

**U.S. Department of the Interior  
U.S. Geological Survey**

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**Shear Wave Velocity Of The Ground Near Southern California TRINET Sites Using  
The Spectral Analysis Of Surface Waves Method (SASW) And Parallel-Arrayed  
Harmonic-Wave Sources**

Robert Kayen<sup>1</sup>, Brad Carkin<sup>1</sup>, Diane Minasian<sup>1</sup> and John Tinsley<sup>2</sup>  
<sup>1</sup>Coastal and Marine Geology Program  
<sup>2</sup>Earthquake Hazards Program  
Menlo Park, CA 94025

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U.S. GEOLOGICAL SURVEY, MENLO PARK, CA 94025

# **Shear Wave Velocity of the Ground Near Southern California TRINET Sites Using the Spectral Analysis of Surface Waves Method (SASW) and Parallel-Arrayed Harmonic-Wave Sources**

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## **INTRODUCTION**

The seismic network for Southern California administered through the TRINET project (the name implies the synthesis of three networks) is a collaborative effort of the administrators of the US Geological Survey Southern California Seismic Network (SCSN), California Institute of Technology network, and California Geological Survey network (CSMIP). Many of these sites have little or no quantitative characterization for site amplification effects or natural period characterization. In this study, we investigate thirteen TRINET sites using an active-source approach that employs ultra-low frequency-controlled harmonic waves to measure the dispersive nature of surface waves in the ground. We use a new spectral analysis of surface waves (SASW) approach by arraying multiple harmonic wave sources that are driven in-phase to excite the ground. An inversion algorithm employing a non-linear least-squares best fit is used to invert shear wave velocities for the upper 40-to-100 meters of the soil column.

## **FIELD METHODS**

Spectral analysis of surface waves (SASW) testing is an inexpensive and efficient means for non-invasively estimating the stiffness properties of the ground. Various active and passive source surface wave methods have been developed to profile the subsurface from tens-of-meters to kilometers in depth. Prior to the development of non-invasive surface wave methods, shear-waves were measured in cased boreholes or during standard or cone penetration tests, both relatively costly methods, using a conventional travel-time approach. Static cone penetration tests often cannot sound to useful depths for site response characterization as the soil stiffness mobilizes to resist the maximum static shear the truck can deliver at shallow depths (<30m) for all but the softest sites. Surface wave test apparatus is highly portable, allowing for measurements in extremely remote locations, at soft sites where vehicles cannot drive, and in sub-aqueous environments (Stokoe and Nazarian, 1985).

We use a surface wave testing system to collect dispersion data with a crew of 2 or 3 people. The test apparatus consists of 1-Hz Kinometrics<sup>1</sup> seismometers, a low frequency spectrum analyzer, a computer-controlled continuous harmonic-wave source (shaker) and amplifier, cables and a small 4.5kW generator. The shaker-source is centered in the SASW seismometer line and receives an oscillatory-signal from a sine function

generator. The output signal from the sine wave source is boosted by an amplifier to produce a continuous harmonic-wave that shakes the ground with surface waves of a specific frequency. The receivers measure the waves and a fast Fourier transform (FFT) is performed on each of the four receiver signals. The test steps through a suite of frequencies for which phase computations, respectively are made. In near-real time, the linear spectra, cross power spectra, and coherence are computed. The ability to perform near real-time frequency domain calculations and monitor the progress and quality of the test allows us to adjust various aspects of the test to optimize the capture of the phase data while on-site in the field. These aspects include the source-wave generation, frequency step-size between each sine-wave burst, number of cycles-per-frequency, total frequency range of all the steps, and receiver spacing. This method of swept-sine surface wave testing will sweep through a broad range of low frequencies in order to capture the surface wave-dispersion characteristics of the ground. This approach is a slight modification of the Continuous Sine wave Source Spectral Analysis of Surface Waves (CSS-SASW) test presented by Kayen and others (2004a; 2004b).

We use a common source-midpoint geometry in our array set up (Figure 1). To do this, we place multiple harmonic-sources at the centerline of the survey with the forward and reverse direction sensor-pairs equidistant from the source for each given array spacing. This configuration allows us to merge the forward and reverse direction dispersion curves if they were similar. In order to build a merged dispersion profile for the site, several different receiver spacings are used to capture the high-, medium-, and low-frequency ranges of the surface wave dispersion. Spacing of the receivers step geometrically from 1 meter to 64 meters, i.e. 1, 2, 4, 8, 16, 32, and 64 meters. The two seismometers are separated by a given distance,  $d$ , and the source is usually placed at a distance of  $2d$  from the inner seismometer. When the array separation increases to a point where the  $d:2d$  spacing became impractical, either due to space limitations, cable limits, or the attenuation, the array spacing is changed to  $d:d$ . Prior investigations have shown that array spacing ratios between  $d:d$  and  $d:2d$  are a good compromise for minimizing near field effects and distant-wave attenuation (Sanchez-Salinerio, et al. 1987).

Rayleigh wave wavelengths ( $\lambda$ ) are computed by relating the seismometer spacing ( $\delta$ ) and the phase angle ( $\theta$ , in radians determined from the cross-power spectra) between the seismometers:

$$\lambda = 2\pi\delta/\theta \dots\dots\dots(1)$$

The Rayleigh wave surface wave velocity,  $V_r$ , is computed as the product of the frequency and its associated wavelength:

$$V_r = f\lambda \dots\dots\dots(2)$$

The grouped and average dispersion curves for the TRINET sites are presented in the Appendix.

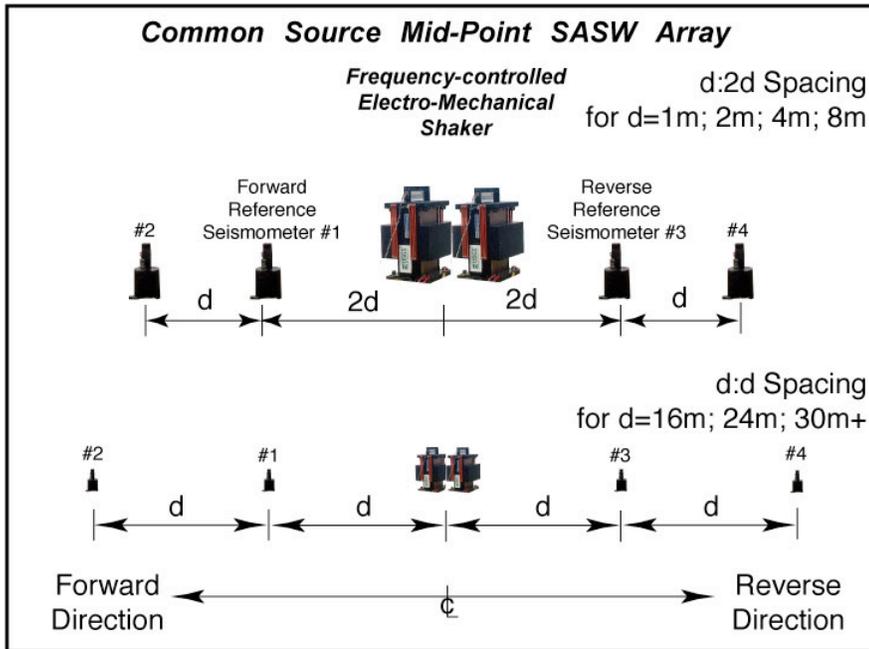


Figure 1. Configuration of the USGS surface wave testing system, composed of 1-Hz sensors and two-100 kg electro-mechanical shakers. The shaker apparatus are arrayed in a parallel circuit to allow for synchronized in-phase frequency controlled swept-sine analysis. Array separation changes from  $d:2d$  to  $d:d$  as forward and reverse sensors are configured for large array separations.

The inversion process is used to estimate the soil stiffness model whose computed theoretical-dispersion curve is a best-fit with the experimental dispersion data collected in the field. That is, we invert shear wave velocity profiles using an inversion code that hunts for the best-fit shear wave velocity profile whose theoretical dispersion curve is the closest match with the averaged field dispersion curve. The term “best-fit” refers to the minimum sum of the squares of residuals from the differences between the theoretical and experimental dispersion curves. The Poisson ratio used in the inversions is 0.33 above the water table and 0.48 below the water table. The water table depth was estimated by observing the water depth of local creek beds, and the local knowledge of the fourth author. The inversion algorithm, WaveEq of OYO Corp. (Hayashi and Kayen, 2003) uses an automated-numerical approach that employs a constrained least-squares fit of the theoretical and experimental dispersion curves. We also ran an independent inversion algorithm, *inverse.m* (Lai and Rix, 1998), to validate the profiles computed from WaveEQ.

## RESULTS

The testing program investigated thirteen sites in the Los Angeles basin. These sites are listed alphabetically in Table 1. Typically, these strong motion recording (SMR)

sites are located within Southern California Edison sub station facilities; SBC Telephone network stations; and public park grounds (Hauksson et al., 2001). We located within these facilities next to the strong motion recording (SMR) station or tested immediately adjacent to the facility (Figure 2).

TRINET Site ID	SASW SITE ID	DATE	SMR STA	LAT	LON	$V_{s30}$ (m/s)	$V_{sMAX}$ (m/s)	Inversion Depth (m)	NEHRP $V_{s30}$ Code
BRE	701BRE	9/17/04	24	33.81127	-117.97935	215	226	40	D
CHN	707CHN	9/20/04	208	33.99965	-117.67734	276	295	40	D
CLT	712CLT	9/21/04	325	34.09338	-117.31172	256	314	50	D
CPP	705CPP	9/19/04	205	34.06065	-117.80795	217	270	50	D
CRN	708CRN	9/20/04	135	33.87525	-117.55939	367	398	40	C
FMP	700FMP	9/17/04	89	33.71337	-118.29436	276	330	50	D
FON	711FON	9/21/04	449	34.09997	-117.43816	405	464	50	C
GSA	706GSA	9/19/04	234	34.13664	-118.12763	325	337	40	D
MLS	709MLS	9/20/04	230	34.00841	-117.56463	296	360	50	D
OLI	704OLI	9/19/04	162	33.94519	-117.92139	328	593	100	D
PDU	710PDU	9/21/04	445	34.11801	-117.63962	424	542	40	C
SRN	703SRN	9/18/04	208	33.82722	-117.78888	261	333	50	D
STG	702STG	9/18/04	49	33.66307	-117.76752	274	406	100	D

Table 1. TRINET stations locations and their corresponding SASW and SMR site identifier. The computed 30-meter averaged shear wave velocity and NEHRP site codes are presented in columns 7 and 10. The average velocity for the entire 40-100 meter profile (see column 9) is presented in column 8. Positions refer to the position of the shaker sources during the SASW test.

The shear wave velocity structure of the study sites is presented for the uppermost thirty meters of the ground in the Appendix figures A1-A13 for each of the thirteen SMR sites. The inversion of a theoretical velocity profile was performed using the inversion codes Wave-EQ (Hayashi and Kayen, 2003). Typically, a ten layer model was used for the inversion, with layer thicknesses geometrically expanding with depth. The increasing layer thicknesses correspond with decreasing dispersion information in the longer wavelength (deeper) portion of the dispersion curve. The profiles generally increase in stiffness with depth, though low velocity layers are present in several of the profiles.

The simplest way of characterizing the overall site condition is to use the average shear wave velocity in the uppermost 30 meters of the subsurface ( $V_{s30}$ ; ICC, 2002). Equation 3 is used to compute the average velocity based on the unit layer thickness ( $d_i$ ) and the corresponding interval-velocity ( $V_{Si}$ ).

$$V_{S-AVERAGE} = \frac{\sum_{i=1}^n d_i}{\sum_{i=1}^n \frac{d_i}{V_{Si}}} \quad (3)$$

In Table 3 and the Appendix, we report the computed average shear wave velocity for the upper 30 meters,  $V_{s30}$ , values from the 8-10 layer models. The tested sites fall within an average velocity range in the upper 30 meters of 215-to-424 m/s. The velocities all fall within NEHRP categories "C" and "D". To better classify the stiffness of these units we have informally subdivided the categories with a + or - prefix to indicate whether the velocity falls within the upper or lower half of the 360 m/s range (e.g. Class D-; D+, C-; C+ soils).

The maximum depth of the shear wave velocity profile ranged from 40-to-100 meters, and from the entire profile we compute an average velocity, presented in column 8. The ratio between the computed  $V_{s30}$ , and  $V_{s100}$  values for sites OLI and STG were 1.48 and 1.86 respectively. Ratios for the  $V_{s50}$  and  $V_{s40}$  values were lower, ranging from 1.04 (almost the same value as the  $V_{s30}$ ) to 1.28 (nearly the same percent change in the velocity as the change in the total depth used to compute the average velocity beyond 30 meters, i.e.  $d_{MAX}/d_{30}$ ). In all cases, the velocity profile and the average velocity increased in value with depth beyond 30 meters.

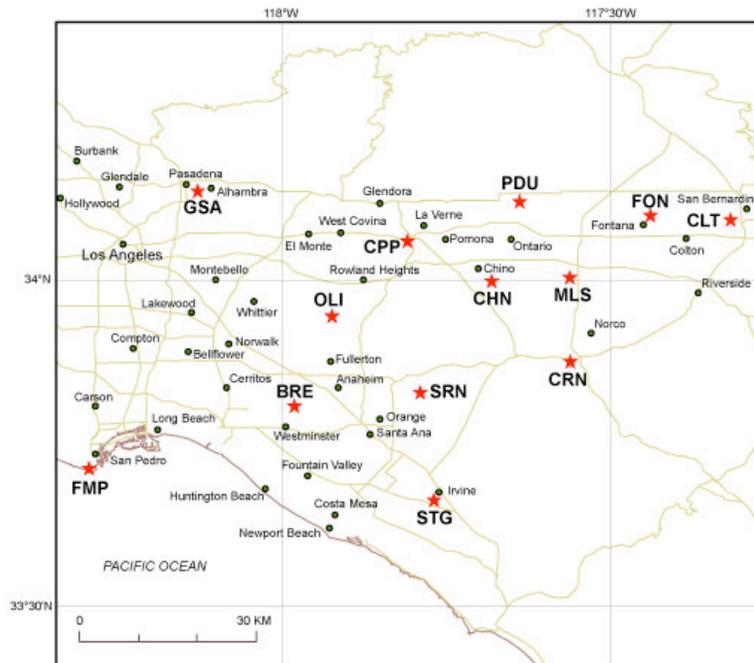


Figure 2. Thirteen TRINET sites tested in this study are located in the greater Los Angeles basin; Santa Ana valley; and Orange county.

## REFERENCES

- Hauksson, E., P. Small, K. Hafner, R. Busby, R. Clayton, J. Goltz, T. Heaton, K. Hutton, H. Kanamori, J. Polet, D. Given, L. M. Jones, and D. Wald, Southern California Seismic Network: Caltech/USGS Element of TriNet 1997-2001, *Seism. Res. Lett.* 72, 697-711, 2001
- Hayashi, K. and Kayen, R. (2003) comparative test of three surface wave methods at Williams Street Park in San Jose, USA. Paper S051-009, 2003 Joint Meeting of Japan Earth and Planetary Science, University of Tokyo, Tokyo, Japan 2003 Joint Meeting, May 26-29, 2003.
- International Code Council, Inc., 2002. *2003 International Building Code*, Falls Church, VA.
- Kayen, R. (2005) The spectral analysis of surface waves measured at William Street Park, San Jose, California, using swept-sine harmonic waves. In Asten and Boore, *eds.*, Blind comparisons of shear-wave velocities at closely-spaced sites in San Jose, California. US Geological Survey Open-File Report 2005-1169, 6 p. [<http://pubs.usgs.gov/of/2005/1169/>].
- Kayen, R., Seed, R. B., Moss, R.E., Cetin, O., Tanaka, Y., and Tokimatsu, K. (2004) Global Shear Wave Velocity Database for Probabilistic Assessment of the Initiation of Seismic-Soil Liquefaction. Proceedings of the 11th Int'l. Conf. On Soil Dynamics and Earthquake Engineering, January 7-9, 2004, Berkeley, CA, p. 506-512.
- Kayen, R., Thompson, E., Minasian, D., Moss, R.E.S., Collins, B.D., Sitar, N., Dreger, D., Carver, G. (2004) Geotechnical Reconnaissance of the November 3, 2002 M7.9 Denali Fault Earthquake, *Earthquake Spectra*, 20(3) p. 639-667.
- Lai, C.G., and G. J. Rix (1998) Simultaneous Inversion of Rayleigh Phase Velocity and Attenuation for Near-Surface Site Characterization," Report No. GIT-CEE/GEO-98-2, Georgia Institute of Technology, School of Civil and Environmental Engineering, 258 pp.
- Stokoe, K. and Nazarian, S. (1985) Use of Raleigh Waves in liquefaction Studies, in, R.D. Woods, ed., Measurement and use of Shear Wave Velocity for Evaluating Dynamic Soil Properties. ASCE, N.Y., 1-17.

## Appendix A.

Photographs, seismic wave velocity profiles, and data sets for thirteen Southern California TRINET stations. No photographs were taken at 702STG or 703SRN.

**TRINET Site Classification**

**Site ID** 700FMP  
**NEHRP CLASS:** D  
**Vs30** 276 (m/s)  
**SUB-CLASS** D+  
**Vs50** 330 (m/s)  
**Location** Fort MacArthur Park  
**SMR Station** 89  
**State** CALIFORNIA

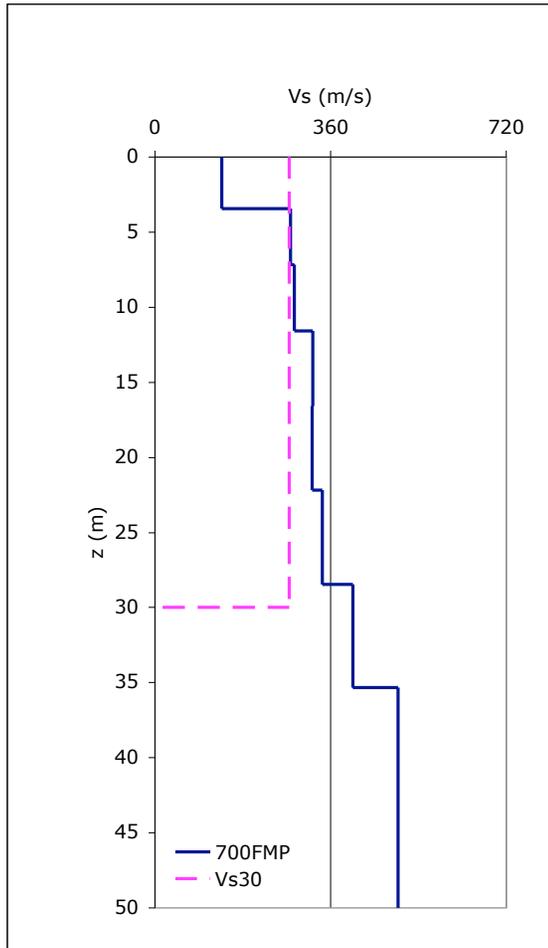
**POSITION DEGREES**  
**GPS LAT (NORTH)** 33.71337  
**GPS LONG (WEST)** 118.29436

**Data Type** SWEPT-SINE SASW  
**Investigators** KAYEN, CARKIN, TINSLEY  
**Date collected** 9/17/2004

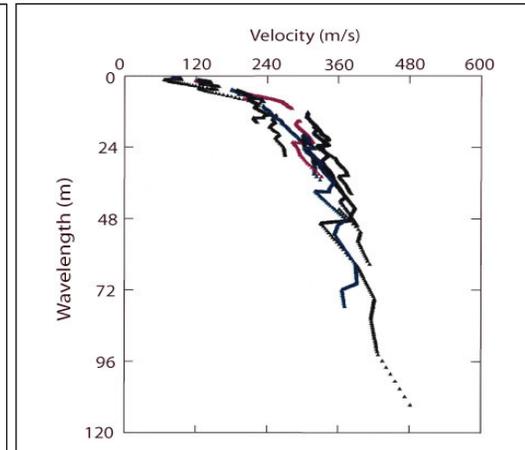
**TEST METHOD** CONTINUOUS HARMONIC WAVE-SASW

**PROJECT NAME** TRINET  
**SPONSORS** EHZ-SCEC

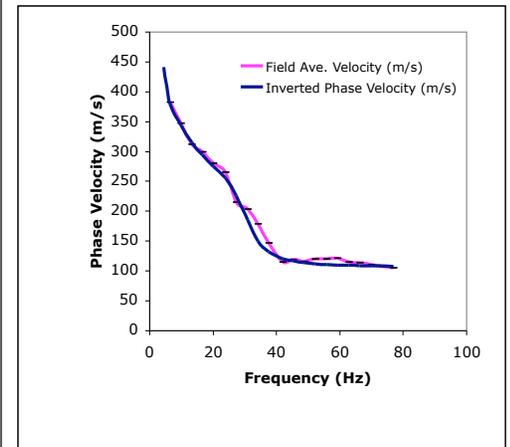
**SITE SUB CLASS: Vs30 (m/s)**  
 A >1500 m/s  
 B+ 1080 < Vs30 ≤ 1500 m/s  
 B- 720 < Vs30 ≤ 1080 m/s  
 C+ 540 < Vs30 ≤ 720 m/s  
 C- 360 < Vs30 ≤ 540 m/s  
 D+ 270 < Vs30 ≤ 360 m/s  
 D- 180 < Vs30 ≤ 270 m/s  
 E <180 m/s  
 F **Special Soil Conditions:** Liquefiable soils; quick and high sensitivity clays; collapsible cemented soils; peats>3m; high (>75) PI soils thicker than 8m; soft/medium stiff clays thicker than 36m.



(A) Vs 50 meters profile (solid) and Vs30 (dashed)



(B) Combined Field-Dispersion Curves



(C) Inversion-based theoretical dispersion curve versus averaged field dispersion curve

Figure A1.—SASW site classification and location information for site 700FMP. The layered inversion model of shear wave velocity in the upper 30 meters is presented in the middle plot. The site dispersion curves are presented in the upper-right plot, and the comparison between the average site dispersion curve and theoretical dispersion curve is presented in the lower-left.



Figure A2.—Site 700FMD (SMR STA 89), located at Fort MacArthur Park, San Pedro, Los Angeles County, California. Site location  $33.71337^{\circ}\text{N}$   $118.29436^{\circ}\text{W}$ . Photo views: A) Looking south, B) looking southwest towards the park summit, C) looking north towards San Pedro, and D) looking west towards Palos Verdes.

<b>700FMP</b>	<b>DISPERSION DATA</b>			<b>INVERSION PROFILE</b>	
<b>Site Disp. Vr (m/s)</b>	<b>Theoretical Disp. Vr (m/s)</b>	<b>Frequency (Hz)</b>		<b>Inversion Vs (m/s)</b>	<b>Depth (m)</b>
482.0		4.3		136.8	0.0
481.0	380.0	4.3		136.8	3.4
383.0	344.0	6.3		278.4	3.4
347.4	315.4	9.8		278.4	7.2
311.9	294.7	13.2		285.1	7.2
300.1	275.5	16.7		285.1	11.6
280.6	256.0	20.1		324.1	11.6
265.0	225.6	23.8		324.1	16.6
215.6	185.6	27.4		322.3	16.6
203.5	149.9	30.9		322.3	22.2
179.2	131.9	34.2		343.3	22.2
147.2	120.9	37.5		343.3	28.4
115.0	116.8	41.9		405.8	28.4
119.1	113.9	45.1		405.8	35.3
115.9	112.2	48.8		498.3	35.3
120.8	110.9	52.2		498.3	50.0
120.6	110.0	55.8			
121.1	109.4	59.3			
114.9	108.9	62.8			
113.8	108.6	66.4			
110.8	108.3	69.8			
107.3	108.1	73.4			
				Vs30	275.6

Figure A3.—Surface wave dispersion curve and shear wave velocity inversion data for site 700FMP.

### TRINET Site Classification

**Site ID** 701BRE  
**NEHRP CLASS:** D  
**Vs30** 215 (m/s)  
**SUB-CLASS** D-  
**Vs40** 226 (m/s)  
**Location** Barre Substation, Stanton  
**SMR Station** 24  
**State** CALIFORNIA

**POSITION DEGREES**  
**GPS LAT (NORTH)** 33.80776  
**GPS LONG (WEST)** 117.98116

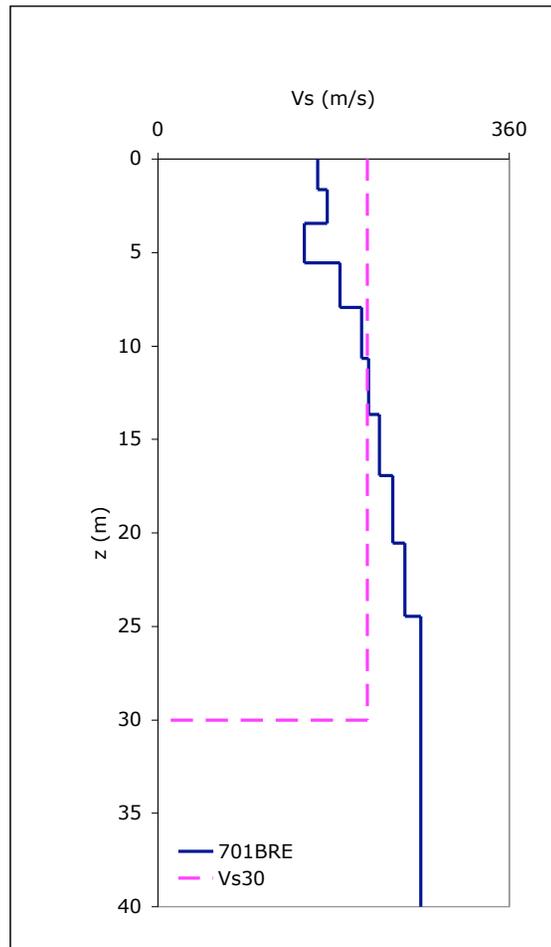
**Data Type** SWEPT-SINE SASW  
**Investigators** KAYEN, CARKIN, TINSLEY  
**Date collected** 9/17/2004

**TEST METHOD** CONTINUOUS HARMONIC WAVE-SASW

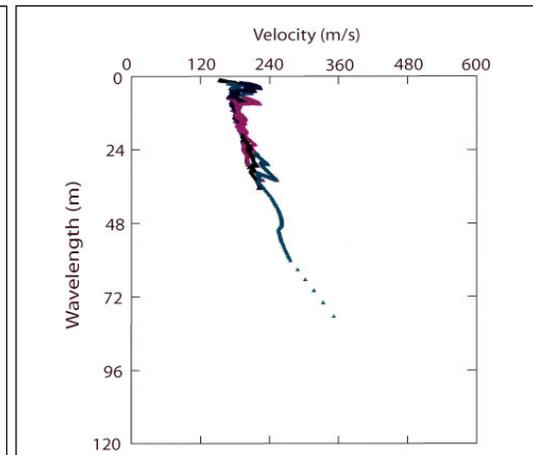
**PROJECT NAME** TRINET  
**SPONSORS** EHZ-SCEC

**SITE SUB CLASS: Vs30 (m/s)**

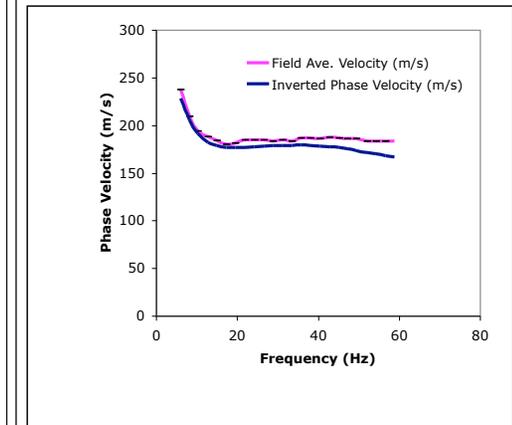
A	>1500 m/s
B+	1080 < Vs30 ≤ 1500 m/s
B-	720 < Vs30 ≤ 1080 m/s
C+	540 < Vs30 ≤ 720 m/s
C-	360 < Vs30 ≤ 540 m/s
D+	270 < Vs30 ≤ 360 m/s
D-	180 < Vs30 ≤ 270 m/s
E	<180 m/s
F	Special Soil Conditions: Liquefiable soils; quick and high sensitivity clays; collapsible cemented soils; peats>3m; high (>75) Pt soils thicker than 8m; soft/medium stiff clays thicker than 36m.



(A) Vs 40 meters profile (solid) and Vs30 (dashed)



(B) Combined Field-Dispersion Curves



(C) Inversion-based theoretical dispersion curve versus averaged field dispersion curve

Figure A4.—SASW site classification and location information for site 701BRE. The layered inversion model of shear wave velocity in the upper 30 meters is presented in the middle plot. The site dispersion curves are presented in the upper-right plot, and the comparison between the average site dispersion curve and theoretical dispersion curve is presented in the lower-left.



Figure A5.—Site 701BRE (SMR STA 24), located at Barre Substation, Stanton, Orange County, California. Site location 33.81127°N 117.97935°W. Photo views: A) Looking northwest into Hollenbeck Park, B) looking southeast towards Cerritos Ave., C) looking north into Hollenbeck Park, and D) looking south towards Cerritos Ave and BRE substation.

<b>701BRE</b>	<b>DISPERSION DATA</b>			<b>INVERSION PROFILE</b>	
<b>Site Disp. Vr (m/s)</b>	<b>Theoretical Disp. Vr (m/s)</b>	<b>Frequency (Hz)</b>		<b>Inversion Vs (m/s)</b>	<b>Depth (m)</b>
276.0		4.5		163.7	0.0
238.2	228.5	6.0		163.7	1.7
210.0	206.1	8.1		173.2	1.7
194.6	191.6	10.2		173.2	3.5
188.4	182.6	12.7		150.0	3.5
184.2	178.8	14.9		150.0	5.6
180.4	177.3	17.3		186.7	5.6
181.5	177.0	19.5		186.7	8.0
185.2	177.2	21.9		208.9	8.0
185.2	177.7	24.2		208.9	10.7
185.2	178.3	26.5		215.6	10.7
183.7	178.7	28.7		215.6	13.7
185.1	179.1	31.1		226.9	13.7
183.6	179.4	33.5		226.9	17.0
187.1	179.4	35.7		240.3	17.0
187.3	179.2	38.1		240.3	20.6
186.2	178.7	40.4		252.9	20.6
187.7	177.9	42.7		252.9	24.5
187.0	176.8	45.0		269.7	24.5
186.1	175.5	47.2		269.7	30.0
186.1	173.9	49.4		269.7	40.0
183.5	171.8	52.0			
183.5	170.1	54.3			
183.5	168.5	56.6			
183.5	167.0	58.8			
				Vs30	214.8

Figure A6.— Surface wave dispersion curve and shear wave velocity inversion data for site 701BRE.

**TRINET Site Classification**

**Site ID** 702STG  
**NEHRP CLASS:** D  
**Vs30** 274 (m/s)  
**SUB-CLASS** D+  
**Vs100** 406 (m/s)

**Location** Santiago  
**SMR Station** 49  
**State** CALIFORNIA

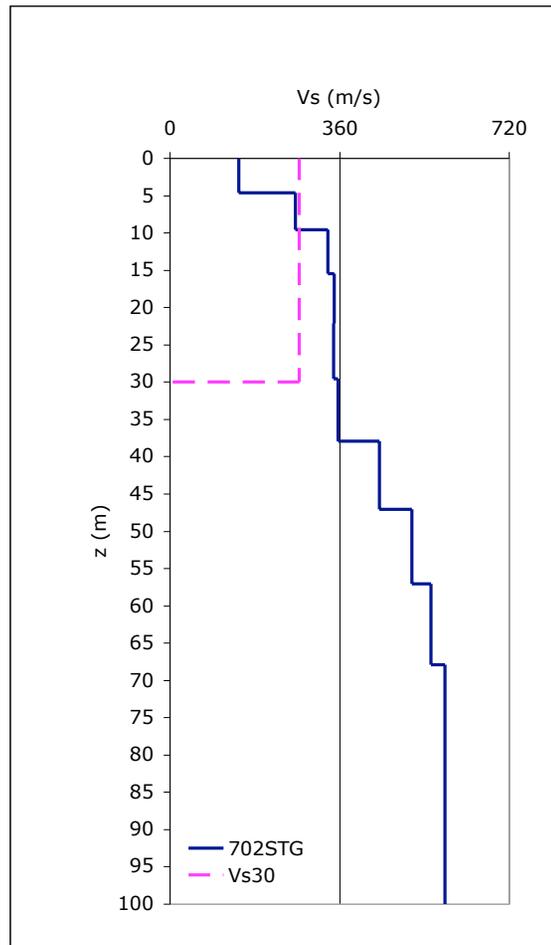
**POSITION DEGREES**  
**GPS LAT (NORTH)** 33.66307  
**GPS LONG (WEST)** 117.76752

**Data Type** SWEPT-SINE SASW  
**Investigators** KAYEN, CARKIN, TINSLEY  
**Date collected** 9/18/2004

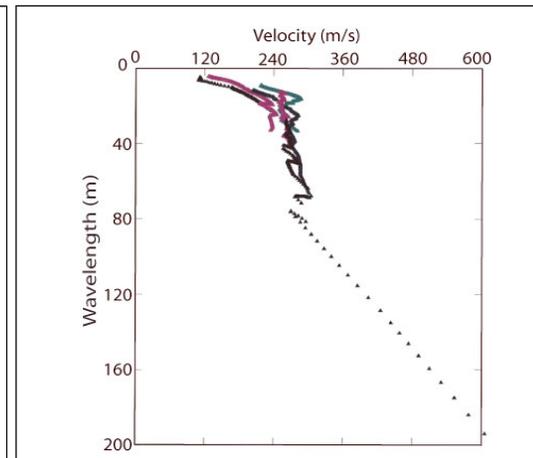
**TEST METHOD** CONTINUOUS HARMONIC WAVE-SASW

**PROJECT NAME** TRINET  
**SPONSORS** EHZ-SCEC

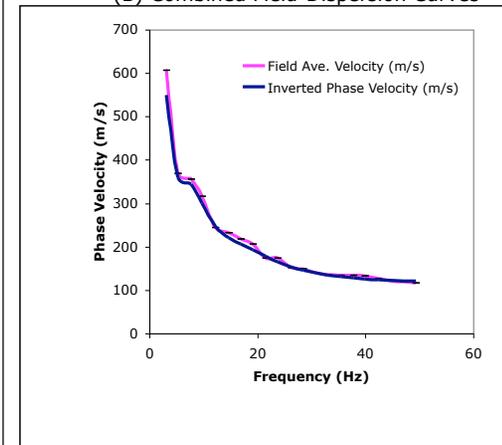
**SITE SUB CLASS: Vs30 (m/s)**  
 A >1500 m/s  
 B+ 1080 < Vs30 ≤ 1500 m/s  
 B- 720 < Vs30 ≤ 1080 m/s  
 C+ 540 < Vs30 ≤ 720 m/s  
 C- 360 < Vs30 ≤ 540 m/s  
 D+ 270 < Vs30 ≤ 360 m/s  
 D- 180 < Vs30 ≤ 270 m/s  
 E <180 m/s  
 F **Special Soil Conditions:** Liquefiable soils; quick and high sensitivity clays; collapsible cemented soils; peats>3m; high (>75) PI soils thicker than 8m; soft/medium stiff clays thicker than 36m.



(A) Vs 100 meters profile (solid) and Vs30 (dashed)



(B) Combined Field-Dispersion Curves



(C) Inversion-based theoretical dispersion curve versus averaged field dispersion curve

Figure A7.—SASW site classification and location information for site 702STG. The layered inversion model of shear wave velocity in the upper 30 meters is presented in the middle plot. The site dispersion curves are presented in the upper-right plot, and the comparison between the average site dispersion curve and theoretical dispersion curve is presented in the lower-left.



Figure A8.—Site 702STG (SMR STA 49), is located at a work site on the corner of Barranca Parkway and Laguna Canyon Road in Irvine, Orange County, California. The site location is at 33.82722°N 117.78888°W. Photo is an aerial photo view of the site. (Map from <http://maps.google.com>).

<b>702STG</b>	<b>DISPERSION DATA</b>			<b>INVERSION PROFILE</b>	
<b>Site Disp. Vr (m/s)</b>	<b>Theoretical Disp. Vr (m/s)</b>	<b>Frequency (Hz)</b>		<b>Inversion Vs (m/s)</b>	<b>Depth (m)</b>
607.0		3.1		145.9	0.0
607.0	550.0	3.1		145.9	4.6
369.3	361.6	5.2		266.0	4.6
356.5	344.8	7.6		266.0	9.6
317.3	300.7	9.7		335.3	9.6
244.4	247.4	12.2		335.3	15.4
232.7	222.0	14.6		348.0	15.4
218.8	207.7	16.8		348.0	22.1
206.7	194.3	19.1		347.7	22.1
175.1	179.8	21.5		347.7	29.6
174.6	166.4	23.7		356.8	29.6
152.2	154.6	26.1		356.8	37.9
149.4	146.3	28.4		445.1	37.9
140.3	140.3	30.7		445.1	47.1
136.7	135.4	33.0		512.9	47.1
134.8	131.7	35.4		512.9	57.1
134.4	128.8	37.7		554.3	57.1
133.6	126.7	39.9		554.3	67.9
128.0	124.8	42.3		583.3	67.9
122.3	123.3	44.6		583.3	100.0
119.7	122.1	47.0		583.3	100.0
				Vs30	274.0

Figure A9.— Surface wave dispersion curve and shear wave velocity inversion data for site 702STG.

**TRINET Site Classification**

**Site ID** 703SRN  
**NEHRP CLASS:** D  
**Vs30** 261 (m/s)  
**SUB-CLASS** D-  
**Vs50** 333 (m/s)

**Location** Serrano  
**SMR Station** 208  
**State** CALIFORNIA

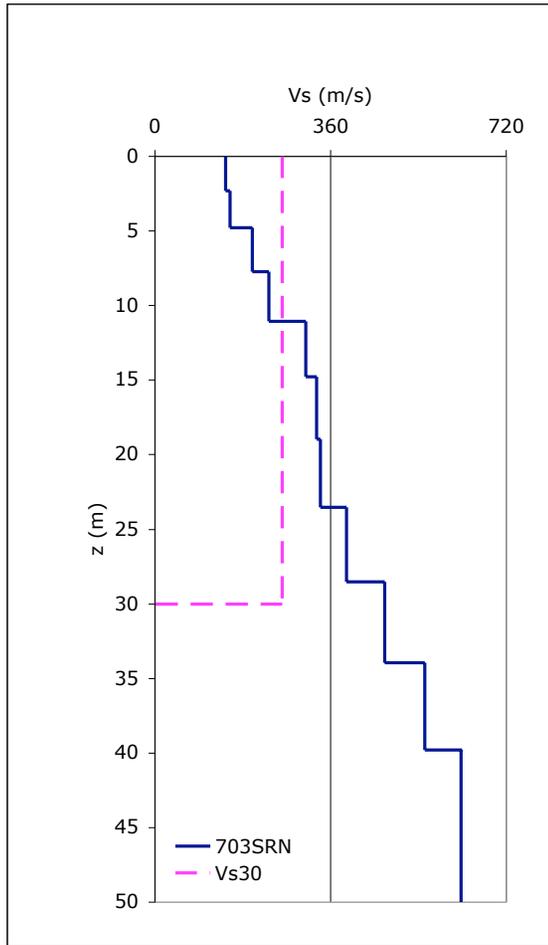
**POSITION DEGREES**  
**GPS LAT (NORTH)** 33.82722  
**GPS LONG (WEST)** 117.78888

**Data Type** SWEPT-SINE SASW  
**Investigators** KAYEN, CARKIN, TINSLEY  
**Date collected** 9/18/2004

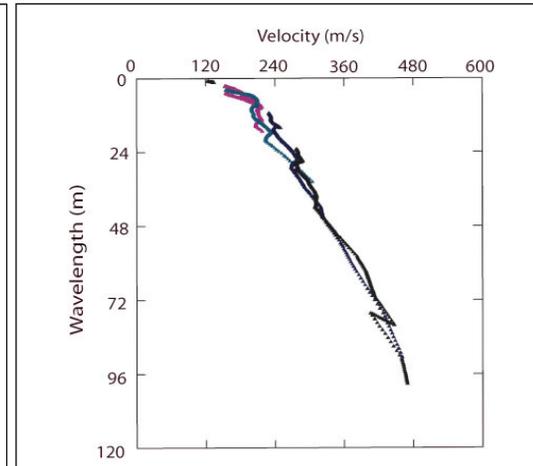
**TEST METHOD** CONTINUOUS HARMONIC WAVE-SASW

**PROJECT NAME** TRINET  
**SPONSORS** EHZ-SCEC

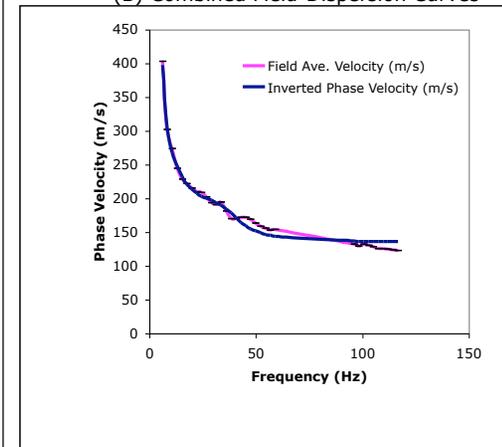
**SITE SUB CLASS: Vs30 (m/s)**  
 A >1500 m/s  
 B+ 1080 < Vs30 ≤ 1500 m/s  
 B- 720 < Vs30 ≤ 1080 m/s  
 C+ 540 < Vs30 ≤ 720 m/s  
 C- 360 < Vs30 ≤ 540 m/s  
 D+ 270 < Vs30 ≤ 360 m/s  
 D- 180 < Vs30 ≤ 270 m/s  
 E <180 m/s  
 F  
 Special Soil Conditions: Liquefiable soils; quick and high sensitivity clays; collapsible cemented soils; peats>3m; high (>75) PI soils thicker than 8m; soft/medium stiff clays thicker than 36m.



(A) Vs 50 meters profile (solid) and Vs30 (dashed)



(B) Combined Field-Dispersion Curves



(C) Inversion-based theoretical dispersion curve versus averaged field dispersion curve

Figure A10.—SASW site classification and location information for site 703SRN. The layered inversion model of shear wave velocity in the upper 30 meters is presented in the middle plot. The site dispersion curves are presented in the upper-right plot, and the comparison between the average site dispersion curve and theoretical dispersion curve is presented in the lower-left.



<b>703SRN</b>	<b>DISPERSION DATA</b>			<b>INVERSION PROFILE</b>	
<b>Site Disp. Vr (m/s)</b>	<b>Theoretical Disp. Vr (m/s)</b>	<b>Frequency (Hz)</b>		<b>Inversion Vs (m/s)</b>	<b>Depth (m)</b>
471.0	440.0	5.4		144.8	0.0
404.2	397.9	5.9		144.8	2.3
303.3	307.2	8.2		153.8	2.3
274.7	269.0	10.5		153.8	4.8
245.0	249.1	12.7		200.0	4.8
229.1	233.0	15.1		200.0	7.7
222.5	221.5	17.4		232.9	7.7
216.2	213.9	19.6		232.9	11.0
209.9	208.0	22.0		309.1	11.0
209.5	204.1	24.3		309.1	14.8
203.1	200.9	26.6		331.5	14.8
194.5	197.9	28.9		331.5	19.0
191.3	194.7	31.2		339.3	19.0
195.4	190.6	33.6		339.3	23.5
182.4	185.3	35.8		392.2	23.5
170.3	178.9	38.1		392.2	28.5
170.6	172.8	40.2		471.1	28.5
172.9	165.6	42.8		471.1	34.0
172.3	160.3	45.1		553.1	34.0
169.6	156.0	47.3		553.1	39.8
164.2	152.5	49.7		627.6	39.8
159.9	149.7	52.0		627.6	50.0
156.2	147.6	54.3		627.6	50.0
154.1	145.8	56.6			
154.3	144.4	58.9			
132.9	137.3	95.8			
130.0	137.2	98.1			
133.4	137.1	100.3			
131.6	137.1	102.7			
129.6	137.0	105.0			
126.4	136.9	107.3			
126.5	136.9	109.7			
125.4	136.8	111.9		Vs30	260.8
124.2	136.8	114.2			
123.1	136.8	116.6			

Figure A12.— Surface wave dispersion curve and shear wave velocity inversion data for site 703SRN.

**TRINET Site Classification**

**Site ID** 704OLI  
**NEHRP CLASS:** D  
**Vs30** 328 (m/s)  
**SUB-CLASS** D+  
**Vs100** 593 (m/s)

**Location** Olinda Substation  
**SMR Station** 162  
**State** CALIFORNIA

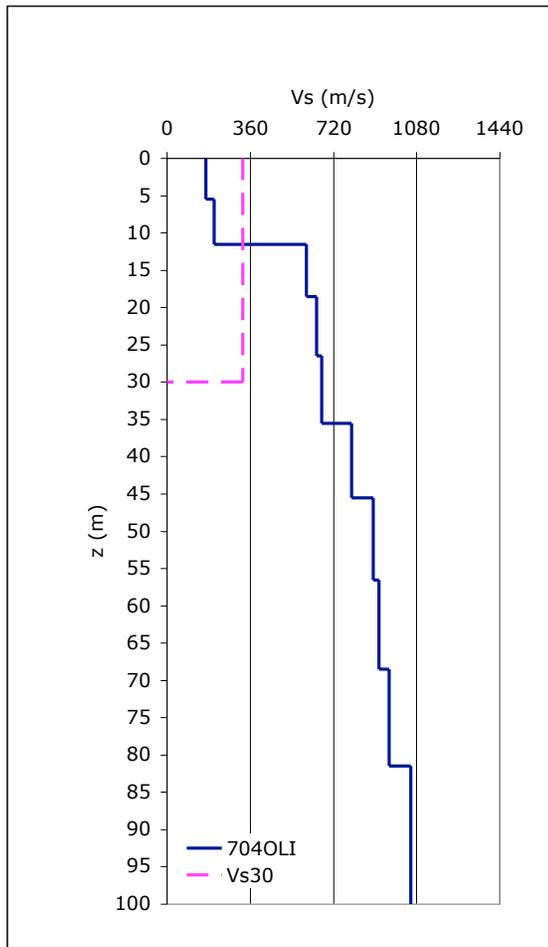
**POSITION DEGREES**  
**GPS LAT (NORTH)** 33.94519  
**GPS LONG (WEST)** 117.92139

**Data Type** SWEPT-SINE SASW  
**Investigators** KAYEN, CARKIN, TINSLEY  
**Date collected** 9/19/2004

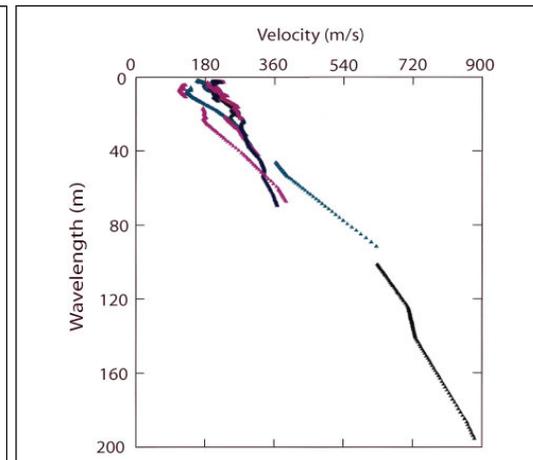
**TEST METHOD** CONTINUOUS HARMONIC WAVE-SASW

**PROJECT NAME** TRINET  
**SPONSORS** EHZ-SCEC

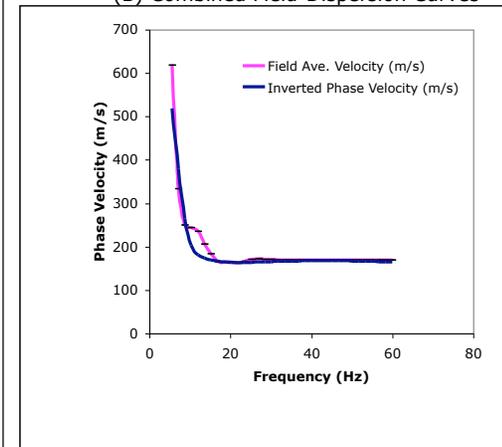
**SITE SUB CLASS: Vs30 (m/s)**  
 A >1500 m/s  
 B+ 1080 < Vs30 ≤ 1500 m/s  
 B- 720 < Vs30 ≤ 1080 m/s  
 C+ 540 < Vs30 ≤ 720 m/s  
 C- 360 < Vs30 ≤ 540 m/s  
 D+ 270 < Vs30 ≤ 360 m/s  
 D- 180 < Vs30 ≤ 270 m/s  
 E <180 m/s  
 F  
**Special Soil Conditions:** Liquefiable soils; quick and high sensitivity clays; collapsible cemented soils; peats>3m; high (>75) PI soils thicker than 8m; soft/medium stiff clays thicker than 36m.



(A) Vs 100 meters profile (solid) and Vs30 (dashed)



(B) Combined Field-Dispersion Curves



(C) Inversion-based theoretical dispersion curve versus averaged field dispersion curve

Figure A13.—SASW site classification and location information for site 704OLI. The layered inversion model of shear wave velocity in the upper 30 meters is presented in the middle plot. The site dispersion curves are presented in the upper-right plot, and the comparison between the average site dispersion curve and theoretical dispersion curve is presented in the lower-left.



Figure A14. —Site 704OLI (SMR STA 162), located at Olinda Substation, La Habra, Orange County, California. Site location 33.94519°N 117.92139°W. Photo views: A) Looking north toward OLI Substation B) looking east along the north edge of the Loma Norte park, C) looking north towards OLI Substation, and D) looking west towards OLI.

<b>704OLI</b>	<b>DISPERSION DATA</b>			<b>INVERSION PROFILE</b>	
<b>Site Disp. Vr (m/s)</b>	<b>Theoretical Disp. Vr (m/s)</b>	<b>Frequency (Hz)</b>		<b>Inversion Vs (m/s)</b>	<b>Depth (m)</b>
882.0		4.3		168.5	0.0
619.3	520.0	5.5		168.5	5.5
334.5	379.4	7.1		202.6	5.5
250.3	265.5	8.6		202.6	11.5
244.4	204.4	10.2		604.0	11.5
235.6	182.3	12.0		604.0	18.5
206.2	174.2	13.6		648.0	18.5
184.3	169.9	15.1		648.0	26.5
166.1	167.1	16.9		668.4	26.5
166.2	165.7	18.6		668.4	35.5
165.4	165.0	20.2		797.8	35.5
162.8	164.8	21.8		797.8	45.5
167.5	164.8	23.5		893.1	45.5
171.5	165.1	25.1		893.1	56.5
173.6	165.5	26.8		918.0	56.5
171.7	165.9	28.5		918.0	68.5
171.7	166.3	30.0		959.8	68.5
170.0	166.8	31.7		959.8	81.5
170.0	167.3	33.4		1055.1	81.5
170.0	167.7	35.1		1055.1	100.0
170.0	168.0	36.8		1055.1	100.0
170.0	168.3	38.4			
170.0	168.4	40.0			
170.0	168.5	41.7			
170.0	168.5	43.3			
170.0	168.4	45.0			
170.0	168.3	46.6			
170.0	168.1	48.3			
170.0	167.8	49.9			
170.0	167.5	51.6			
170.0	167.2	53.2			
170.0	166.8	54.9			
170.0	166.4	56.5		Vs30	328.1

Figure A15.— Surface wave dispersion curve and shear wave velocity inversion data for site 704OLI.

**TRINET Site Classification**

**Site ID** 705CPP  
**NEHRP CLASS:** D  
**Vs30** 217 (m/s)  
**SUB-CLASS** D-  
**Vs50** 270 (m/s)

**Location** Cal Poly Pomona  
**SMR Station** 205  
**State** CALIFORNIA

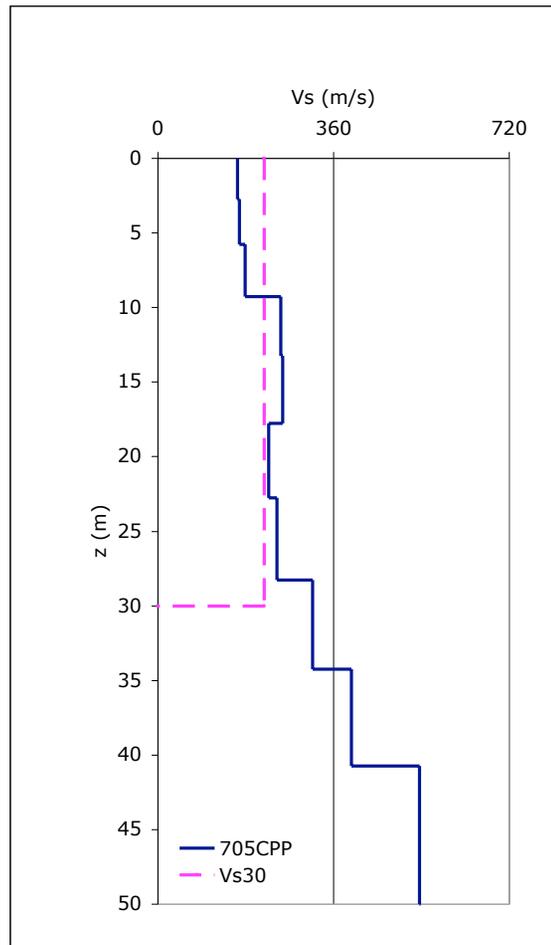
**POSITION DEGREES**  
**GPS LAT (NORTH)** 34.06065  
**GPS LONG (WEST)** 117.80795

**Data Type** SWEPT-SINE SASW  
**Investigators** KAYEN, CARKIN, TINSLEY  
**Date collected** 9/19/2004

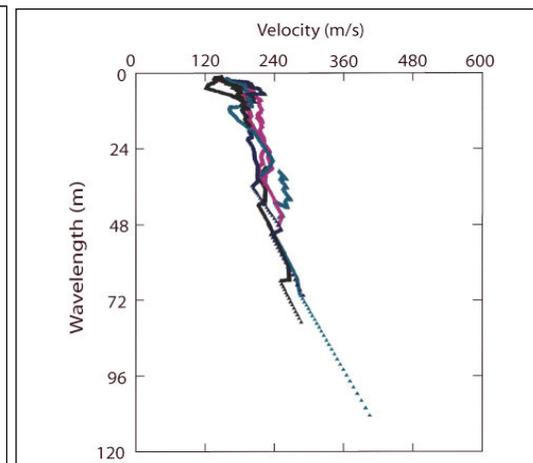
**TEST METHOD** CONTINUOUS HARMONIC WAVE-SASW

**PROJECT NAME** TRINET  
**SPONSORS** EHZ-SCEC

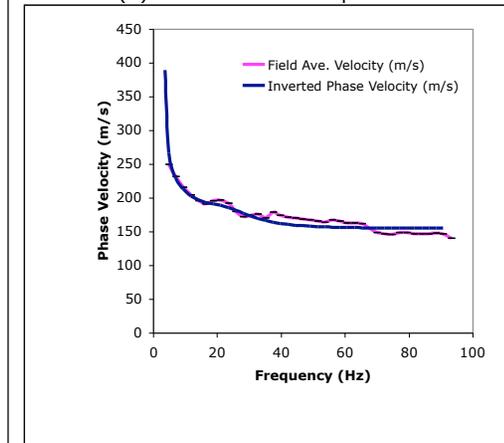
**SITE SUB CLASS: Vs30 (m/s)**  
 A >1500 m/s  
 B+ 1080 < Vs30 ≤ 1500 m/s  
 B- 720 < Vs30 ≤ 1080 m/s  
 C+ 540 < Vs30 ≤ 720 m/s  
 C- 360 < Vs30 ≤ 540 m/s  
 D+ 270 < Vs30 ≤ 360 m/s  
 D- 180 < Vs30 ≤ 270 m/s  
 E <180 m/s  
 F  
 Special Soil Conditions: Liquefiable soils; quick and high sensitivity clays; collapsible cemented soils; peats>3m; high (>75) PI soils thicker than 8m; soft/medium stiff clays thicker than 36m.



(A) Vs 50 meters profile (solid) and Vs30 (dashed)



(B) Combined Field-Dispersion Curves



(C) Inversion-based theoretical dispersion curve versus averaged field dispersion curve

Figure A16.—SASW site classification and location information for site 705CPP. The layered inversion model of shear wave velocity in the upper 30 meters is presented in the middle plot. The site dispersion curves are presented in the upper-right plot, and the comparison between the average site dispersion curve and theoretical dispersion curve is presented in the lower-left.



Figure A17. —Site 705CPP (SMR STA 205), located at Cal Poly, Pomona, Los Angeles County, California. Site location 34.06065°N 117.80795°W. Photo views: A) Looking north on Citrus Lane, B) & C) looking south on Citrus Lane, and D) looking west towards the Cal Poly Pomona Agriculture Center.

<b>705CPP</b>	<b>DISPERSION DATA</b>			<b>INVERSION PROFILE</b>	
<b>Site Disp. Vr (m/s)</b>	<b>Theoretical Disp. Vr (m/s)</b>	<b>Frequency (Hz)</b>		<b>Inversion Vs (m/s)</b>	<b>Depth (m)</b>
407.0		3.6		162.5	0.0
407.0	389.9	3.6		162.5	2.8
250.4	266.6	4.9		166.6	2.8
232.1	228.8	7.0		166.6	5.8
216.1	212.8	9.5		179.2	5.8
204.4	202.5	11.8		179.2	9.3
196.2	196.8	14.1		251.9	9.3
191.6	193.6	16.4		251.9	13.3
196.4	191.3	18.7		255.3	13.3
197.1	189.2	21.0		255.3	17.8
192.4	186.1	23.4		226.8	17.8
180.1	182.5	25.6		226.8	22.8
177.7	177.8	28.1		244.3	22.8
174.4	173.5	30.3		244.3	28.3
176.4	169.6	32.7		316.5	28.3
177.1	166.6	35.0		316.5	34.3
176.0	164.2	37.4		396.2	34.3
174.9	162.4	39.7		396.2	40.8
172.0	161.0	42.0		536.3	40.8
170.8	159.9	44.3		536.3	50.0
168.9	159.0	46.7		536.3	50.0
167.8	158.3	49.0			
166.5	157.7	51.3			
164.3	157.3	53.7			
167.5	156.9	55.9			
166.1	156.6	58.3			
163.5	156.4	60.7			
163.0	156.2	63.0			
162.1	156.0	65.3			
155.9	155.9	67.6			
149.2	155.8	69.9			
147.3	155.7	72.3			
146.5	155.6	74.5		Vs30	217.3
149.3	155.5	77.0			
148.7	155.5	79.3			

Figure A18.— Surface wave dispersion curve and shear wave velocity inversion data for site 705CPP.

### TRINET Site Classification

**Site ID** 706GSA  
**NEHRP CLASS:** D  
**Vs30** 325 (m/s)  
**SUB-CLASS** D+  
**Vs40** 337 (m/s)  
**Location** USGS Office, Pasadena  
**SMR Station** 234  
**State** CALIFORNIA

**POSITION DEGREES**  
**GPS LAT (NORTH)** 34.13664  
**GPS LONG (WEST)** 118.01276

**Data Type** SWEPT-SINE SASW  
**Investigators** KAYEN, CARKIN, TINSLEY  
**Date collected** 9/19/2004

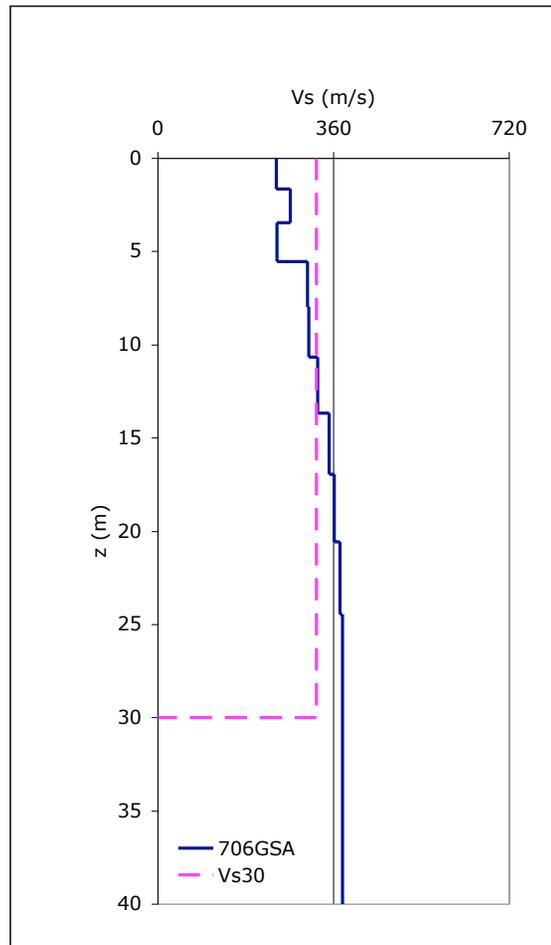
**TEST METHOD** CONTINUOUS HARMONIC WAVE-SASW

**PROJECT NAME** TRINET  
**SPONSORS** EHZ-SCEC

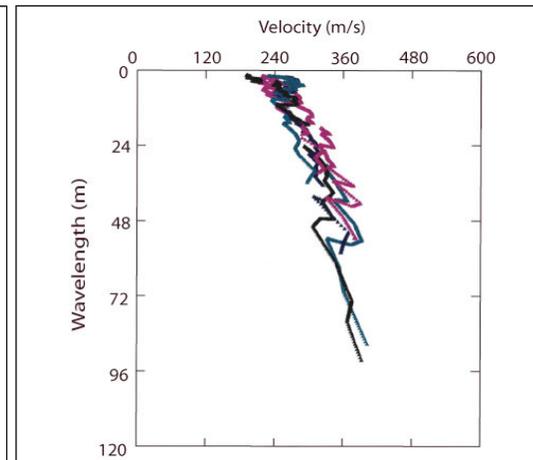
**SITE SUB CLASS: Vs30 (m/s)**

A	>1500 m/s
B+	1080 < Vs30 ≤ 1500 m/s
B-	720 < Vs30 ≤ 1080 m/s
C+	540 < Vs30 ≤ 720 m/s
C-	360 < Vs30 ≤ 540 m/s
D+	270 < Vs30 ≤ 360 m/s
D-	180 < Vs30 ≤ 270 m/s
E	<180 m/s
F	

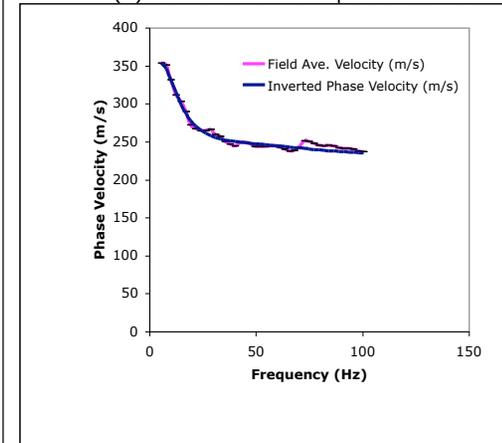
**Special Soil Conditions:** Liquefiable soils; quick and high sensitivity clays; collapsible cemented soils; peats>3m; high (>75) PI soils thicker than 8m; soft/medium stiff clays thicker than 36m.



(A) Vs 40 meters profile (solid) and Vs30 (dashed)



(B) Combined Field-Dispersion Curves



(C) Inversion-based theoretical dispersion curve versus averaged field dispersion curve

Figure A19.—SASW site classification and location information for site 706GSA. The layered inversion model of shear wave velocity in the upper 30 meters is presented in the middle plot. The site dispersion curves are presented in the upper-right plot, and the comparison between the average site dispersion curve and theoretical dispersion curve is presented in the lower-left.

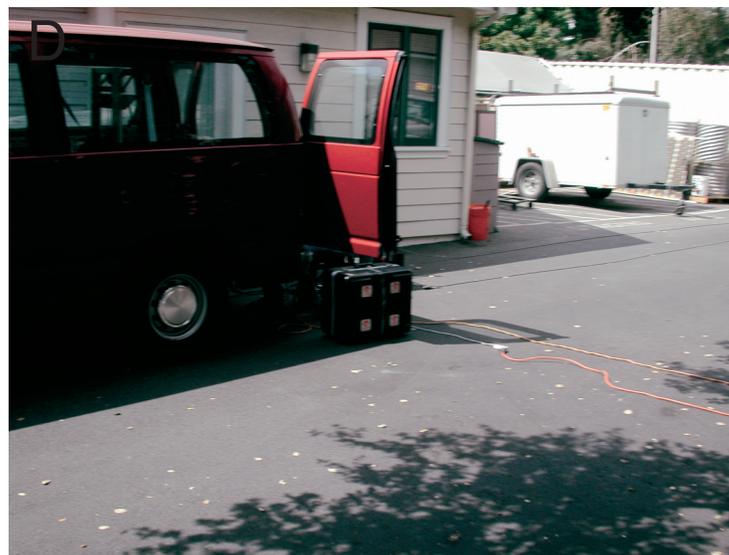


Figure A20. —Site 706GSA (SMR STA 234), located at the USGS office at CIT, Pasadena, Los Angeles County, California. Site location  $34.13664^{\circ}\text{N}$   $118.12762^{\circ}\text{W}$ . Photo views: A) Looking west towards S. Lake Ave., B) looking north towards San Pasqual St., C) looking south towards E. California Blvd., and D) looking west.

<b>706GSA</b>	<b>DISPERSION DATA</b>			<b>INVERSION PROFILE</b>	
<b>Site Disp. Vr (m/s)</b>	<b>Theoretical Disp. Vr (m/s)</b>	<b>Frequency (Hz)</b>		<b>Inversion Vs (m/s)</b>	<b>Depth (m)</b>
400.0		4.8		242.2	0.0
354.1	353.9	5.5		242.2	1.7
351.2	346.0	7.7		271.1	1.7
332.1	331.7	10.0		271.1	3.5
311.7	315.7	12.2		243.9	3.5
303.9	299.5	14.7		243.9	5.6
289.8	287.9	16.9		307.1	5.6
272.1	278.5	19.2		307.1	8.0
267.6	271.0	21.6		309.2	8.0
264.6	265.5	23.9		309.2	10.7
265.2	261.4	26.3		326.8	10.7
266.4	258.3	28.6		326.8	13.7
260.4	256.0	30.9		351.5	13.7
257.8	254.1	33.2		351.5	17.0
250.6	252.8	35.3		361.5	17.0
247.3	251.5	37.8		361.5	20.6
244.8	250.6	40.1		373.7	20.6
248.7	249.7	42.4		373.7	24.5
249.5	249.0	44.8		377.8	24.5
248.3	248.3	47.1		377.8	40.0
244.0	247.6	49.4		377.8	40.0
243.6	247.0	51.7			
243.7	246.4	54.1			
245.1	245.7	56.3			
245.7	245.1	58.7			
243.4	244.5	61.0			
240.9	243.9	63.3			
238.2	243.2	65.6			
239.2	242.6	67.9			
243.5	242.0	70.0			
252.0	241.4	72.6			
250.5	240.8	74.8			
247.9	240.2	77.2		Vs30	325.1

Figure A21.— Surface wave dispersion curve and shear wave velocity inversion data for site 706GSA.

**TRINET Site Classification**

**Site ID** 707CHN  
**NEHRP CLASS:** D  
**Vs30** 276 (m/s)  
**SUB-CLASS** D+  
**Vs40** 295 (m/s)

**Location** Chino  
**SMR Station** 208  
**State** CALIFORNIA

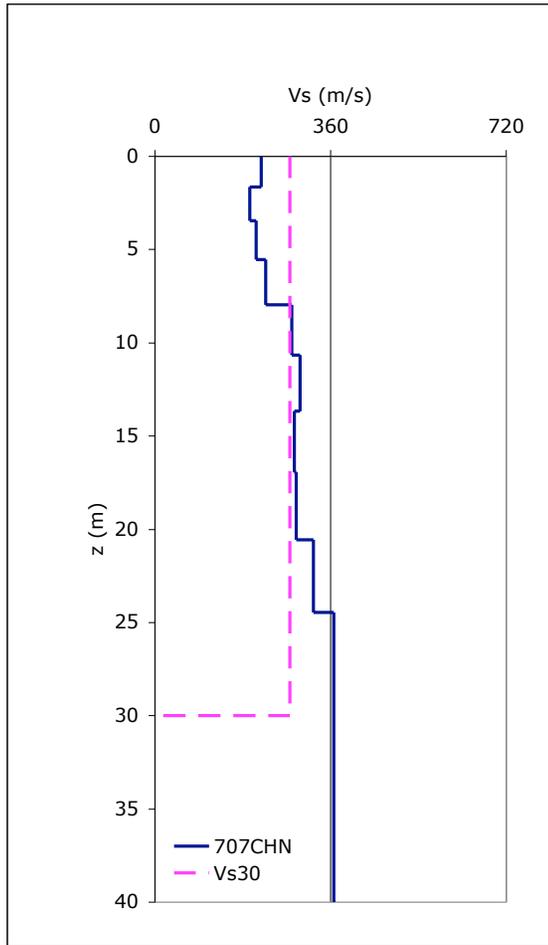
**POSITION DEGREES**  
**GPS LAT (NORTH)** 33.99965  
**GPS LONG (WEST)** 117.67734

**Data Type** SWEPT-SINE SASW  
**Investigators** KAYEN, CARKIN, TINSLEY  
**Date collected** 9/20/2004

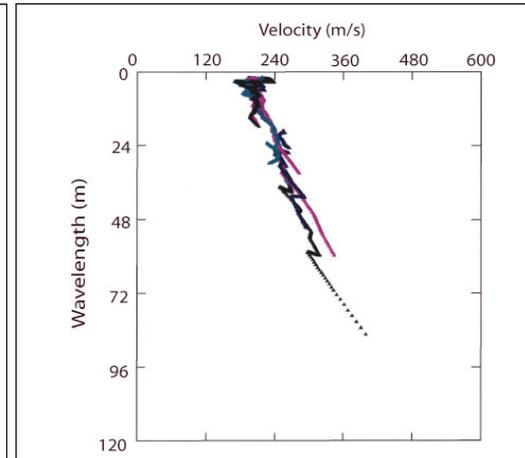
**TEST METHOD** CONTINUOUS HARMONIC WAVE-SASW

**PROJECT NAME** TRINET  
**SPONSORS** EHZ-SCEC

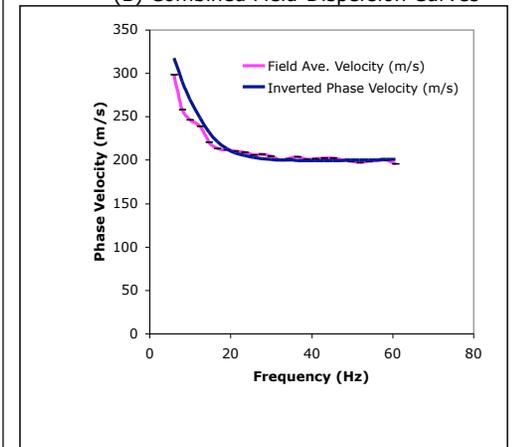
**SITE SUB CLASS: Vs30 (m/s)**  
 A >1500 m/s  
 B+ 1080 < Vs30 ≤ 1500 m/s  
 B- 720 < Vs30 ≤ 1080 m/s  
 C+ 540 < Vs30 ≤ 720 m/s  
 C- 360 < Vs30 ≤ 540 m/s  
 D+ 270 < Vs30 ≤ 360 m/s  
 D- 180 < Vs30 ≤ 270 m/s  
 E <180 m/s  
 F  
**Special Soil Conditions:** Liquefiable soils; quick and high sensitivity clays; collapsible cemented soils; peats>3m; high (>75) PI soils thicker than 8m; soft/medium stiff clays thicker than 36m.



(A) Vs 40 meters profile (solid) and Vs30 (dashed)



(B) Combined Field-Dispersion Curves



(C) Inversion-based theoretical dispersion curve versus averaged field dispersion curve

Figure A22.—SASW site classification and location information for site 707CHN. The layered inversion model of shear wave velocity in the upper 30 meters is presented in the middle plot. The site dispersion curves are presented in the upper-right plot, and the comparison between the average site dispersion curve and theoretical dispersion curve is presented in the lower-left.

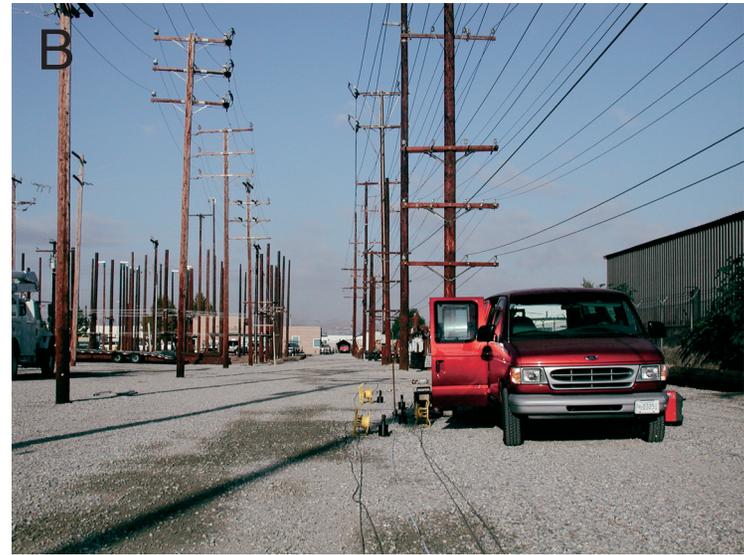


Figure A23.—Site 707CHN (SMR STA 208), located in Chino, San Bernardino County, California. Site location 33.99965°N 117.677342°W. Photo views: A) Looking north towards Benson Ave, B) looking west towards SCE linesman training center C) looking northeast, and D) looking south towards CHN substation.

<b>707CHN</b>	<b>DISPERSION DATA</b>			<b>INVERSION PROFILE</b>	
<b>Site Disp. Vr (m/s)</b>	<b>Theoretical Disp. Vr (m/s)</b>	<b>Frequency (Hz)</b>		<b>Inversion Vs (m/s)</b>	<b>Depth (m)</b>
400.0		3.9		218.3	0.0
298.7	317.6	6.0		218.3	1.7
258.6	290.3	8.1		194.8	1.7
246.5	270.0	10.0		194.8	3.5
238.8	248.4	12.4		207.1	3.5
221.1	232.3	14.6		207.1	5.6
213.7	221.3	16.7		226.5	5.6
212.2	213.6	18.9		226.5	8.0
210.5	208.7	21.1		279.8	8.0
209.4	205.5	23.3		279.8	10.7
206.5	203.4	25.6		297.1	10.7
206.8	202.0	27.7		297.1	13.7
204.4	201.0	29.9		285.1	13.7
200.3	200.4	32.2		285.1	17.0
202.1	200.0	34.3		289.0	17.0
203.9	199.8	36.5		289.0	20.6
200.8	199.6	38.7		324.2	20.6
201.6	199.6	40.9		324.2	24.5
202.4	199.7	43.1		366.1	24.5
202.3	199.8	45.3		366.1	40.0
200.4	199.9	47.5		366.1	40.0
198.5	200.0	49.7			
197.3	200.2	51.9			
198.9	200.4	54.1			
199.5	200.6	56.3			
200.5	200.7	58.5			
195.9	200.9	60.6			
				Vs30	276.5

Figure A24.— Surface wave dispersion curve and shear wave velocity inversion data for site 707CHN.

**TRINET Site Classification**

**Site ID** 708CRN  
**NEHRP CLASS:** C  
**Vs30** 367 (m/s)  
**SUB-CLASS** C-  
**Vs40** 398 (m/s)

**Location** Corona SBC Telephone Bldg  
**SMR Station** 135  
**State** CALIFORNIA

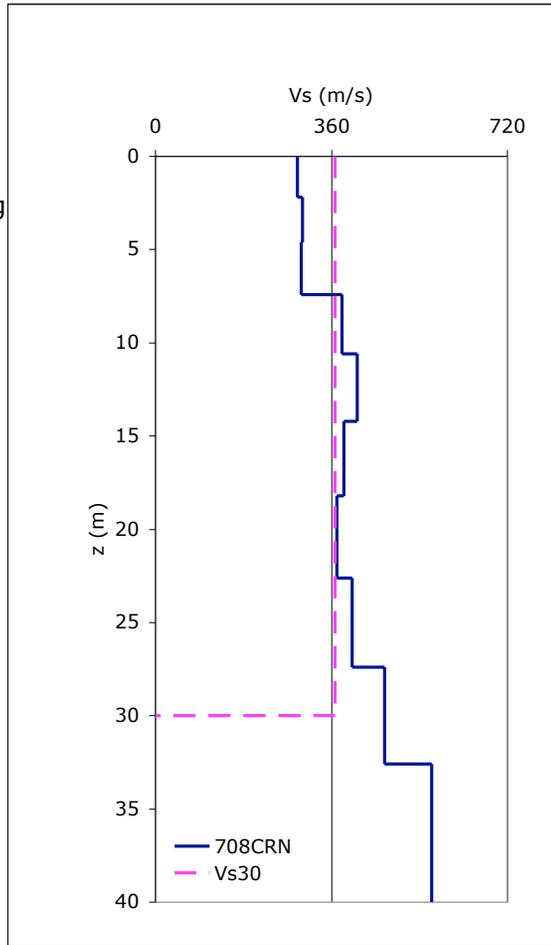
**POSITION DEGREES**  
**GPS LAT (NORTH)** 33.87525  
**GPS LONG (WEST)** 117.55939

**Investigators** SWEPT-SINE SASW  
**Date collected** KAYEN, CARKIN, TINSLEY  
 9/20/2004

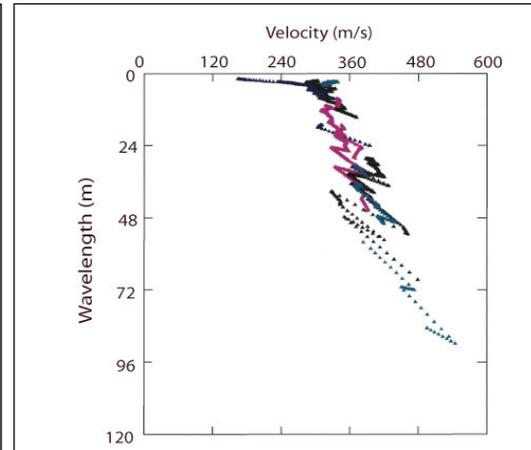
**TEST METHOD** CONTINUOUS HARMONIC WAVE-SASW

**PROJECT NAME** TRINET  
**SPONSORS** EHZ-SCEC

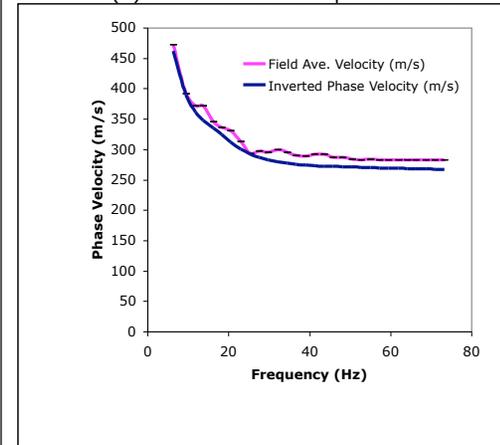
**SITE SUB CLASS: Vs30 (m/s)**  
 A >1500 m/s  
 B+ 1080 < Vs30 ≤ 1500 m/s  
 B- 720 < Vs30 ≤ 1080 m/s  
 C+ 540 < Vs30 ≤ 720 m/s  
 C- 360 < Vs30 ≤ 540 m/s  
 D+ 270 < Vs30 ≤ 360 m/s  
 D- 180 < Vs30 ≤ 270 m/s  
 E <180 m/s  
 F **Special Soil Conditions:** Liquefiable soils; quick and high sensitivity clays; collapsible cemented soils; peats>3m; high (>75) PI soils thicker than 8m; soft/medium stiff clays thicker than 36m.



(A) Vs 40 meters profile (solid) and Vs30 (dashed)



(B) Combined Field-Dispersion Curves



(C) Inversion-based theoretical dispersion curve versus averaged field dispersion curve

Figure A25.—SASW site classification and location information for site 708CRN. The layered inversion model of shear wave velocity in the upper 30 meters is presented in the middle plot. The site dispersion curves are presented in the upper-right plot, and the comparison between the average site dispersion curve and theoretical dispersion curve is presented in the lower-left.



Figure A26.—Site 708CRN (SMR STA 135), located at the SBC Telephone building, Corona, Riverside County, California. Site location 33.87525°N 117.55939°W. Photo views: A) Looking east in alley between E. 5th St. and E. 6th St., B) looking north along S. Joy St., C) looking west along alley, and D) looking south along S. Joy St.

<b>708CRN</b>	<b>DISPERSION DATA</b>			<b>INVERSION PROFILE</b>	
<b>Site Disp. Vr (m/s)</b>	<b>Theoretical Disp. Vr (m/s)</b>	<b>Frequency (Hz)</b>		<b>Inversion Vs (m/s)</b>	<b>Depth (m)</b>
545.0		6.9		290.6	0.0
472.6	461.8	6.3		290.6	2.2
392.3	390.3	9.4		300.8	2.2
372.4	361.5	11.7		300.8	4.6
372.6	348.2	13.7		297.7	4.6
345.7	335.2	16.3		297.7	7.4
336.2	324.7	18.3		381.7	7.4
331.3	312.7	20.5		381.7	10.6
313.6	301.0	23.0		412.4	10.6
293.4	292.7	25.4		412.4	14.2
297.9	287.2	27.5		385.0	14.2
295.2	283.1	29.7		385.0	18.2
299.3	279.9	32.1		370.8	18.2
295.8	277.6	34.4		370.8	22.6
290.0	275.9	36.7		402.3	22.6
289.6	274.6	39.0		402.3	27.4
292.1	273.6	41.2		468.9	27.4
292.2	272.8	43.5		468.9	32.6
287.5	272.2	45.8		565.7	32.6
286.7	271.6	48.1		565.7	40.0
283.7	271.1	50.4		565.7	40.0
282.8	270.6	52.6			
284.0	270.2	55.0			
282.7	269.8	57.2			
282.7	269.5	59.4			
282.7	269.1	61.8			
282.7	268.7	64.1			
282.7	268.4	66.2			
282.7	268.0	68.6			
282.7	267.6	70.9			
282.7	267.6	73.2			
				Vs30	366.7

Figure A27.—Surface wave dispersion curve and shear wave velocity inversion data for site 708PDU.

**TRINET Site Classification**

**Site ID** 709MLS  
**NEHRP CLASS:** D  
**Vs30** 296 (m/s)  
**SUB-CLASS** D+  
**Vs50** 360 (m/s)

**Location** Mira Loma Substation  
**SMR Station** 230  
**State** CALIFORNIA

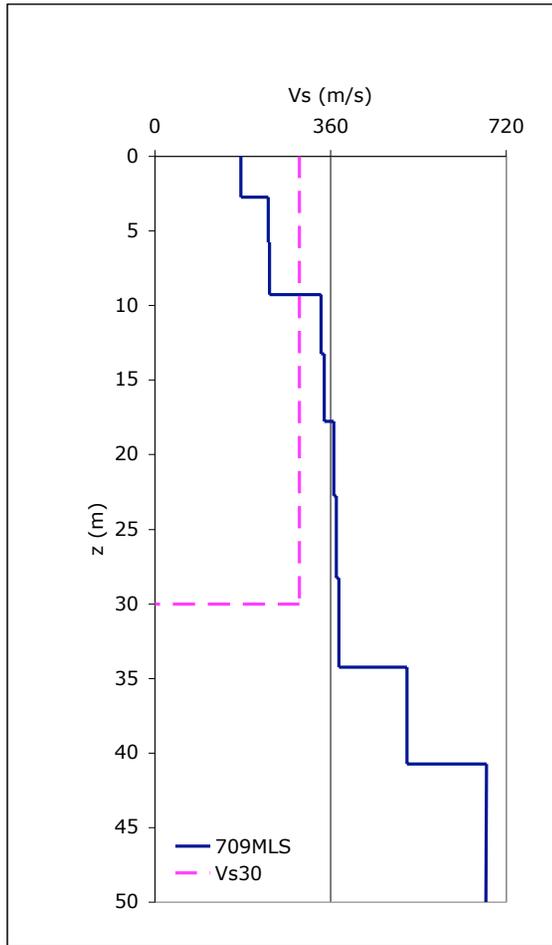
**POSITION DEGREES**  
**GPS LAT (NORTH)** 34.00841  
**GPS LONG (WEST)** 117.56463

**Data Type** SWEPT-SINE SASW  
**Investigators** KAYEN, CARKIN, TINSLEY  
**Date collected** 9/20/2004

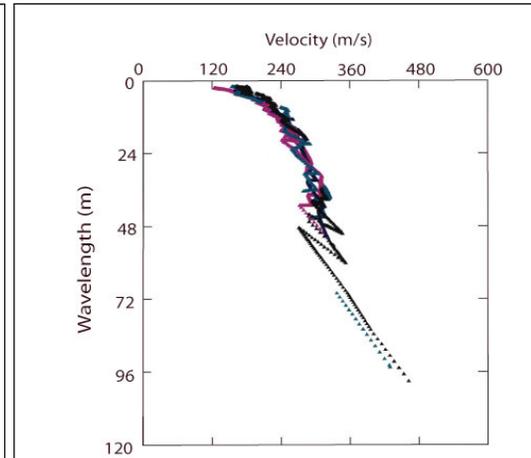
**TEST METHOD** CONTINUOUS HARMONIC WAVE-SASW

**PROJECT NAME** TRINET  
**SPONSORS** EHZ-SCEC

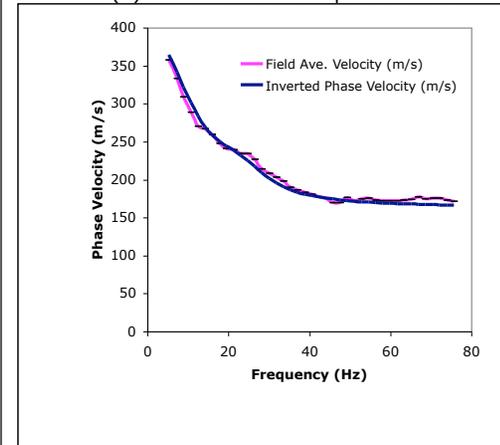
**SITE SUB CLASS: Vs30 (m/s)**  
 A >1500 m/s  
 B+ 1080 < Vs30 ≤ 1500 m/s  
 B- 720 < Vs30 ≤ 1080 m/s  
 C+ 540 < Vs30 ≤ 720 m/s  
 C- 360 < Vs30 ≤ 540 m/s  
 D+ 270 < Vs30 ≤ 360 m/s  
 D- 180 < Vs30 ≤ 270 m/s  
 E <180 m/s  
 F  
 Special Soil Conditions: Liquefiable soils; quick and high sensitivity clays; collapsible cemented soils; peats>3m; high (>75) PI soils thicker than 8m; soft/medium stiff clays thicker than 36m.



(A) Vs 50 meters profile (solid) and Vs30 (dashed)



(B) Combined Field-Dispersion Curves



(C) Inversion-based theoretical dispersion curve versus averaged field dispersion curve

Figure A28.—SASW site classification and location information for site 709MLS. The layered inversion model of shear wave velocity in the upper 30 meters is presented in the middle plot. The site dispersion curves are presented in the upper-right plot, and the comparison between the average site dispersion curve and theoretical dispersion curve is presented in the lower-left.

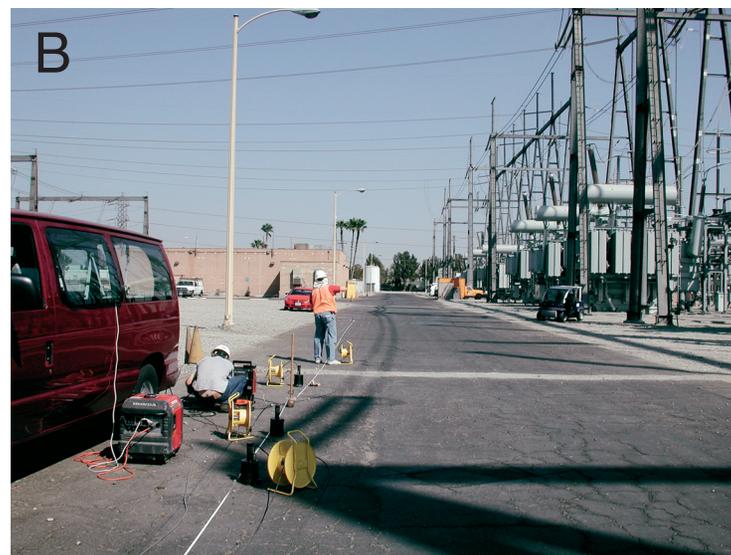
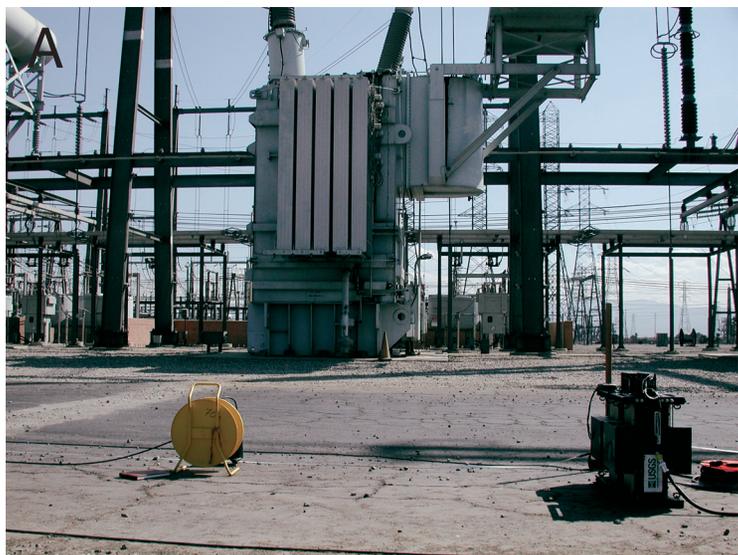


Figure A29.—Site 709MLS (SMR STA 230), located at the Mira Loma Substation, Mira Loma, San Bernardino County, California. Site location  $34.00841^{\circ}\text{N}$   $117.56463^{\circ}\text{W}$ . Photo views: A) Looking south toward E. Edison Ave, B) looking east towards S. Milliken Ave, C) looking southwest, and D) looking west towards S. Haven Ave.

<b>709MLS</b>	<b>DISPERSION DATA</b>		<b>INVERSION PROFILE</b>		
<b>Site Disp. Vr (m/s)</b>	<b>Theoretical Disp. Vr (m/s)</b>	<b>Frequency (Hz)</b>		<b>Inversion Vs (m/s)</b>	<b>Depth (m)</b>
503.0		4.7		175.5	0.0
358.3	364.8	5.1		175.5	2.8
333.7	342.0	7.3		231.8	2.8
309.6	322.1	8.9		231.8	5.8
289.5	302.1	10.6		234.8	5.8
270.9	284.0	12.4		234.8	9.3
267.7	269.6	14.2		340.2	9.3
260.2	258.8	15.9		340.2	13.3
248.0	250.7	17.7		346.6	13.3
241.8	244.6	19.4		346.6	17.8
239.6	238.6	21.2		366.9	17.8
234.8	232.5	23.0		366.9	22.8
234.5	225.5	24.7		371.3	22.8
227.3	217.7	26.4		371.3	28.3
215.1	209.8	28.1		377.4	28.3
208.4	202.0	30.0		377.4	34.3
204.0	196.0	31.7		516.0	34.3
198.7	191.1	33.5		516.0	40.8
190.4	187.1	35.2		678.9	40.8
187.2	184.0	37.0		678.9	50.0
183.8	181.4	38.8		678.9	50.0
180.9	179.3	40.5			
178.0	177.6	42.2			
176.3	176.2	44.0			
170.4	174.9	45.7			
170.6	173.8	47.5			
176.8	172.9	49.2			
172.8	172.2	50.9			
175.4	171.4	52.8			
176.2	170.8	54.5			
173.2	170.2	56.3			
172.4	169.7	58.0			
173.1	169.3	59.8		Vs30	296.1
172.6	168.9	61.6			
173.7	168.5	63.2			
174.6	168.2	65.0			
178.0	167.9	66.8			
175.7	167.6	68.6			
176.3	167.4	70.3			
176.1	167.2	72.0			
173.6	167.0	73.8			
172.0	166.8	75.6			
0.0	0.0	0.0			
0.0	0.0	0.0			
0.0	0.0	0.0			
0.0	0.0	0.0			
0.0	0.0	0.0			
0.0	0.0	0.0			
0.0	0.0	0.0			
0.0	0.0	0.0			
0.0	0.0	0.0			

Figure A30.— Surface wave dispersion curve and shear wave velocity inversion data for site 709MLS.

**TRINET Site Classification**

**Site ID** 710PDU  
**NEHRP CLASS:** C  
**Vs30** 424 (m/s)  
**SUB-CLASS** C-  
**Vs40** 542 (m/s)  
**Location** Padua Substation, Upland  
**SMR Station** 445  
**State** CALIFORNIA

**POSITION DEGREES**  
**GPS LAT (NORTH)** 34.11801  
**GPS LONG (WEST)** 117.63962

**Data Type** SWEPT-SINE SASW  
**Investigators** KAYEN, CARKIN, TINSLEY  
**Date collected** 9/21/2004

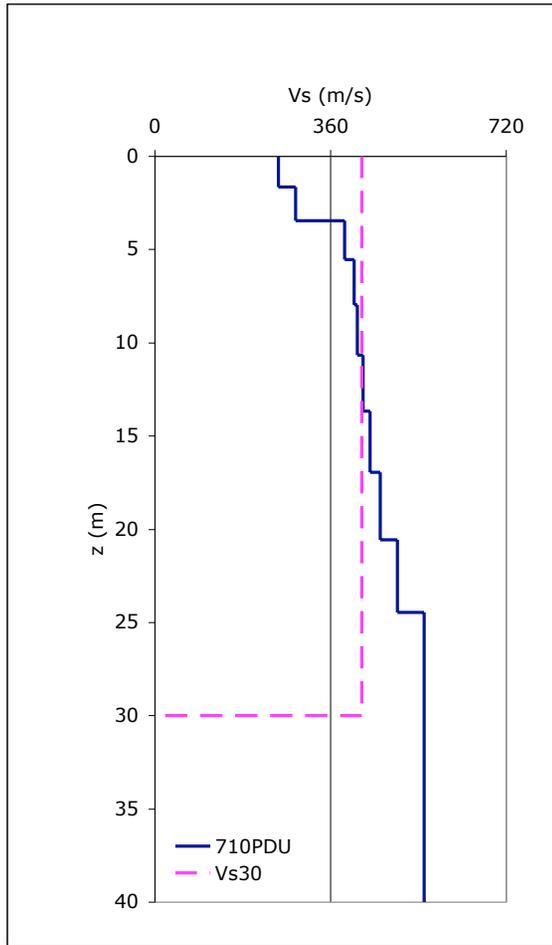
**TEST METHOD** CONTINUOUS HARMONIC WAVE-SASW

**PROJECT NAME** TRINET  
**SPONSORS** EHZ-SCEC

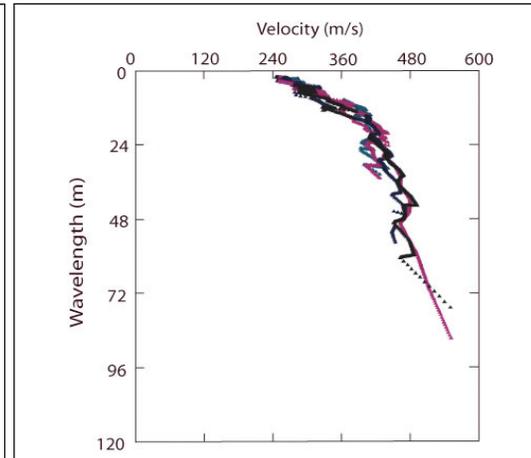
**SITE SUB CLASS: Vs30 (m/s)**

- A >1500 m/s
- B+ 1080 < Vs30 ≤ 1500 m/s
- B- 720 < Vs30 ≤ 1080 m/s
- C+ 540 < Vs30 ≤ 720 m/s
- C- 360 < Vs30 ≤ 540 m/s
- D+ 270 < Vs30 ≤ 360 m/s
- D- 180 < Vs30 ≤ 270 m/s
- E <180 m/s
- F

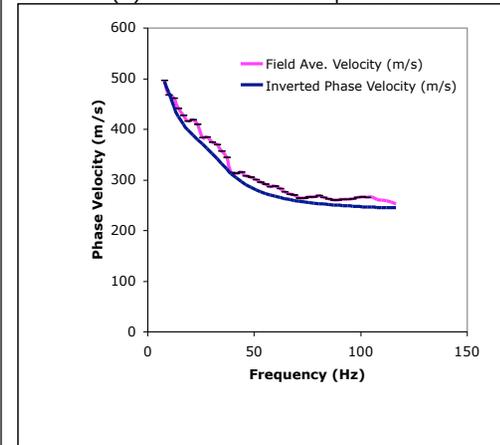
**Special Soil Conditions:** Liquefiable soils; quick and high sensitivity clays; collapsible cemented soils; peats>3m; high (>75) PI soils thicker than 8m; soft/medium stiff clays thicker than 36m.



(A) Vs 40 meters profile (solid) and Vs30 (dashed)



(B) Combined Field-Dispersion Curves



(C) Inversion-based theoretical dispersion curve versus averaged field dispersion curve

Figure A31.—SASW site classification and location information for site 710PDU. The layered inversion model of shear wave velocity in the upper 30 meters is presented in the middle plot. The site dispersion curves are presented in the upper-right plot, and the comparison between the average site dispersion curve and theoretical dispersion curve is presented in the lower-left.



Figure A32. — Site 710PDU (SMR STA 445), located at the Padua Substation, Upland, San Bernardino County, California. Site location  $34.11801^{\circ}\text{N}$   $117.63962^{\circ}\text{W}$ . Photo views: A) Testing adjacent to Upland Fire Station, B) looking north on E. 15th St., C) looking northwest towards PDU substation, and D) looking west towards Animal Shelter.

<b>710PDU</b>	<b>DISPERSION DATA</b>			<b>INVERSION PROFILE</b>	
<b>Site Disp. Vr (m/s)</b>	<b>Theoretical Disp. Vr (m/s)</b>	<b>Frequency (Hz)</b>		<b>Inversion Vs (m/s)</b>	<b>Depth (m)</b>
551.0		6.0		252.6	0.0
496.9	493.8	7.7		252.6	1.7
468.1	472.5	9.8		288.0	1.7
462.2	445.1	12.1		288.0	3.5
442.0	425.0	14.3		388.1	3.5
427.8	409.8	16.6		388.1	5.6
416.5	398.5	18.9		408.0	5.6
419.1	389.1	21.1		408.0	8.0
409.9	380.4	23.4		414.8	8.0
383.2	371.5	25.7		414.8	10.7
384.8	362.8	27.9		427.1	10.7
375.0	352.8	30.2		427.1	13.7
370.3	342.4	32.5		441.2	13.7
356.7	332.0	34.7		441.2	17.0
344.6	321.8	37.0		461.8	17.0
313.9	312.5	39.3		461.8	20.6
312.9	304.1	41.6		497.2	20.6
315.5	296.8	43.9		497.2	24.5
308.8	290.4	46.2		551.3	24.5
306.0	285.1	48.4		551.3	40.0
301.0	280.4	50.7		551.3	40.0
295.7	276.4	53.0			
292.4	273.0	55.2			
287.4	270.0	57.5			
288.2	267.3	59.7			
282.5	264.9	62.1			
276.7	262.9	64.3			
272.0	261.1	66.6			
270.2	259.4	68.9			
263.7	257.8	71.2			
264.2	256.5	73.4			
266.3	255.4	75.5			
267.0	254.2	77.9		Vs30	423.8
268.6	253.2	80.3			
266.0	252.3	82.5			

Figure A33.—Surface wave dispersion curve and shear wave velocity inversion data for site 710PDU.

**TRINET Site Classification**

**Site ID** 711FON  
**NEHRP CLASS:** C  
**Vs30** 405 (m/s)  
**SUB-CLASS** C-  
**Vs50** 464 (m/s)

**Location** Fontana  
**SMR Station** 449  
**State** CALIFORNIA

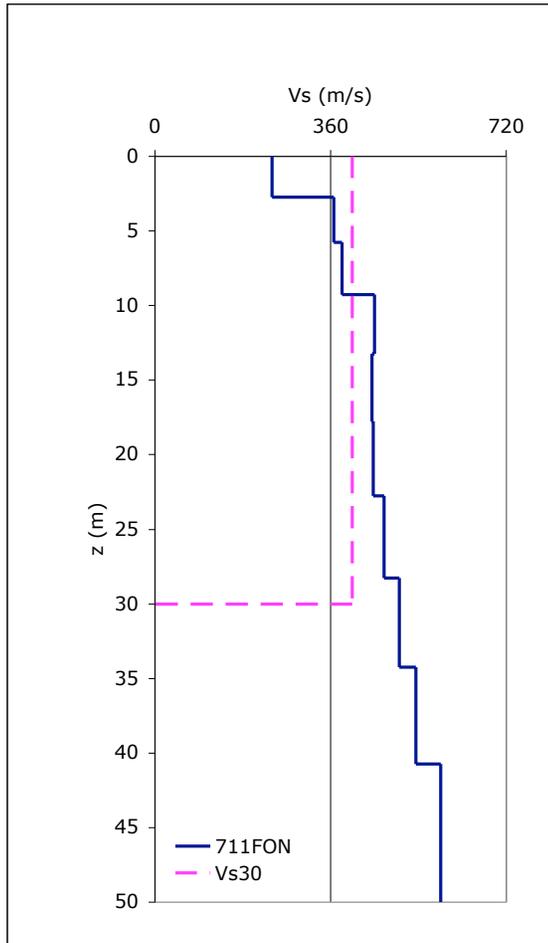
**POSITION DEGREES**  
**GPS LAT (NORTH)** 34.09997  
**GPS LONG (WEST)** 117.43816

**Data Type** SWEPT-SINE SASW  
**Investigators** KAYEN, CARKIN, TINSLEY  
**Date collected** 9/21/2004

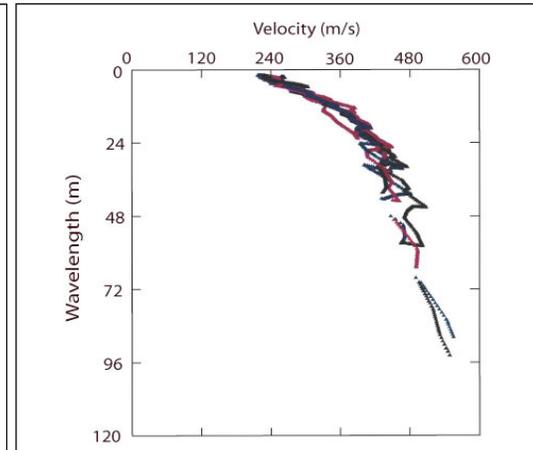
**TEST METHOD** CONTINUOUS HARMONIC WAVE-SASW

**PROJECT NAME** TRINET  
**SPONSORS** EHZ-SCEC

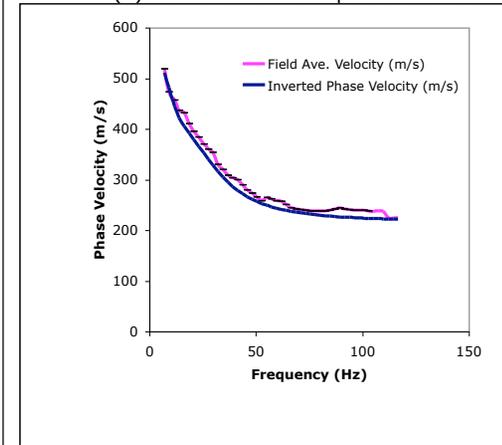
**SITE SUB CLASS: Vs30 (m/s)**  
 A >1500 m/s  
 B+ 1080 < Vs30 ≤ 1500 m/s  
 B- 720 < Vs30 ≤ 1080 m/s  
 C+ 540 < Vs30 ≤ 720 m/s  
 C- 360 < Vs30 ≤ 540 m/s  
 D+ 270 < Vs30 ≤ 360 m/s  
 D- 180 < Vs30 ≤ 270 m/s  
 E <180 m/s  
 F  
 Special Soil Conditions: Liquefiable soils; quick and high sensitivity clays; collapsible cemented soils; peats>3m; high (>75) PI soils thicker than 8m; soft/medium stiff clays thicker than 36m.



(A) Vs 50 meters profile (solid) and Vs30 (dashed)



(B) Combined Field-Dispersion Curves



(C) Inversion-based theoretical dispersion curve versus averaged field dispersion curve

Figure A34.—SASW site classification and location information for site 711FON. The layered inversion model of shear wave velocity in the upper 30 meters is presented in the middle plot. The site dispersion curves are presented in the upper-right plot, and the comparison between the average site dispersion curve and theoretical dispersion curve is presented in the lower-left.



Figure A35.—Site 711FON (SMR STA 449), located in Fontana, San Bernardino County, California. Site location 34.09997°N 117.43816°W. Photo views:  
A) Looking west along Arrow Blvd., B) looking east along Arrow Blvd., C) looking north, and D) looking north toward Spring St. and the Santa Ana Mountains.

<b>711FON</b>	<b>DISPERSION DATA</b>			<b>INVERSION PROFILE</b>	
<b>Site Disp. Vr (m/s)</b>	<b>Theoretical Disp. Vr (m/s)</b>	<b>Frequency (Hz)</b>		<b>Inversion Vs (m/s)</b>	<b>Depth (m)</b>
556.0		6.3		240.6	0.0
519.0	512.5	6.8		240.6	2.8
474.8	482.4	9.1		366.7	2.8
457.9	445.9	11.6		366.7	5.8
437.3	422.8	13.9		383.0	5.8
433.3	406.1	16.2		383.0	9.3
410.8	392.8	18.4		450.1	9.3
396.3	380.1	20.6		450.1	13.3
384.8	366.5	23.0		445.2	13.3
371.7	353.5	25.3		445.2	17.8
361.5	341.1	27.5		447.0	17.8
354.6	329.1	29.7		447.0	22.8
331.2	317.0	32.1		470.1	22.8
320.4	306.0	34.4		470.1	28.3
309.3	296.2	36.7		501.0	28.3
304.7	287.3	38.9		501.0	34.3
300.0	279.5	41.2		535.3	34.3
290.4	272.7	43.5		535.3	40.8
280.8	266.7	45.8		585.7	40.8
274.2	261.7	48.1		585.7	50.0
266.7	257.5	50.2		585.7	50.0
258.5	253.4	52.7			
265.4	250.0	55.0			
263.4	247.2	57.2			
259.1	244.5	59.5			
258.0	242.1	61.8			
251.4	240.0	64.1			
245.4	238.2	66.4			
242.3	236.5	68.7			
241.4	235.0	70.9			
239.8	233.7	73.1			
239.2	232.4	75.4			
239.3	231.3	77.8			
239.1	230.3	80.0			
239.6	229.3	82.3			
239.8	228.5	84.7			
242.7	227.7	86.9			
244.8	227.0	89.2			
243.1	226.4	91.5			
241.4	225.8	93.7			
240.8	225.3	95.9			
240.3	224.8	98.3			
				Vs30	404.7

Figure A36.—Surface wave dispersion curve and shear wave velocity inversion data for site 711FON.

### TRINET Site Classification

**Site ID** 712CLT  
**NEHRP CLASS:** D  
**Vs30** 258 (m/s)  
**SUB-CLASS** D-

**Location** Colton  
**SMR Station** 325  
**State** CALIFORNIA

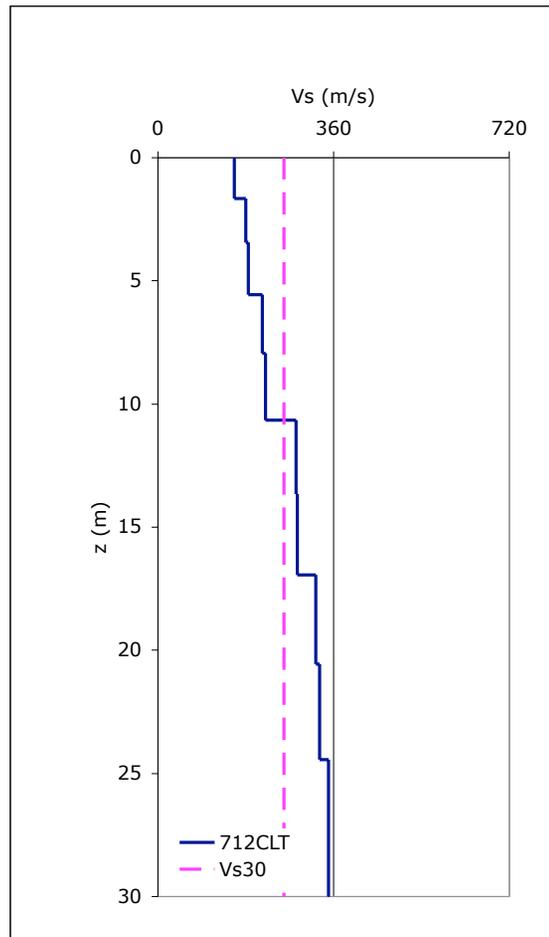
**POSITION DEGREES**  
**GPS LAT (NORTH)** 34.09338  
**GPS LONG (WEST)** 117.31172

**Data Type** SWEPT-SINE SASW  
**Investigators** KAYEN, CARKIN, TINSLEY  
**Date collected** 9/21/2004

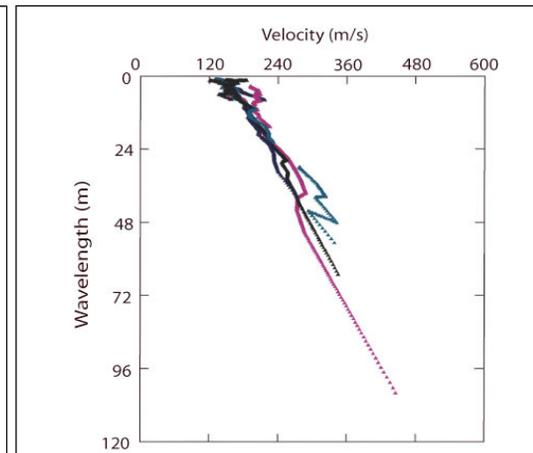
**TEST METHOD** CONTINUOUS HARMONIC WAVE-SASW

**PROJECT NAME** TRINET  
**SPONSORS** EHZ-SCEC

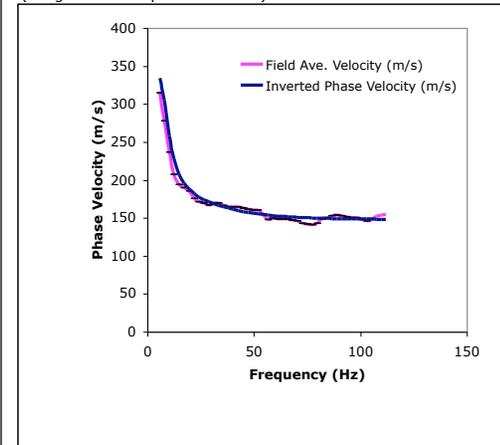
**SITE SUB CLASS: Vs30 (m/s)**  
A >1500 m/s  
B+ 1080 < Vs30 ≤ 1500 m/s  
B- 720 < Vs30 ≤ 1080 m/s  
C+ 540 < Vs30 ≤ 720 m/s  
C- 360 < Vs30 ≤ 540 m/s  
D+ 270 < Vs30 ≤ 360 m/s  
D- 180 < Vs30 ≤ 270 m/s  
E <180 m/s  
F **Special Soil Conditions:** Liquefiable soils; quick and high sensitivity clays; collapsible cemented soils; peats>3m; high (>75) PI soils thicker than 8m; soft/medium stiff clays thicker than 36m.



(Vs profile in upper 30 meters (solid) and Vs30 (dashed))



(Merged Field-Dispersion Curves)



(Inverted-theoretical-dispersion curve versus average field curve, bars represent ±1σ range of merged field data)

Figure A37.—SASW site classification and location information for site 712CLT. The layered inversion model of shear wave velocity in the upper 30 meters is presented in the middle plot. The site dispersion curves are presented in the upper-right plot, and the comparison between the average site dispersion curve and theoretical dispersion curve is presented in the lower-left.



Figure A38.—Site 712CLT (SMR STA 325), located in Colton, San Bernardino County, California. Site location 34.09338°N 117.311715°W. Photo views: A) Looking south toward W. Mill St., B) looking north towards the CLT Substation, C) looking east towards CLT Substation, and D) looking southwest towards Atchison, Topeka & Santa Fe Railway and W. Mill St. overcrossing.

<b>712CLT</b>	<b>DISPERSION DATA</b>			<b>INVERSION PROFILE</b>	
<b>Site Disp. Vr (m/s)</b>	<b>Theoretical Disp. Vr (m/s)</b>	<b>Frequency (Hz)</b>		<b>Inversion Vs (m/s)</b>	<b>Depth (m)</b>
446.0		4.8		156.9	0.0
315.5	334.7	5.6		156.9	1.7
278.4	305.6	7.8		180.3	1.7
237.1	258.4	10.0		180.3	3.5
208.4	228.6	12.2		184.7	3.5
194.6	208.2	14.7		184.7	5.6
190.6	196.4	17.0		213.7	5.6
186.0	188.4	19.3		213.7	8.0
176.0	182.4	21.7		220.0	8.0
172.2	178.1	23.9		220.0	10.7
170.5	174.6	26.3		282.5	10.7
167.9	171.7	28.6		282.5	13.7
169.8	169.2	30.9		285.0	13.7
170.1	167.0	33.2		285.0	17.0
166.9	165.0	35.5		323.8	17.0
165.4	163.2	37.9		323.8	20.6
165.6	161.6	40.1		331.1	20.6
165.5	160.2	42.5		331.1	24.5
163.5	158.8	44.8		349.9	24.5
161.9	157.7	47.1		349.9	30.0
161.2	156.6	49.4		349.9	30.0
161.0	155.7	51.7			
155.0	154.8	54.0			
148.7	154.1	56.4			
150.0	153.4	58.7			
149.0	152.8	61.0			
149.5	152.3	63.3			
149.5	151.9	65.7			
147.9	151.5	67.9			
146.5	151.1	70.2			
143.8	150.8	72.6			
142.7	150.6	74.9			
141.7	150.3	77.2		Vs30	257.9

Figure A39.—Surface wave dispersion curve and shear wave velocity inversion data for site 712CLT.