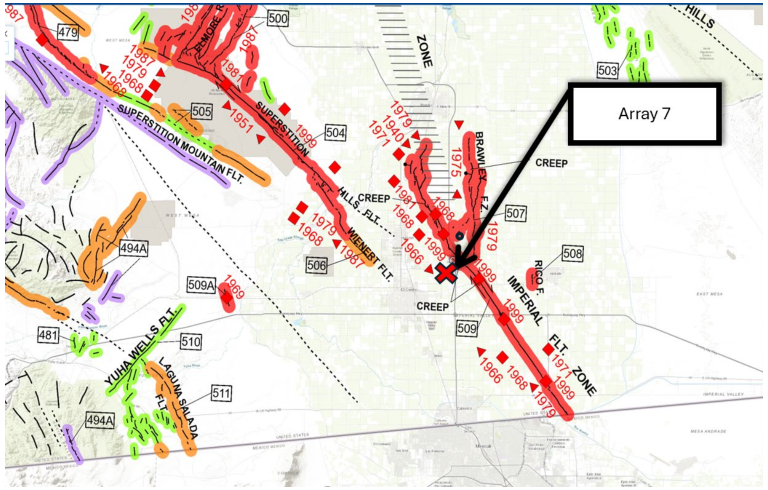
1979 Imperial Valley – Array 7

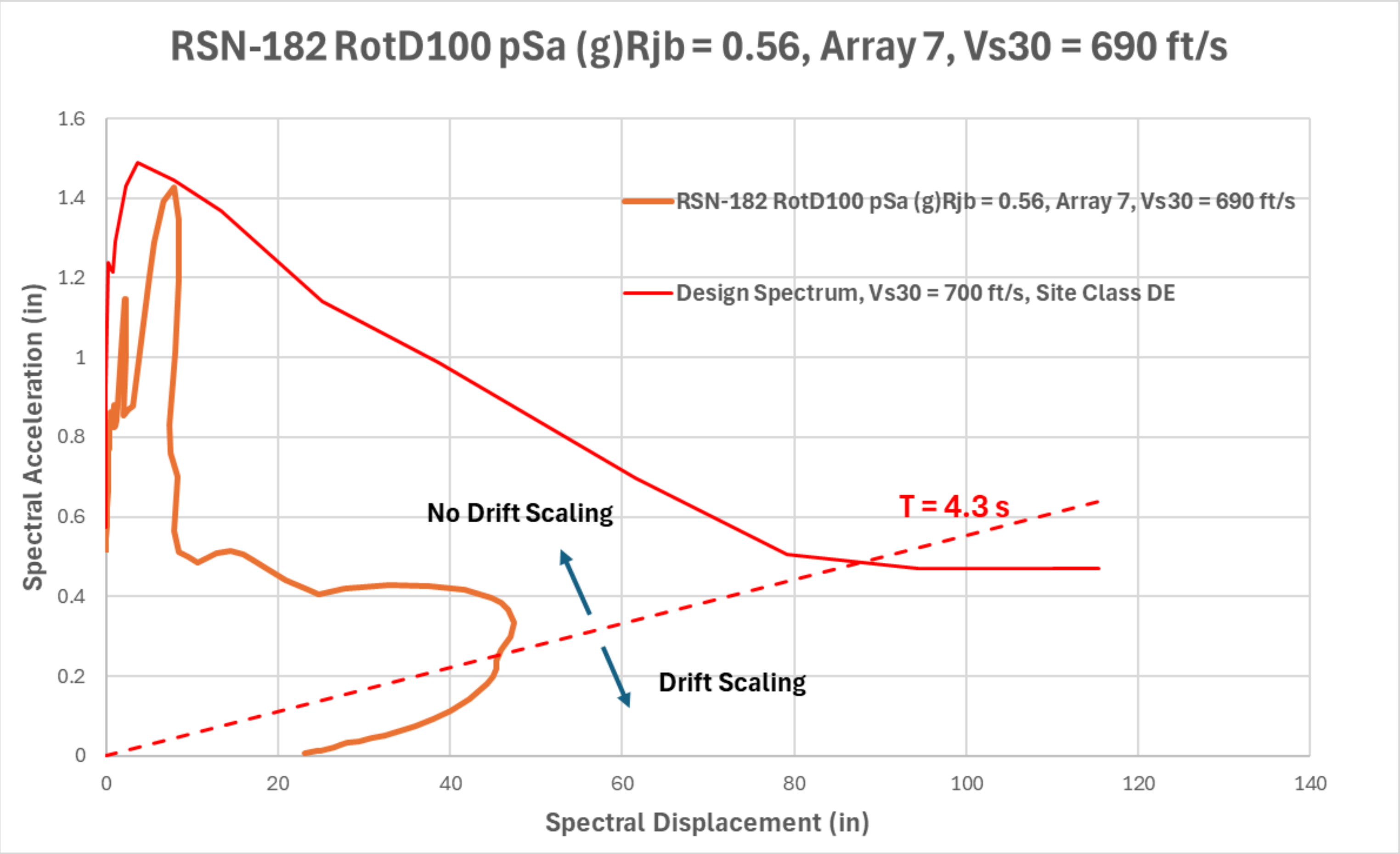


1979 Imperial Valley – Array 7
Comparison with ASCE 7-22 Design Spectrum

- $S_1 = 0.94$ g
- $S_{Ds} = 1.25$ g
- $S_{D1} = 2.13$ g

- $C_u T_a \geq 4.3$ s Drift Scaling Required





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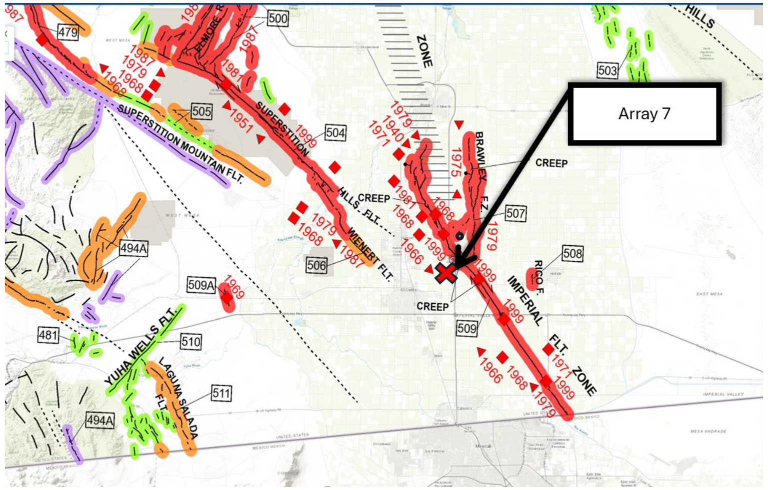
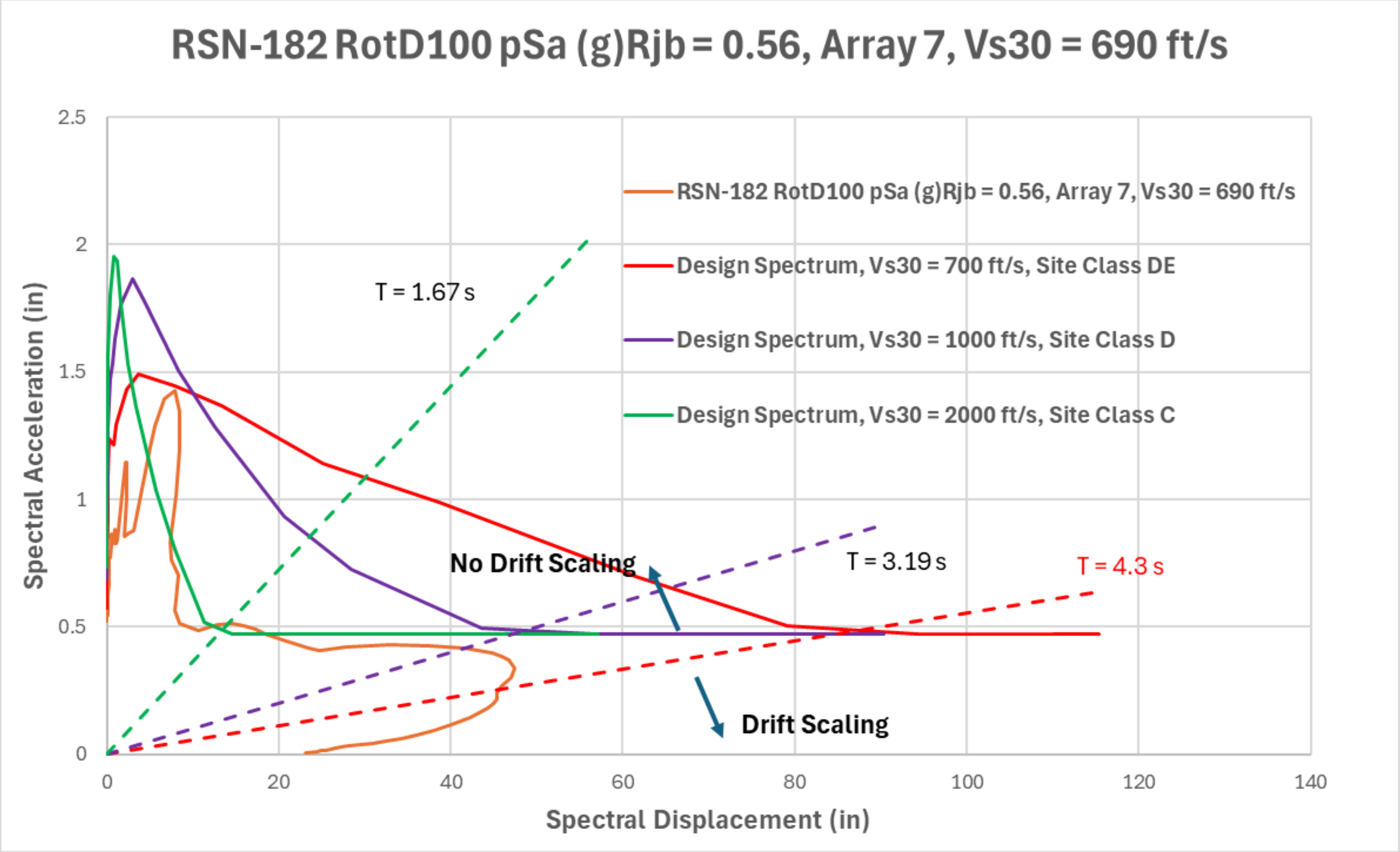
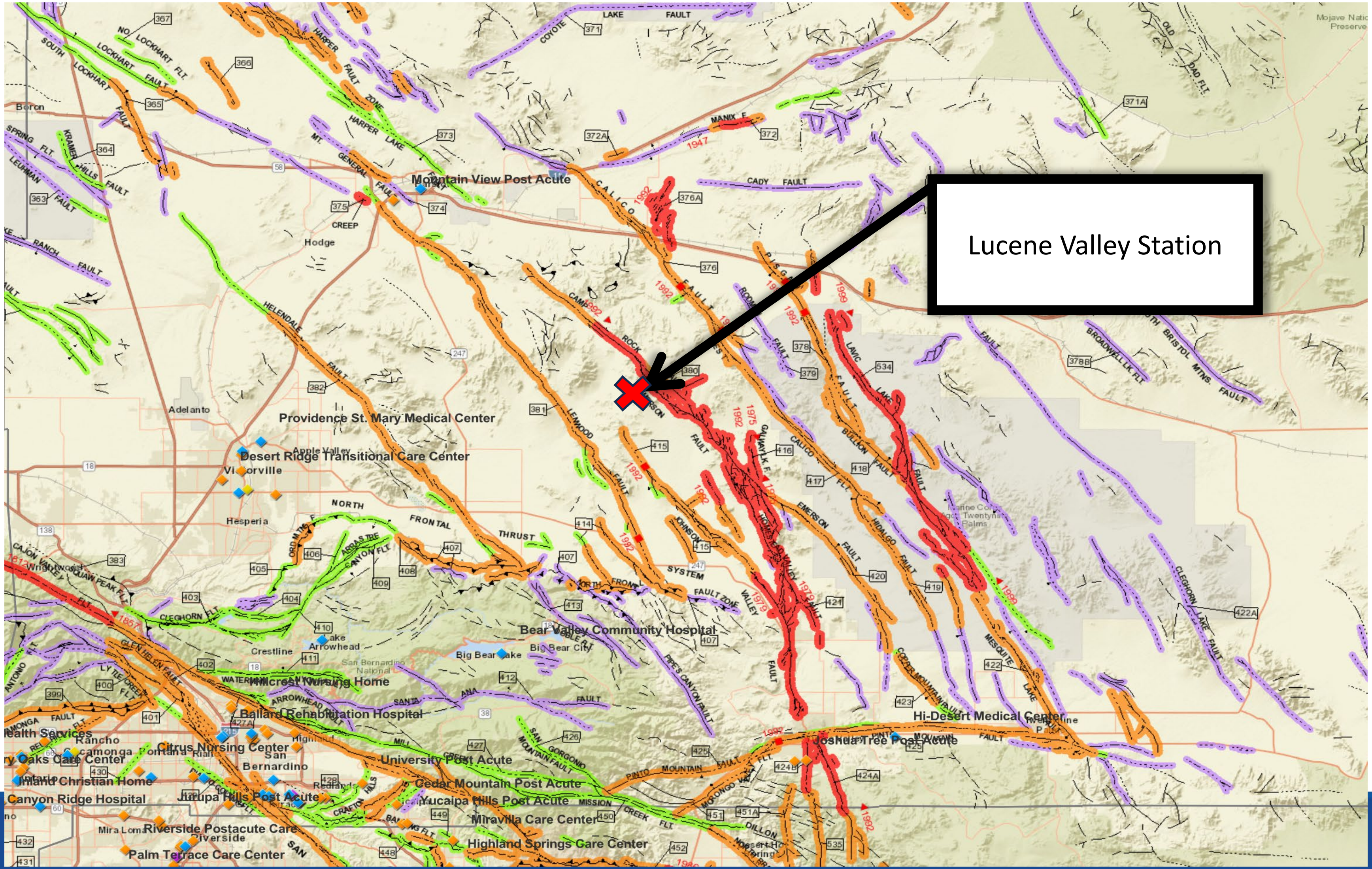




1992 Landers Eqk. – Lucerne Valley Station



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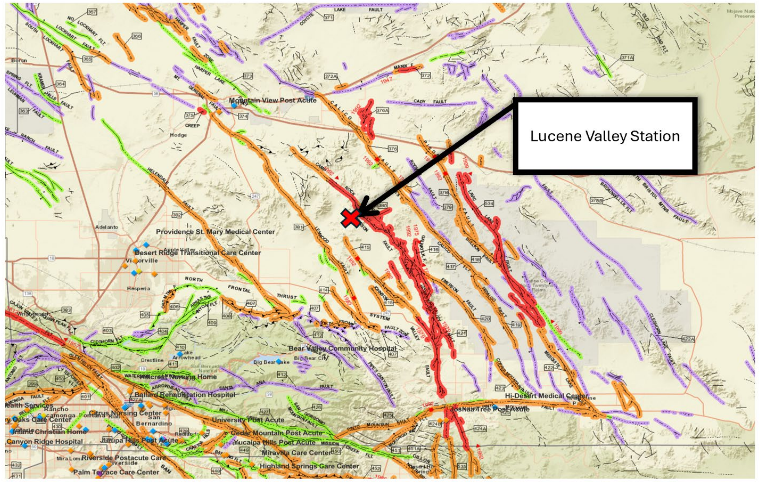
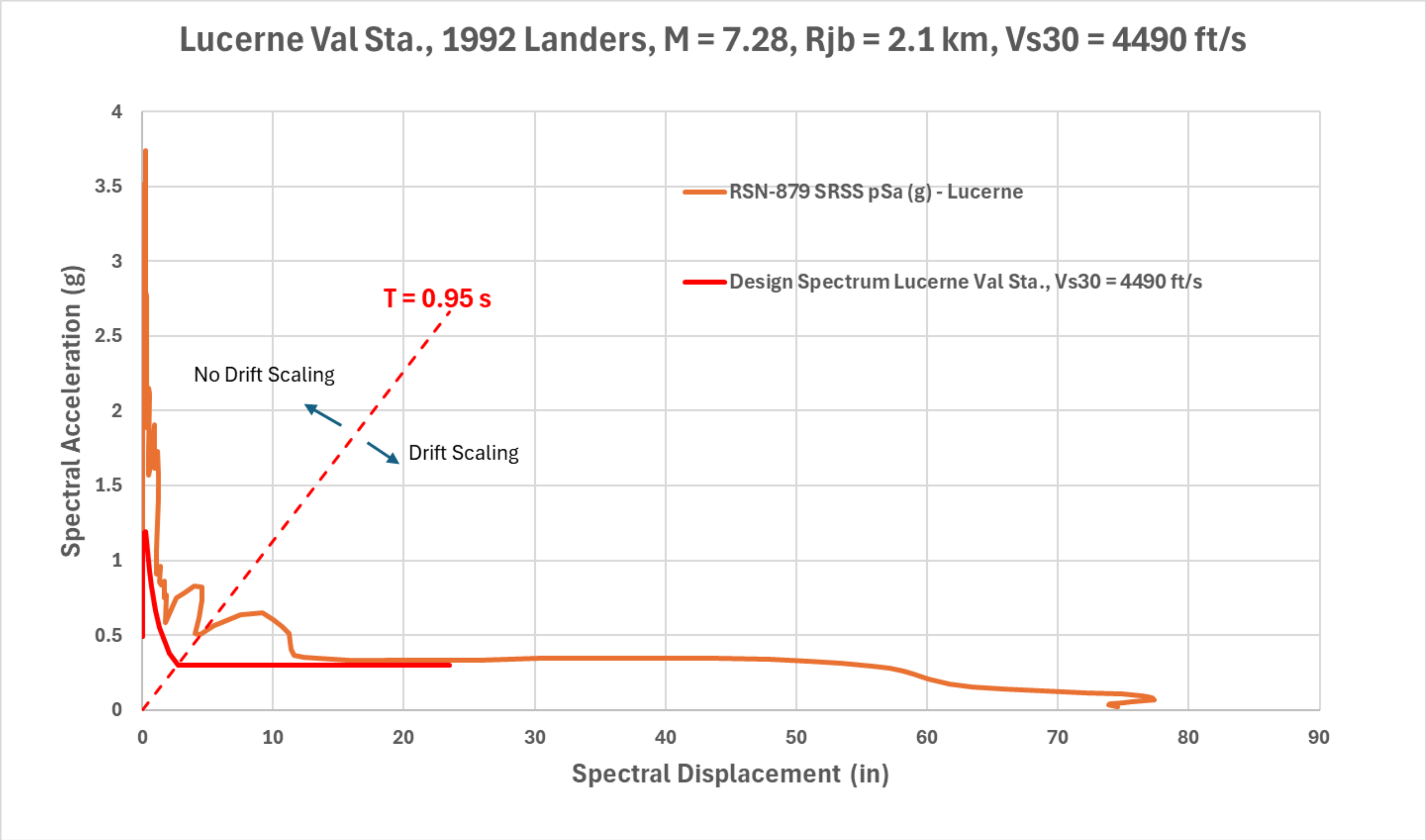
1992 Landers Eqk. – Lucerne Valley Station Comparison with ASCE 7-22 Design Spectrum

- $S_1 = 0.6$ g
- $S_{Ds} = 0.96$ g
- $S_{D1} = 0.28$ g

- $C_u T_a \geq 0.95$ s Drift Scaling Required





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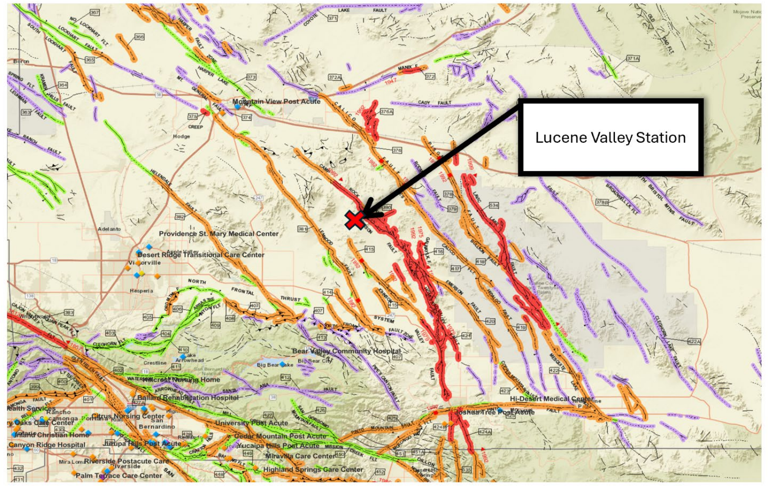
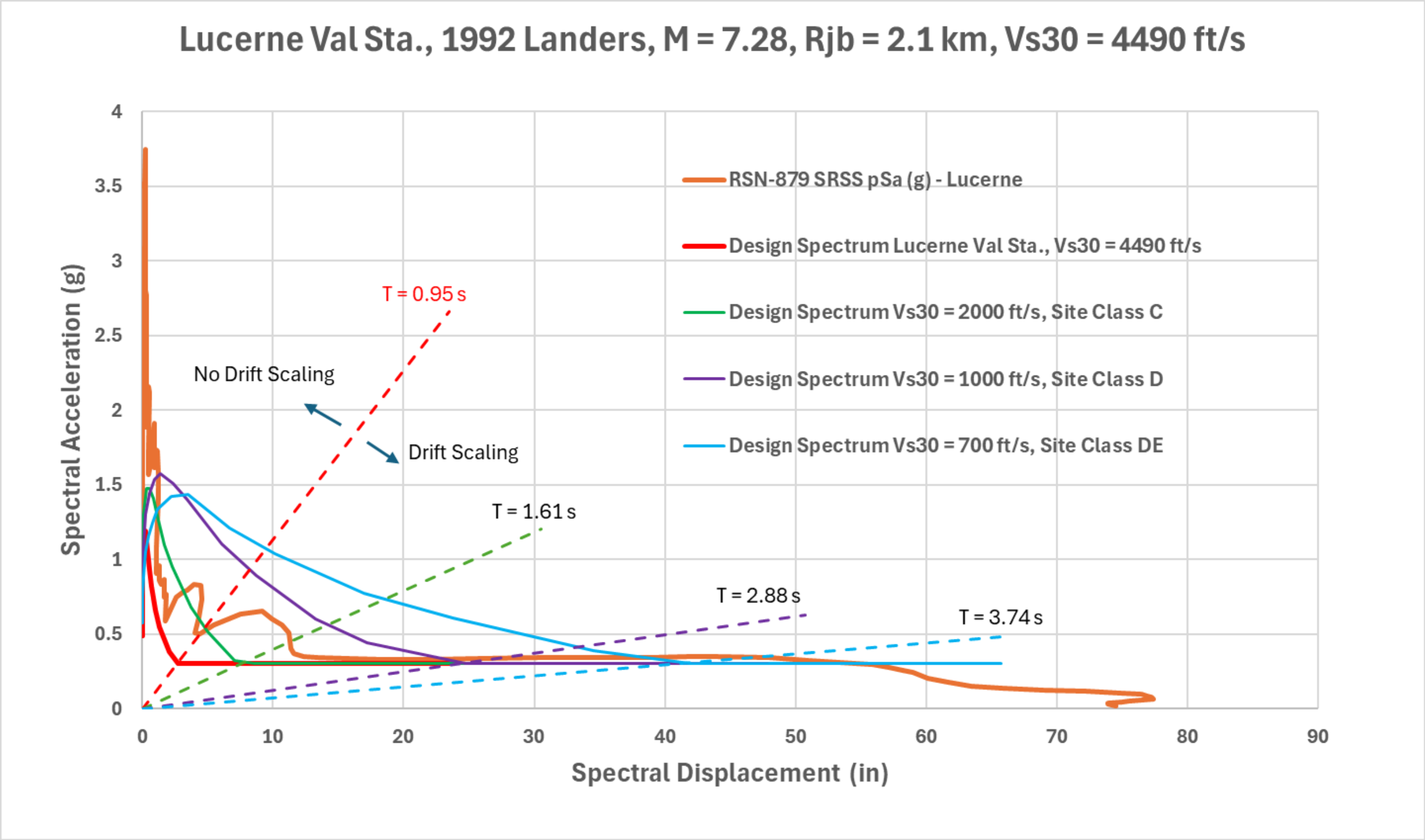
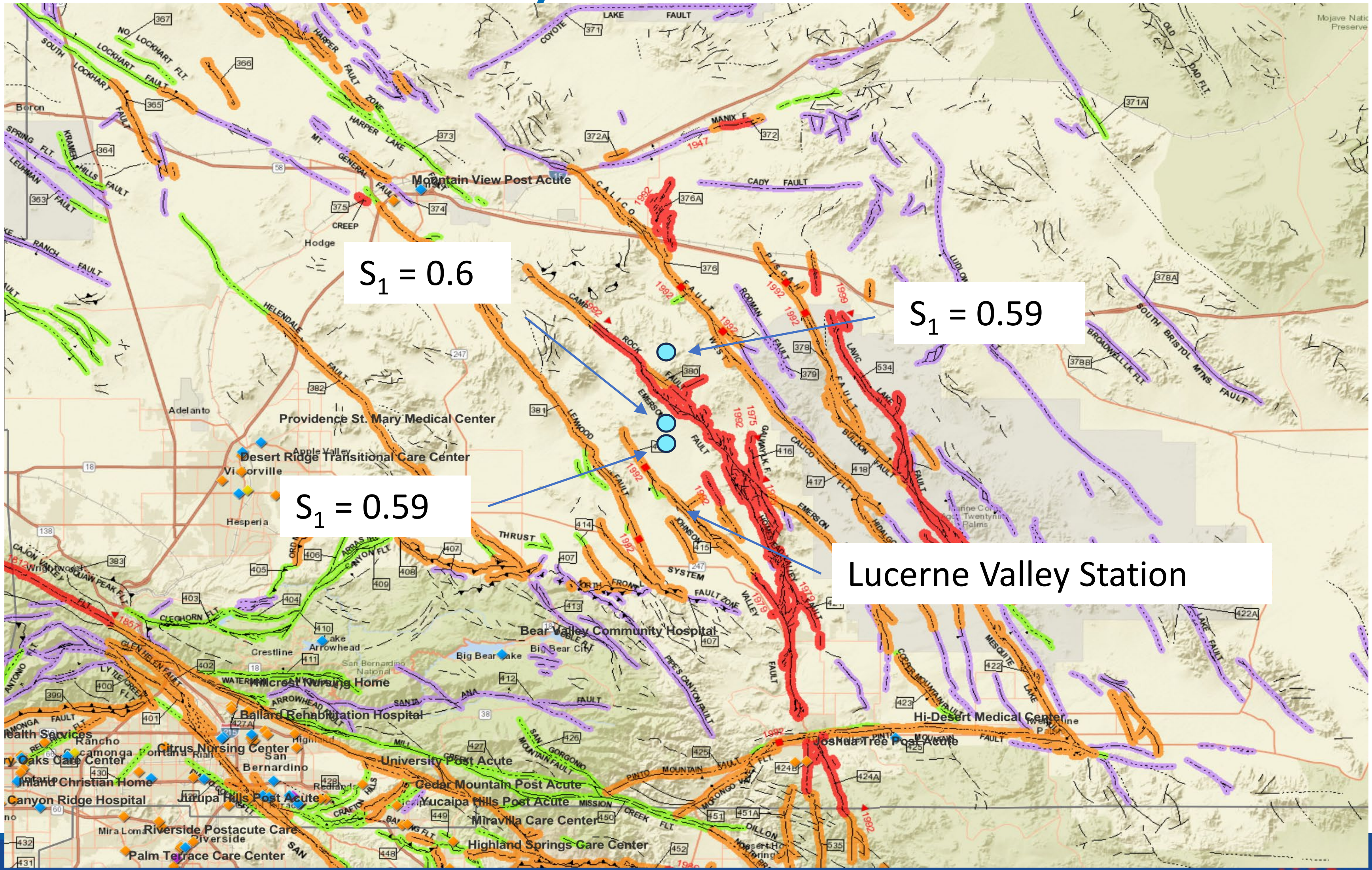
- $C_u T_a \geq$ 0.95 s Drift Scaling Required



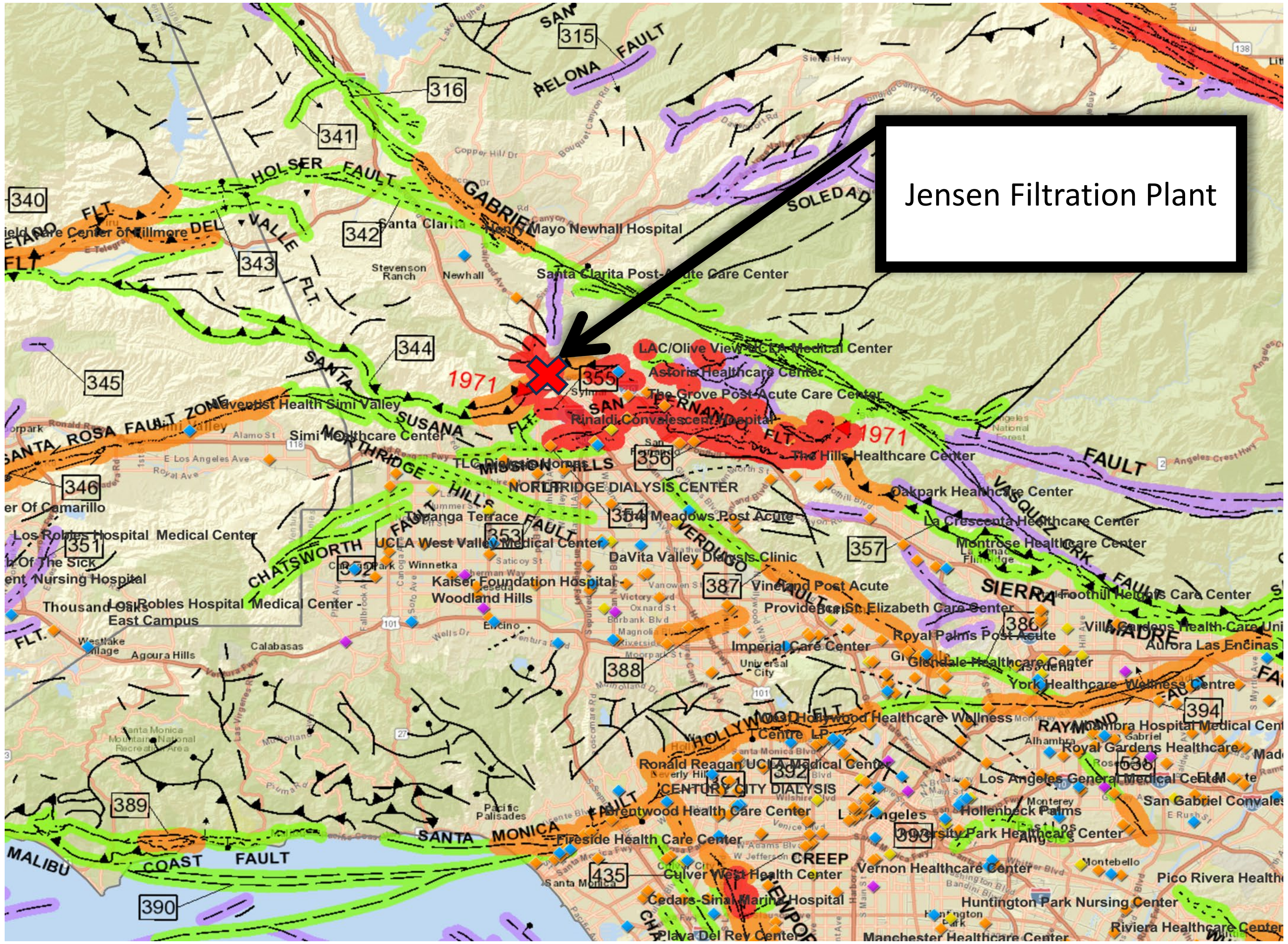


S_1 values near Lucerne Valley Station

- $S_1 < 0.6$ g No drift scaling



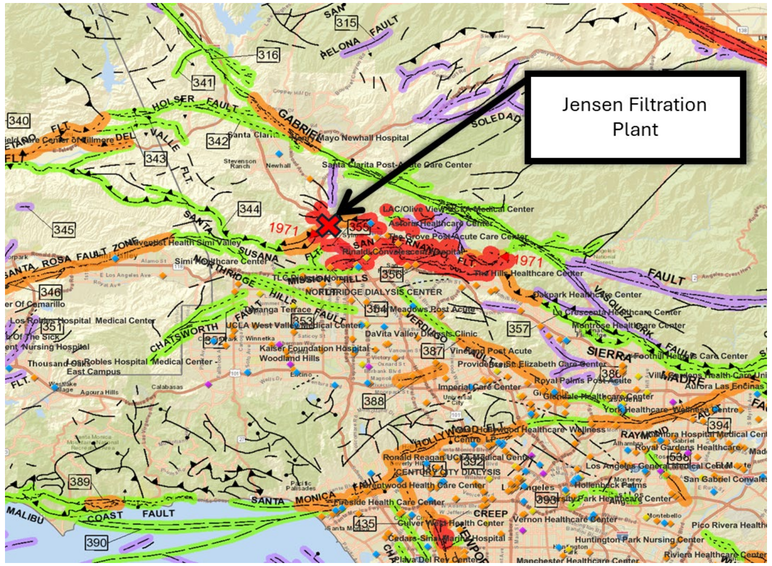
1994 Northridge – Jensen Filtration Plant Generator Building

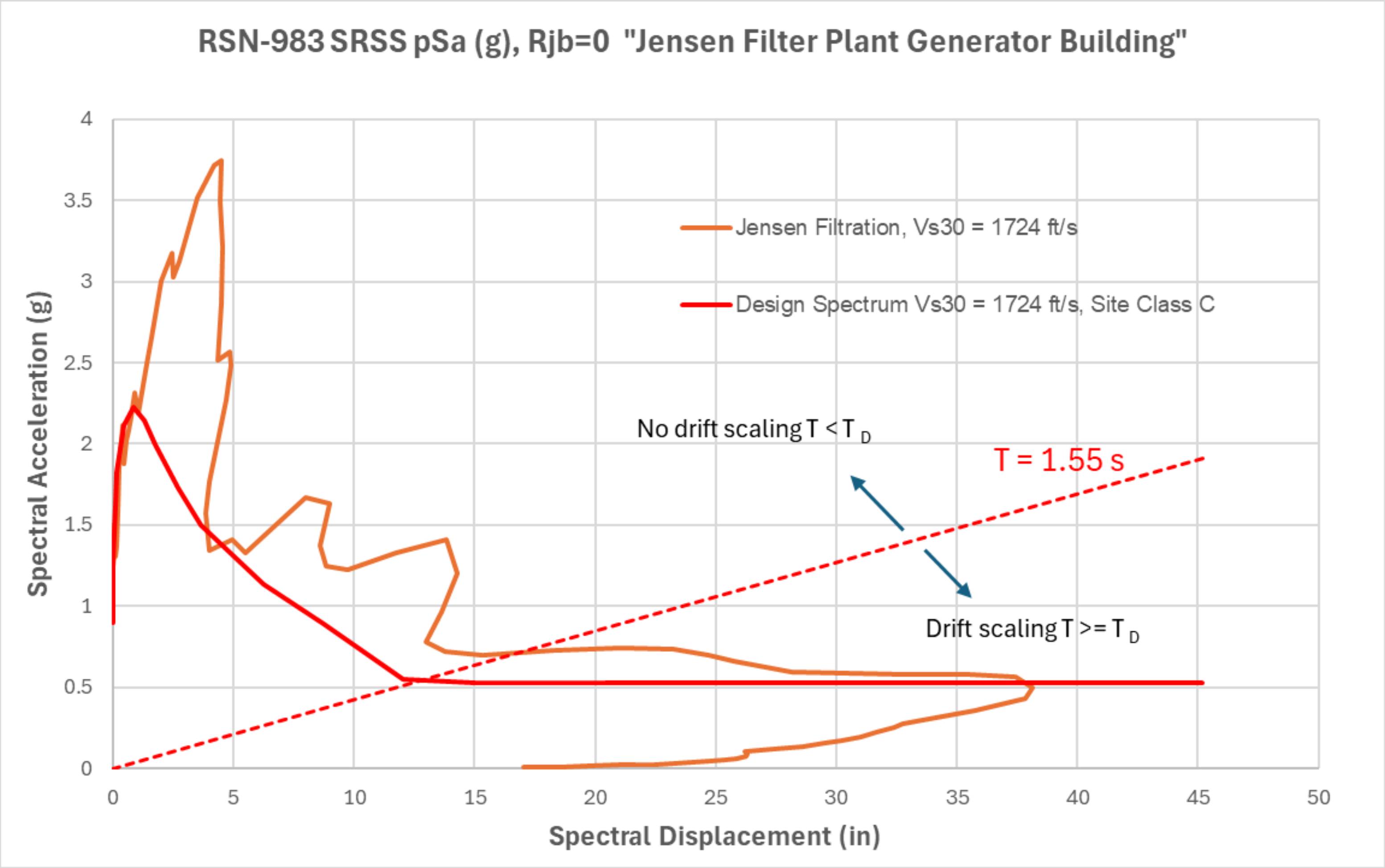


Jensen Filtration Plant Generator Building Comparison with ASCE 7-22 Design Spectrum

- S_1 = 1.06 g
- S_{Ds} = 2.08 g
- S_{D1} = 0.99 g

- $C_u T_a \geq$ 1.55 s Drift Scaling Required





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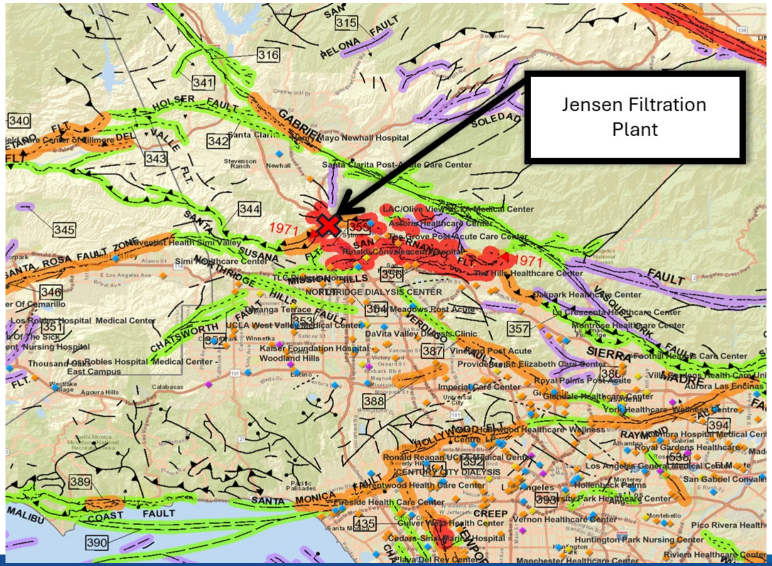

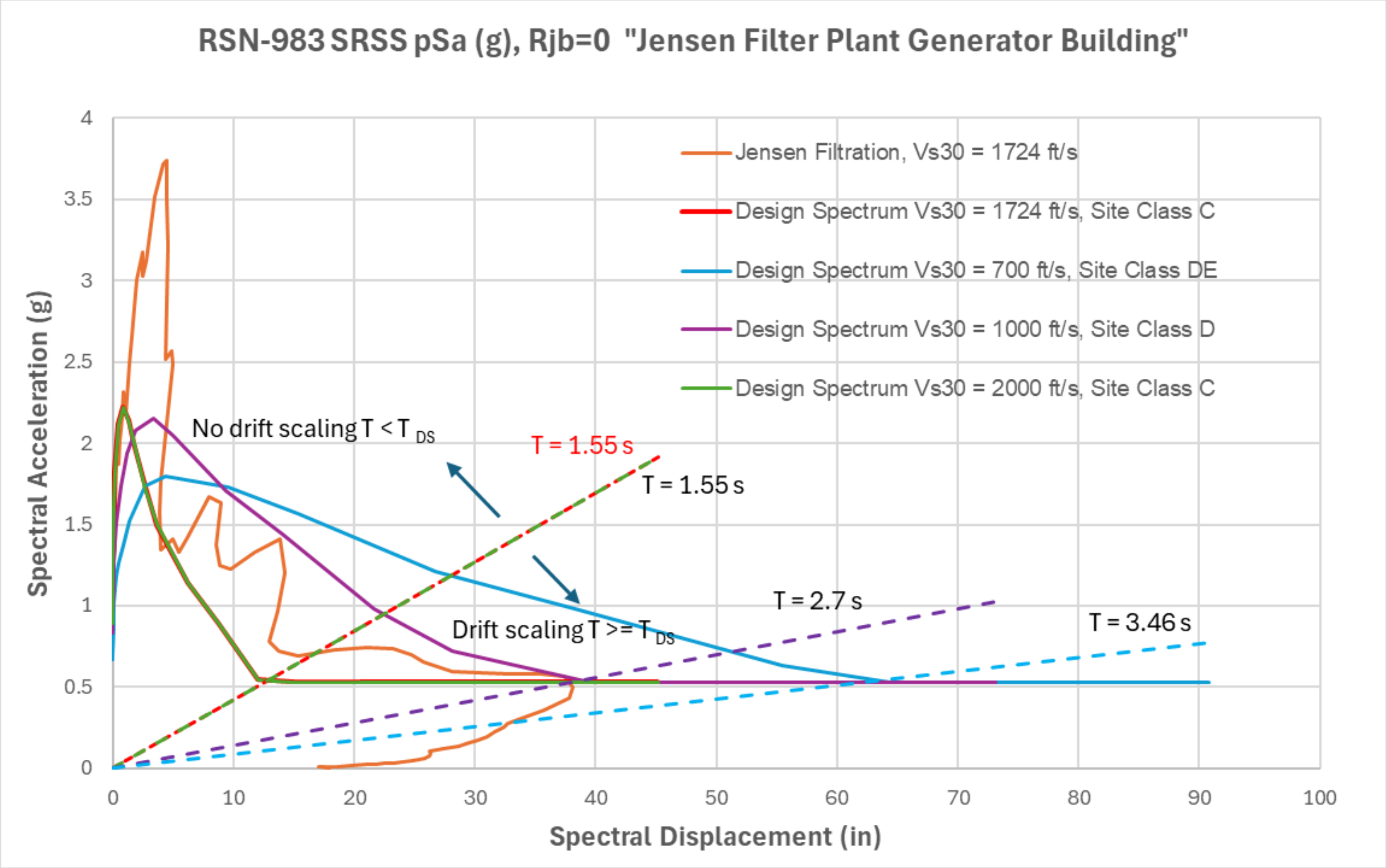

1994 Northridge – Newhall Fire Station

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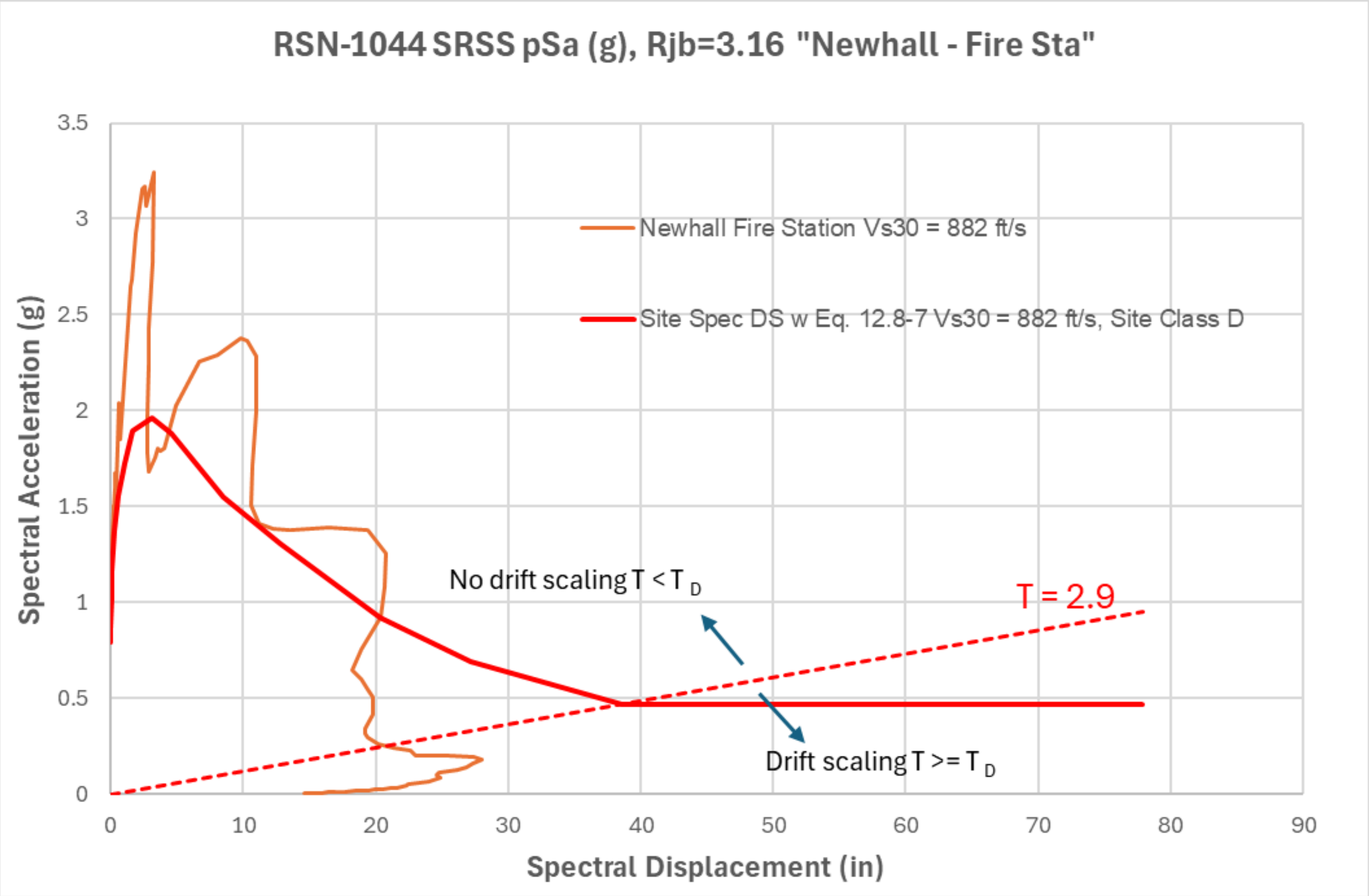
1994 Northridge – Newhall Fire Station
Comparison with ASCE 7-22 Design Spectrum

- S_1 = 0.93 g
- S_{Ds} = 1.85 g
- S_{D1} = 0.86 g

- $C_u T_a \geq 2.9$ s Drift Scaling Required



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1994 Northridge – Newhall Fire Station
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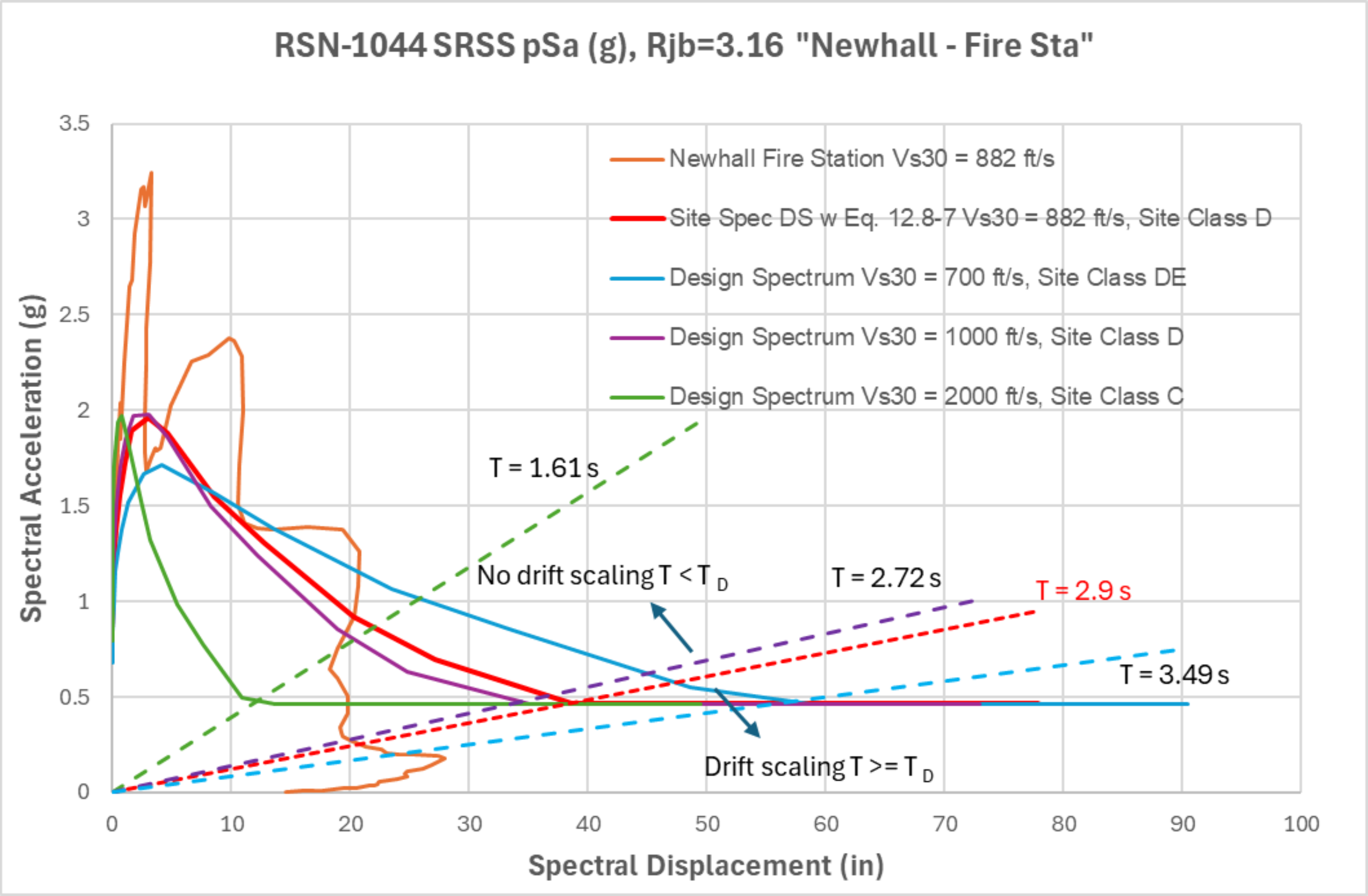
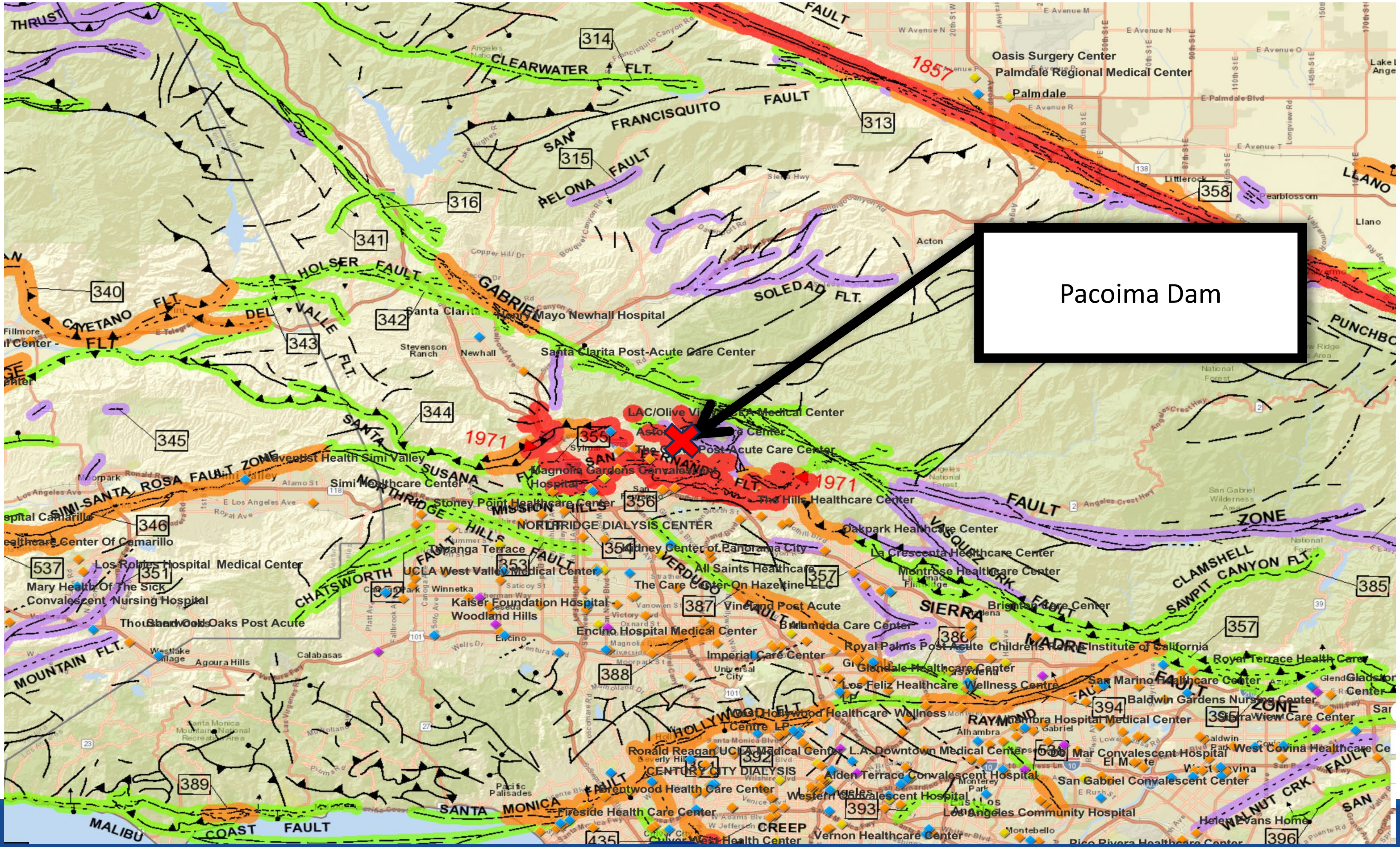


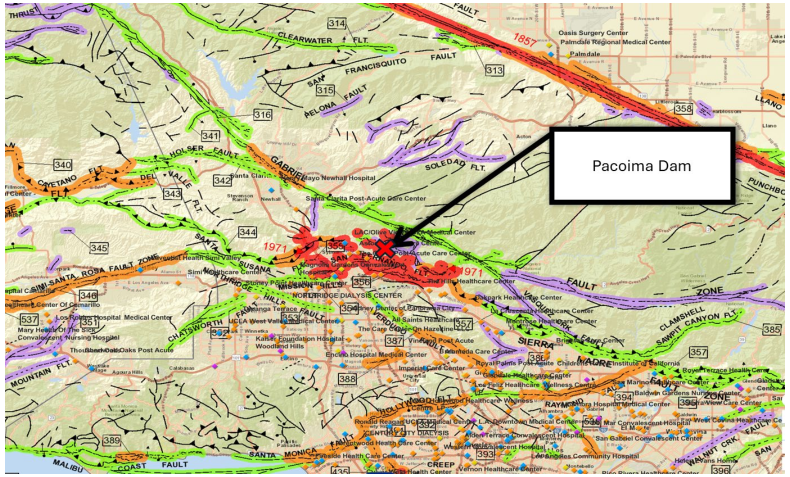
1971 San Fernando – Pacoima Dam

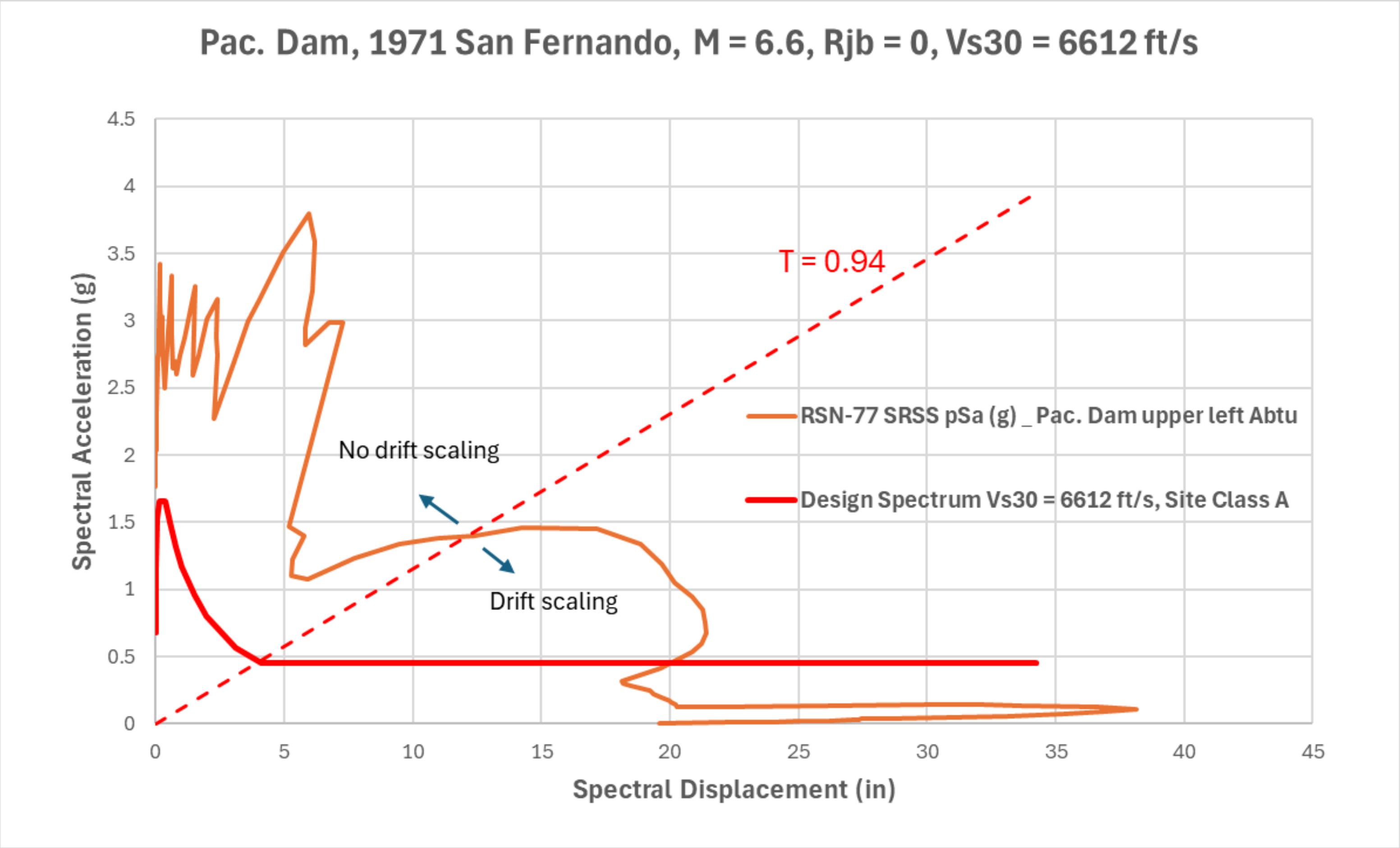


1971 San Fernando – Pacoima Dam
Comparison with ASCE 7-22 Design Spectrum

- $S_1 = 0.91$ g
- $S_{Ds} = 1.17$ g
- $S_{D1} = 0.38$ g

- $C_u T_a \geq 0.94$ s Drift Scaling Required





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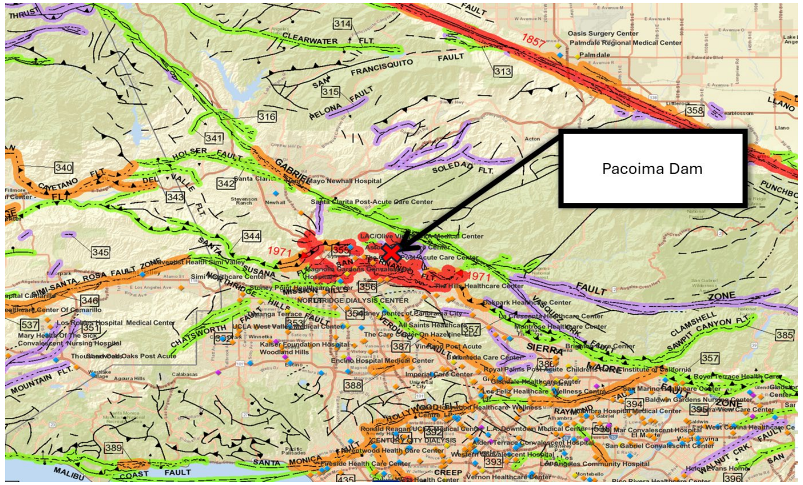
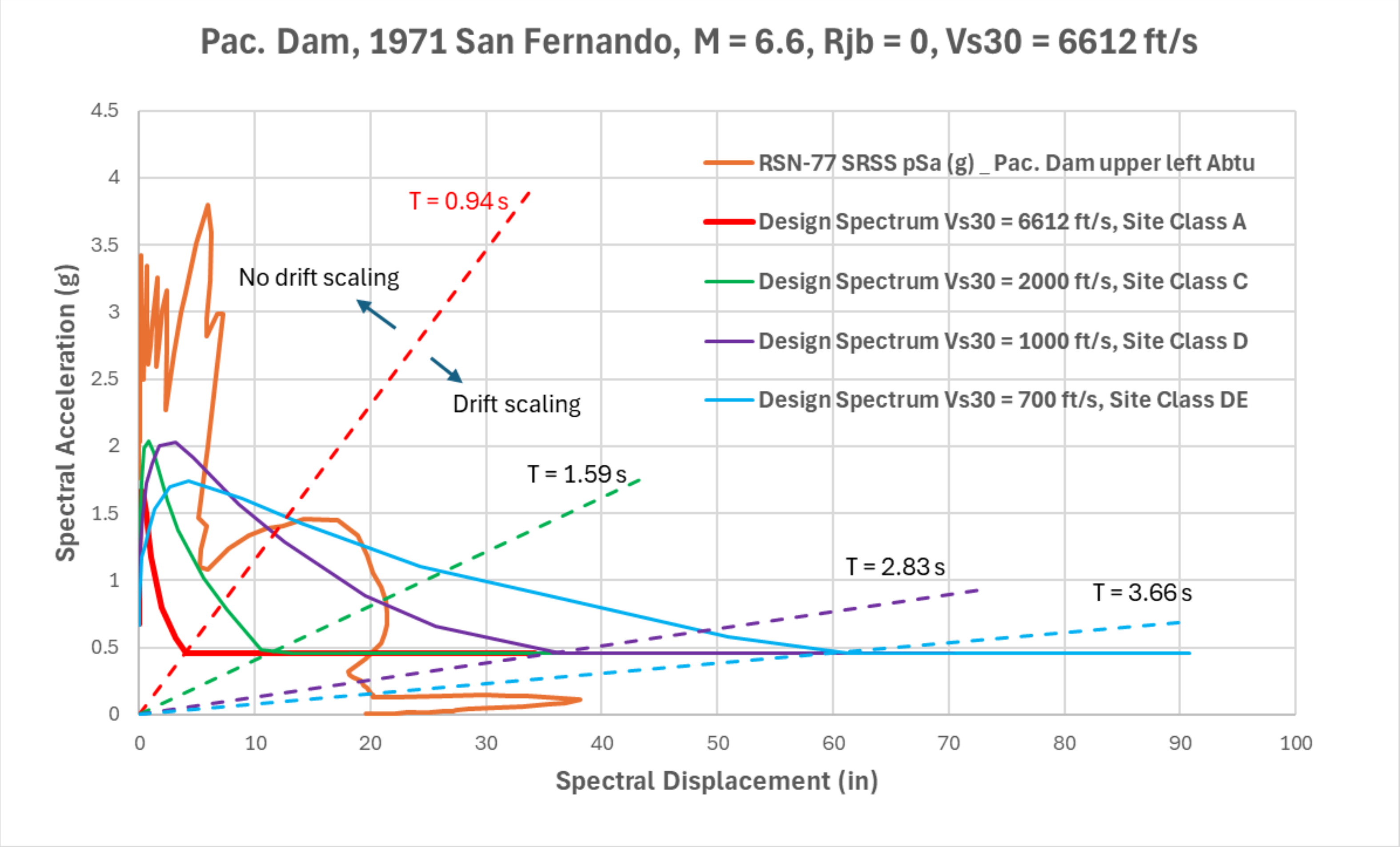


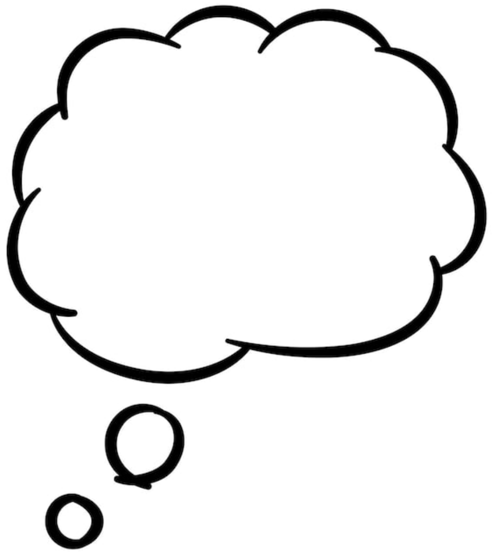


Summary

- Design ground motion spectra do not capture near fault effects.
- Stiff sites produce high velocity pulses that could affect long period structures.
- Drift scaling not required for buildings on soft soils with Vs30 < 1000 ft/s or for Site Class D or lower.
- Drift scaling should be considered for buildings in Site Class CD or better regardless of the S_1 value when the building site is less that 5 km from a known active fault of Source Type B, M > 6.5.

Proposed Change Currently being balloted in ASCE 7-28

- Limit drift scaling to sites classified as near fault in accordance with ASCE 7-22, Section 11.4.



Case Study

PROJECT DESCRIPTION:

- 240-ft tall OSHPD-1 bed tower located in San Diego, California
- Distance from fault < 5km
- S_s = 1.38g
- S_1 = 0.472g
- S_{DS} = 1.028g
- S_{D1} = 0.444g
- Building codes:
  - CBC 2016
  - ASCE 7-10
- Risk category IV
- I_e = 1.5
- SFRS:
  - Longitudinal direction: Steel special moment resisting frames
  - Transverse direction: Steel buckling restrained braced frames
- R = 8
- C_d = 5.5 (longitudinal direction)
- C_d = 5 (transverse direction)

Case Study

RESPONSE SPECTRUM ANALYSIS (RSA):

ASCE 7-10 Eq (12.8-5) (which is Eq (12.8-6) in ASCE 7-22) governed minimum base shear as S_1 was less than 0.6g.

ASCE 7-10:	ASCE 7-22:
C_s shall not be less than $C_s = 0.044 S_{DS} I_e \geq 0.01$ (12.8-5) In addition, for structures located where S_1 is equal to or greater than $0.6g$, C_s shall not be less than $C_s = 0.5 S_1/(R/I_e)$ (12.8-6)	**Lower Bounds for C_s for Both Methods:** C_s shall not be less than $C_s = 0.044 S_{DS} I_e \geq 0.01$ (12.8-6) In addition, for structures located where S_1 is equal to or greater than 0.6, C_s shall not be less than $C_s = 0.5 S_1/(R/I_e)$ (12.8-7) where S_1 is the mapped maximum considered earthquake spectral response acceleration parameter determined in accordance with Section 11.4.2 or 11.4.4.

This resulted in C_s of 0.068g. Due to the requirement in CBC 2016 §1616A.1.13 (snip below), drifts were also evaluated at a base shear of 0.068W.

Case Study

(**Note:** §1616A.1.13 provision in CBC 2016 has been removed in CBC 2022. CBC 2022 has no amendments on the drift scaling provision of ASCE 7-16.)

ASCE 7-10:

12.9.4.1 Scaling of Forces

Where the calculated fundamental period exceeds C_uT_a in a given direction, C_uT_a shall be used in lieu of T in that direction. Where the combined response for the modal base shear (V_t) is less than 85 percent of the calculated base shear (V) using the equivalent lateral force procedure, the forces shall be multiplied by $0.85\frac{V}{V_t}$:

where

V = the equivalent lateral force procedure base shear, calculated in accordance with this section and Section 12.8

12.9.4.2 Scaling of Drifts

Where the combined response for the modal base shear (V_t) is less than $0.85C_sW$, and where C_s is determined in accordance with Eq. 12.8-6, drifts shall be multiplied by $0.85\frac{C_sW}{V_t}$

CBC 2016, OSHPD 1, 4 & DSA-SS:

1616A.1.13 ASCE 7, Section 12.9.4. *Replace ASCE 7 Section 12.9.4 as follows:*

12.9.4 Scaling design values of combined response. *Modal base shears used to determine forces and drifts shall not be less than the base shear calculated using the equivalent lateral force procedure of Section 12.8.*

Base shears that correspond to drifts scaled by C_d/I_e, were approximately 0.23W and 0.25W in the longitudinal and transverse directions, respectively.

Case Study

It is also observed that the drift scaling requirement for RSA resulted in DE-level base shears that are greater than the MCE-level base shears obtained through NLRHA.

Hazard	Direction	Base Shears at which Drifts are Evaluated*	
		RSA	NLRHA
DE	Longitudinal	0.23W	0.16W
	Transverse	0.25W	0.14W
MCE	Longitudinal	-	0.21W
	Transverse	-	0.17W

Table below compares RSA drifts, with and without base shear scaling to ELF, of the revised design with 40% less steel SFRS tonnage. It is observed that the drift limit of 1% is still satisfied with the revised design if base shear is not scaled to the ELF base shear.

Level	RSA Drift Limit	Max. RSA Drifts of the Revised Design			
		Base Shear Scaled to ELF		Base Shear not Scaled to ELF	
		Longitudinal Dir.	Transverse Dir.	Longitudinal Dir.	Transverse Dir.
Roof	1%	1.8%	2.4%	0.6%	0.9%
L1 – L15		2.4%	1.8%	0.8%	0.7%

Takeaway from Case Study

- Drift scaling was intended to prevent weak buildings from collapse of buildings subject to pulse period drifts, the NLRHA shows that buildings with sufficient ductility are adequate to accommodate these pulse period drifts and also satisfy the minimum drift requirement.

Additional studies

- Additional studies were performed to investigate the impact of drift scaling for randomly selected near fault and far field sites with high S_{D1} values.

Additional studies

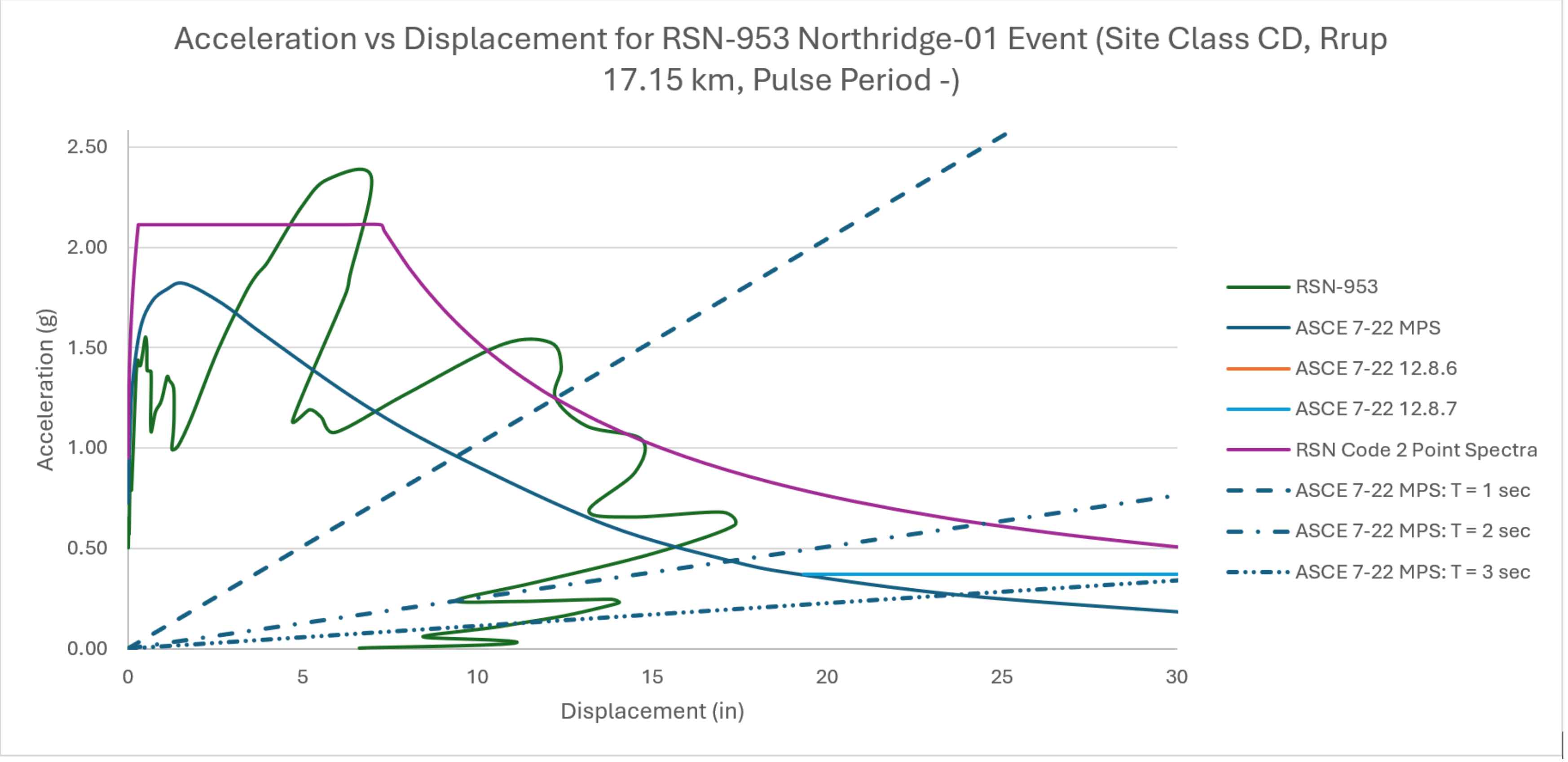


Figure 1: RSN-953, Spectral Acceleration vs Spectral Displacement plot

Mapped S_1 : 0.74

Additional studies

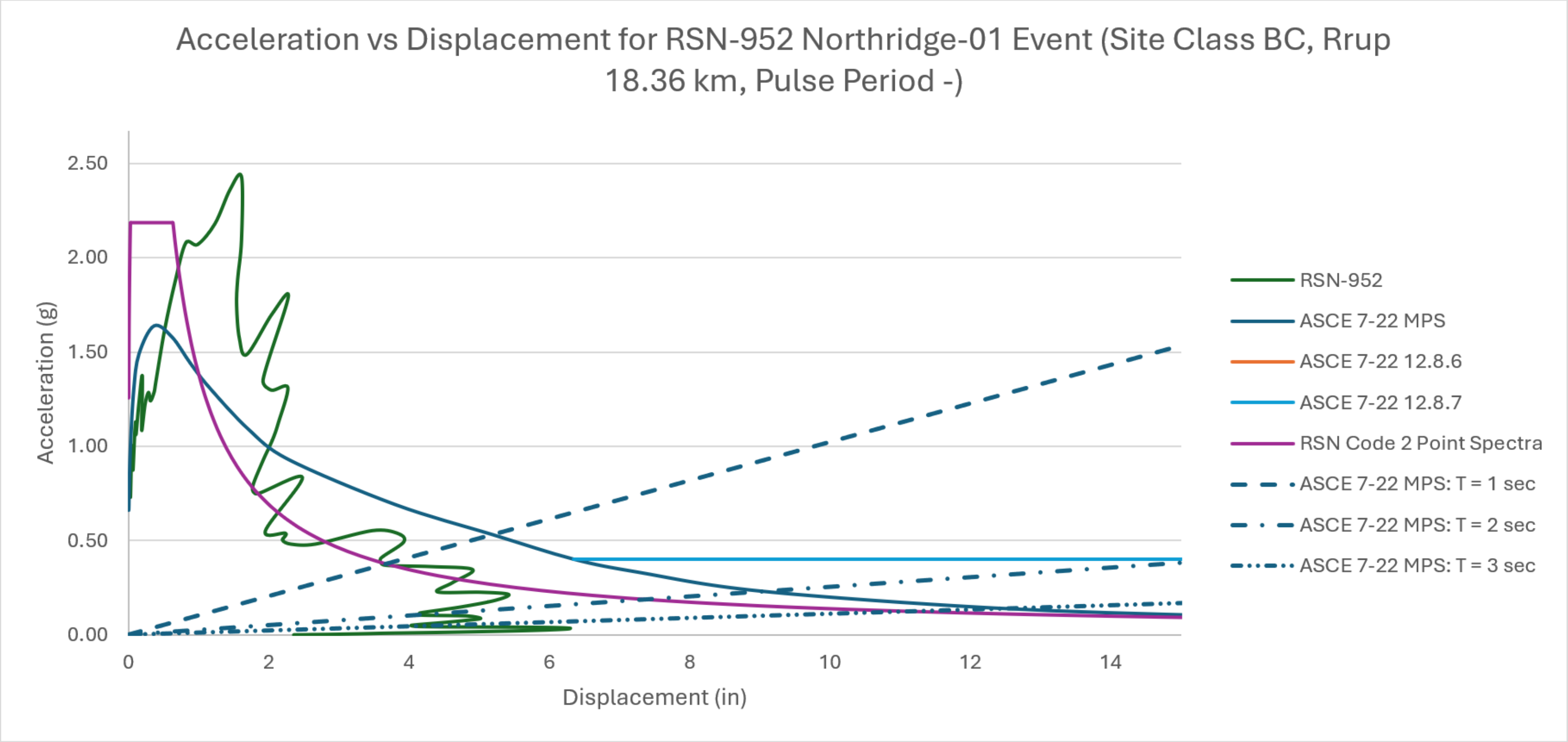


Figure 2: RSN-953, Spectral Acceleration vs Spectral Displacement plot

Mapped S_1: 0.80

Additional studies

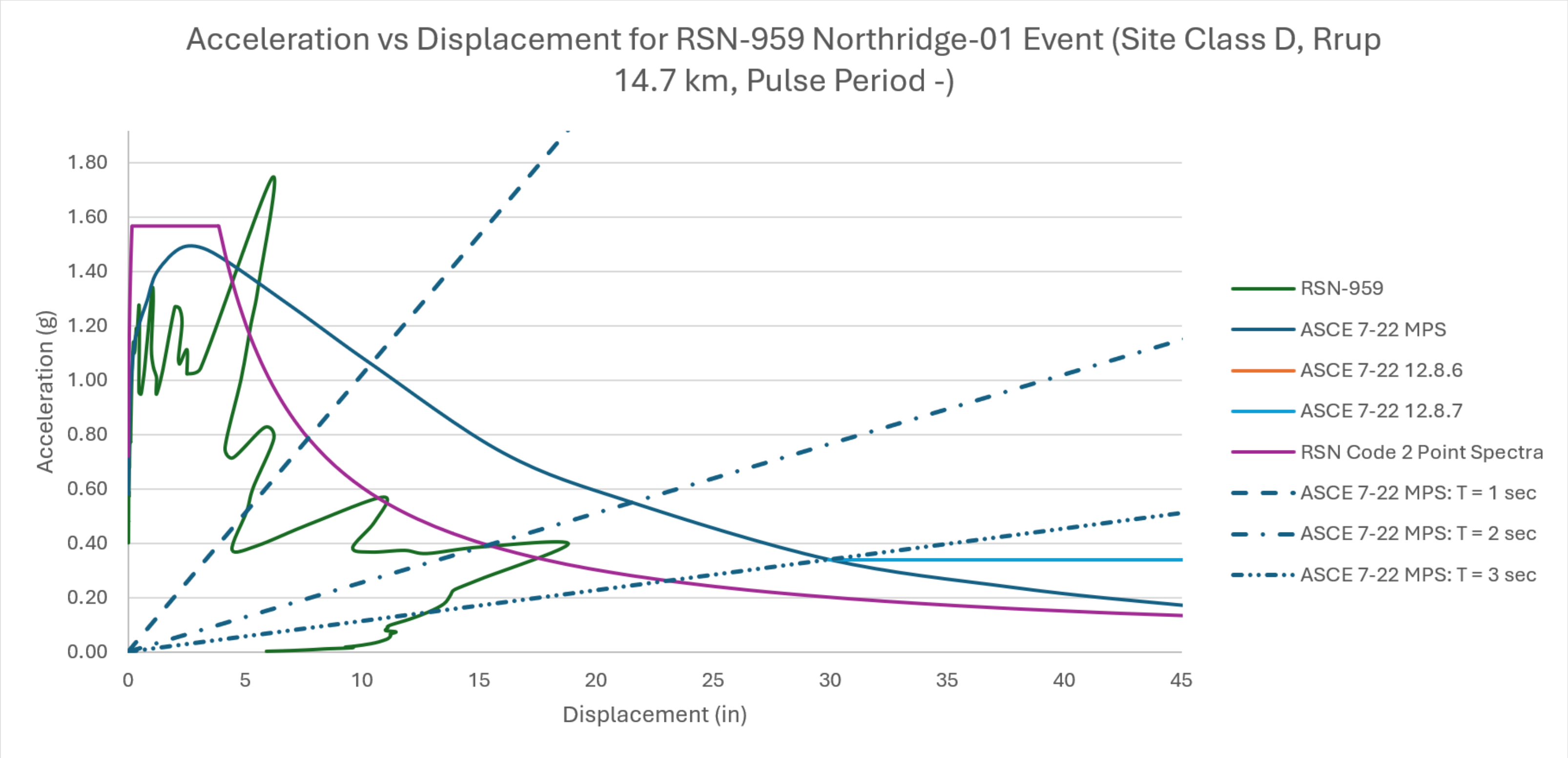


Figure 3: RSN-959, Spectral Acceleration vs Spectral Displacement plot

Mapped S_1: 0.68

Additional studies

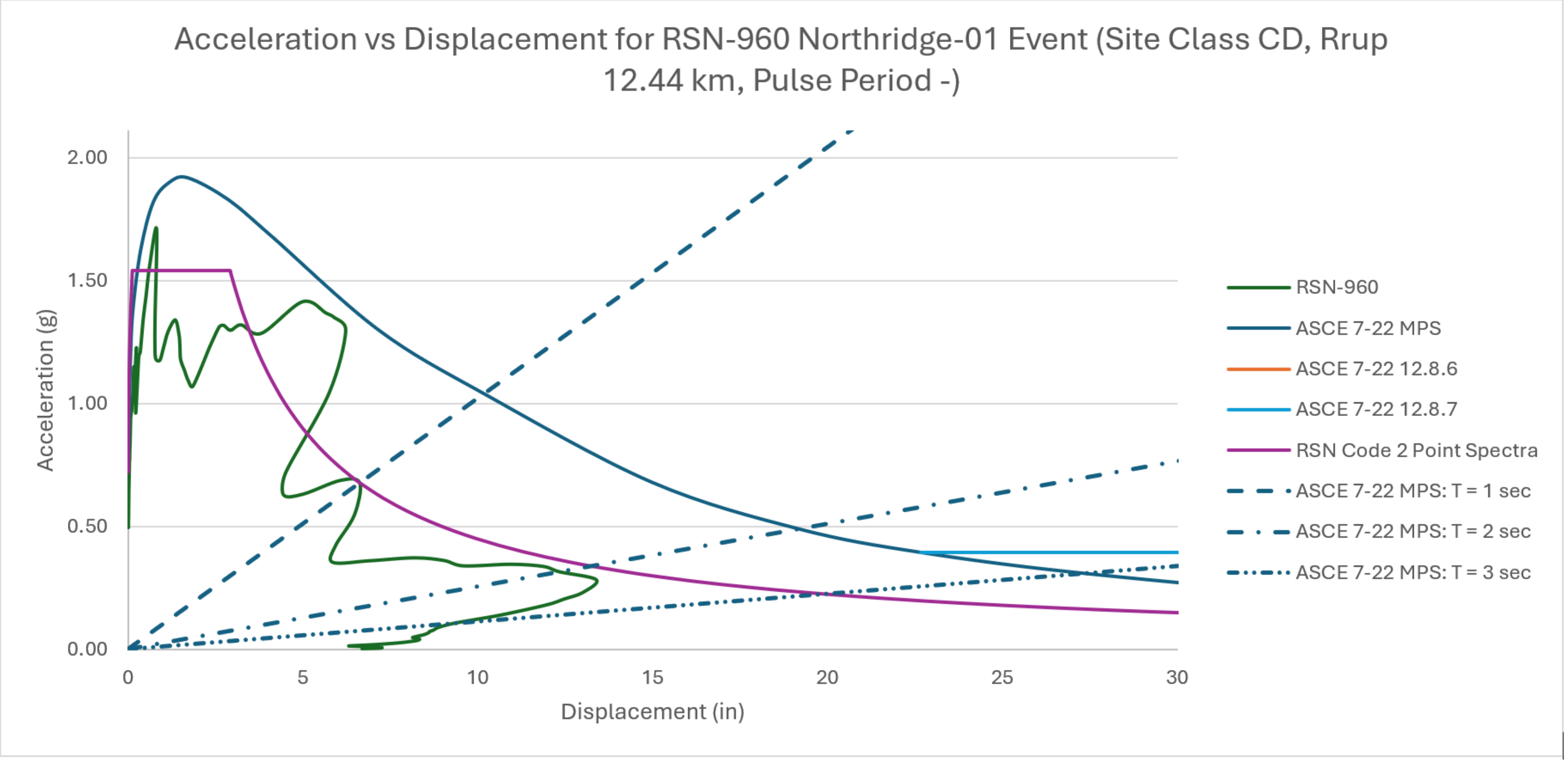


Figure 4: RSN-960, Spectral Acceleration vs Spectral Displacement plot

Mapped S_1: 0.79

Additional studies

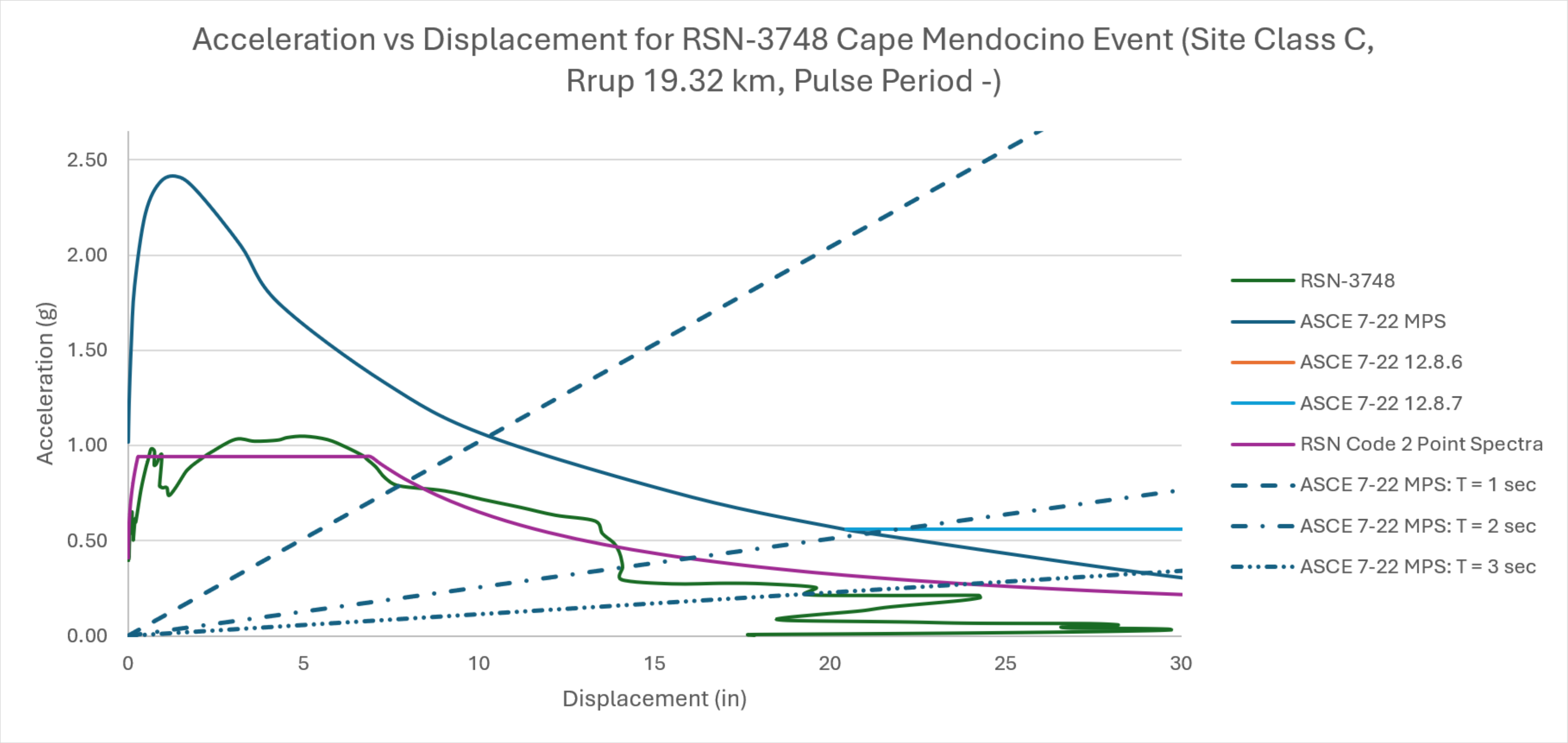


Figure 5: RSN-3748, Spectral Acceleration vs Spectral Displacement plot

Recommendations!

- Keep drift scaling similar to proposed ballot in ASCE 7-28
- Keep drift scaling only for near fault sites in Site Classes C and Better
- Other?