

STATE-OF-THE-ART REACTOR CONSEQUENCE ANALYSES (SOARCA) LIQUEFACTION ANALYSES

Prepared by
Thomas Weaver, RES/DE/SGSEB
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This is a short description and summary of ground deformation assessments associated with earthquake induced soil liquefaction at the Surry nuclear power plant performed for the State of the Art Reactor Consequence Analyses study.

Laboratory and field data demonstrate that volumetric strain manifested as ground surface settlement occurs after earthquake induced soil liquefaction. Analyses have been performed to estimate liquefaction induced settlements at the Surry nuclear power plant. The objectives of these analyses were to confirm estimates of settlement presented in NUREG-CR 4450 [1] for an earthquake inducing a peak ground surface acceleration of 0.4 g at the site and to estimate surface settlements for an earthquake having an annual frequency of occurrence on the order of 1×10^{-6} to 1×10^{-7} with an associated peak ground surface acceleration of 0.75 g.

Geologic and geotechnical data used for the analyses was obtained from the Surry UFSAR [2] and the original geotechnical investigation report by Dames and Moore [3]. Boring logs from the Dames and Moore [3] geotechnical report were used to develop idealized geologic cross sections which show the depth and thickness of potentially liquefiable soils across the site. The potential for soil liquefaction in sandy materials was estimated using the procedure presented by Youd et al. [4] and the magnitude of ground surface settlement was estimated using a method proposed by Ishihara and Yoshimine [5]. Tables of calculated factors of safety against liquefaction, volumetric strain, and ground surface settlement for peak ground accelerations of 0.4 g and 0.75 g and associated earthquake magnitudes of 5.8 and 6.5, respectively, are attached.

The estimated ground surface settlement associated with a peak ground surface acceleration of 0.4 g, earthquake magnitude of 5.8, and a water table elevation of 5 ft mean sea level are in general agreement with the NUREG-CR 4450 [1] settlement estimates. Ground surface settlements are expected to approximately double in magnitude when the peak ground surface acceleration increases to 0.75 g with an associated magnitude 6.5 earthquake. Table 1 and Table 2 provide a summary of estimated ground surface settlements for these two events:

Table 1: Liquefaction induced settlement for a magnitude 5.8 earthquake, 0.4 pga, and groundwater table at 5 ft mean sea level

Table 2: Liquefaction induced settlement for a magnitude 6.5 earthquake, 0.75 pga, and groundwater table at 5 ft mean sea level.

References

1. Bohn, M. P., Lambright, J. A., Daniel, S. L., Johnson, J. J., Ravindra, M. K., Hashimoto, P. O., Mraz, M. J., Tong, W. H. "Analysis of core damage frequency: Surry power station, unit 1 external events," NUREG/CR-4550, U.S. Nuclear Regulatory Commission, December 1990.
2. Virginia Electric and Power Company, Surry Power Station Updated Final Safety Analysis Report, 2011.
3. Dames and Moore, "Report, Environmental Studies, Proposed Nuclear Power Plant, Surry, Virginia, Virginia Electric and Power Company," December 1966.
4. Youd, T. L., Idriss, I. M., Andrus, R. D., Arango, I., Castro, G., Christian, J. T., Dobry, R., Liam Finn, W. D., Harder, L. F., Hynes, M. E., Ishihara, K., Koester, J. P., Liao, S. S. C., Marcuson, W. F., Martin, G. R., Mitchell, J. K., Moriwaki, Y., Power, M. S., Robertson, P. K., Seed, R. B., and Stokoe, K. H. "Liquefaction resistance of soils: summary report from the 1996 NCEER and 1998 NCEER/NSF workshops on evaluation of liquefaction resistance of soils." *J. Geotech. Geoenviron. Eng.* ASCE, 127(10). 817 – 833, 2001.
5. Ishihara, K. and Yoshimine, M. "Evaluation of settlements in sand deposits following liquefaction during earthquakes," *Soils and Foundations*, Japanese Society of Soil Mechanics and Foundations Engineering, 32(1), 173-188, 1992.

SOARCA Study
Surry Nuclear Power Plant
Liquefaction Induced Settlement Calculations

Calculations By: T. Weaver
Date: 10/27/2011

Notes:

- Ishihara and Yoshimine (1992) method used to calculate settlement.
- The FSAR N-value sampler correction, C_s , was used.
- Factor of safety against liquefaction was computed using the procedure recommended by Youd et al. (2001).
- Magnitude, $M_w = 5.8$
- Peak ground acceleration, $p_{ga} = 0.4g$
- Ground water table, Elev = 5 ft

Table 1: Liquefaction induced settlement for a magnitude 5.8 earthquake, 0.4 p_{ga}, and groundwater table at 5 ft mean sea level

Section	Boring	Soil Type	Fines Content	N	(N ₁) ₆₀	(N ₁) _{60CS}	(N ₁) _{72CS}	FS	Vol. Strain %	Thickness ft	Settlement in	Elevation ft
A	B-11	SP	4	19	15	15	13	5.94	0.00	6.60	0.0	-4.6
A	B-11	SP	4	45	38	38	32	0.82	0.69	7.40	0.6	-8.6
A	B-11	SP	4	13	8	8	7	0.68	4.27	6.00	3.1	-29.6
Total Set.											3.7	

A	B-17	SP	4	49	39	39	32	5.95	0.00	8.00	0.0	-6.3
A	B-17	SP/ML	4	20	12	12	10	0.82	3.41	5.00	2.0	-36.3
Total Set.											2.0	Fill

A	B-22	SM-ML	24	34	29	36	30	1.14	0.27	2.50	0.1	4.5
A	B-22	SP	4	24	19	19	16	2.83	0.00	3.00	0.0	0.5
A	B-22	SP	4	28	22	22	18	1.01	0.87	7.00	0.7	-1.5
Total Set.											0.8	

Table 1: Liquefaction induced settlement for a magnitude 5.8 earthquake, 0.4 pga, and groundwater table at 5 ft mean sea level

Section	Boring	Soil Type	Fines Content	N	(N ₁) ₆₀	(N ₁) _{60cs}	(N ₁) _{72cs}	FS	Vol. Strain %	Thickness ft	Settlement in	Elevation ft
A	B-27	SP	4	37	30	30	25	1.96	0.01	1.50	0.0	4.5
A	B-27	SP	4	69	61	61	51	6.60	0.00	2.00	0.0	2.5
A	B-27	SP	4	26	21	21	17	6.59	0.00	4.00	0.0	0.5
A	B-27	SP	4	53	43	43	36	1.60	0.06	4.50	0.0	-5.5
A	B-27	SM-ML	24	14	8	13	11	1.56	0.18	6.00	0.1	-35.5
A	B-27	SW	4	37	23	23	19	1.56	0.13	3.00	0.0	-40.5
Total Set.											0.2	
C	B-12	SP	4	28	24	24	20	5.71	0.00	1.30	0.0	-6.7
C	B-12	SP	4	24	20	20	17	0.72	2.43	3.25	0.9	-7.9
C	B-12	SP	4	24	19	19	16	1.08	0.67	3.00	0.2	-13.2
C	B-12	SP	4	29	23	23	19	0.61	2.23	2.35	0.6	-13.9
C	B-12	SM	24	9	7	12	10	1.05	1.03	5.00	0.6	-17.9
C	B-12	SM	24	19	14	20	17	0.96	1.19	5.00	0.7	-23.9
C	B-12	SM	24	18	13	18	15	0.87	2.03	5.00	1.2	-27.9
C	B-12	SM	24	17	12	17	14	0.82	2.61	4.10	1.3	-33.9
Total Set.											5.6	
C	B-15	SP	4	48	38	38	32	0.95	0.50	8.00	0.5	-6.3
C	B-15	SM	24	17	12	17	14	0.97	1.29	6.30	1.0	-26.3
C	B-15	SM	24	20	14	19	16	1.05	0.76	7.20	0.7	-30.3
Total Set.											2.1	
C	B-20	SP	4	19	15	15	12	6.89	0.00	1.90	0.0	4.1
C	B-20	SP	4	17	13	13	11	1.43	0.26	2.00	0.1	2.1
C	B-20	SP	4	25	20	20	16	0.80	2.32	2.25	0.6	0.1
C	B-20	SP	4	15	11	11	9	6.03	0.00	1.25	0.0	-2.4
C	B-20	SM-ML	24	11	7	12	10	1.07	0.89	4.40	0.5	-24.9
C	B-20	SM-ML	24	19	13	18	15	0.69	2.63	2.50	0.8	-25.9
C	B-20	SP	4	8	4	4	4	0.69	5.24	5.00	3.1	-29.9
C	B-20	SP	4	52	35	35	29	5.81	0.00	3.00	0.0	-35.9
Total Set.											5.1	

Table 1: Liquefaction induced settlement for a magnitude 5.8 earthquake, 0.4 pga, and groundwater table at 5 ft mean sea level

Section	Boring	Soil Type	Fines Content	N	(N ₁) ₆₀	(N ₁) _{60cs}	(N ₁) _{72cs}	FS	Vol. Strain %	Thickness ft	Settlement in	Elevation ft
C	B-25	SP	4	25	19	19	16	1.50	0.18	2.70	0.1	4.3
C	B-25	SP	4	50	42	42	35	1.54	0.08	5.00	0.0	0.3
C	B-25	SW	4	62	51	51	43	0.93	0.52	3.00	0.2	-5.7
Total Set.											0.3	
D	B-13	SP	4	19	14	14	12	0.67	3.10	0.95	0.4	-7.7
D	B-13	SP	4	65	55	55	46	5.85	0.00	2.50	0.0	-8.2
D	B-13	SP	4	26	19	19	16	0.60	2.54	2.25	0.7	-12.7
D	B-13	SP	4	20	15	15	12	2.02	0.00	3.00	0.0	-12.7
D	B-13	SM-ML	24	7	5	9	8	0.83	4.04	5.00	2.4	-18.7
D	B-13	SM-ML	24	12	8	13	11	0.67	3.31	5.00	2.0	-22.7
D	B-13	SM-ML	24	15	10	15	13	1.03	1.00	5.00	0.6	-28.7
D	B-13	SM-ML	24	10	6	11	9	1.06	0.98	4.80	0.6	-32.7
Total Set.											6.6	
D	B-18	SP	4	41	33	33	27	1.19	0.28	2.00	0.1	-9.6
D	B-18	SP	4	36	27	27	23	0.75	1.55	5.00	0.9	-13.6
D	B-18	SP	4	24	17	17	14	0.87	2.33	4.00	1.1	-19.6
D	B-18	SM	24	17	12	17	15	1.23	0.41	2.00	0.1	-21.6
D	B-18	SM	24	15	10	16	13	1.13	0.60	4.00	0.3	-23.6
D	B-18	SM	24	13	8	13	11	1.22	0.47	5.00	0.3	-29.6
D	B-18	SM	24	17	11	16	14	5.81	0.00	4.90	0.0	-33.6
Total Set.											2.8	
D	B-23	SP	4	24	15	15	13	1.36	0.31	4.05	0.1	-26.1
D	B-23	SP	4	14	8	8	7	0.69	4.29	2.00	1.0	-29
D	B-23	SM	24	17	11	16	13	0.68	2.85	2.00	0.7	-30.1
D	B-23	SM	24	68	61	72	60	0.89	0.58	2.95	0.2	-33
Total Set.											2.1	
D	B-28	SP	4	26	24	24	20	0.67	2.15	4.30	1.1	0.7
D	B-28	SP	4	40	34	34	29	5.94	0.00	5.00	0.0	-5.3
D	B-28	SP	4	13	11	11	9	5.45	0.00	8.70	0.0	-9.3
Total Set.											1.1	

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Mw = 5.8, PGA = 0.4g, GWT Elev. = 5 ft

FSAR Sampler Size Correction

Table 1: Liquefaction induced settlement for a magnitude 5.8 earthquake, 0.4 pga, and groundwater table at 5 ft mean sea level

Section	Boring	Soil Type	Fines Content	N	(N ₁) ₆₀	(N ₁) _{60cs}	(N ₁) _{72cs}	FS	Vol. Strain %	Thickness ft	Settlement in	Elevation ft
E	B-14	SP	4	5	3	3	3	5.59	0.00	4.40	0.0	-6.9
E	B-14	SM-ML	24	57	51	61	51	1.16	0.25	2.94	0.1	-10.9
E	B-14	SM-ML	24	18	13	19	16	1.51	0.18	3.00	0.1	-12.78
E	B-14	SM-ML	24	10	7	12	10	1.60	0.16	3.00	0.1	-16.9
E	B-14	SM-ML	24	26	19	25	21	0.84	1.39	2.00	0.3	-18.78
E	B-14	SM-ML	24	12	8	13	11	0.97	1.66	4.06	0.8	-20.9
E	B-14	SM-ML	24	9	5	10	9	0.59	3.85	5.00	2.3	-26.9
E	B-14	SM-ML	24	9	5	10	8	5.43	0.00	4.10	0.0	-30.9
Total Set.											3.7	

E	B-19	SM	24	12	9	14	12	1.82	0.05	2.00	0.0	3.8
E	B-19	SM	24	24	19	26	21	5.95	0.00	2.95	0.0	-3.7
E	B-19	SP	4	42	33	33	27	5.82	0.00	2.50	0.0	-7.2
E	B-19	SP	4	14	10	10	8	0.82	3.96	1.50	0.7	-8.7
E	B-19	SP	4	18	13	13	10	0.93	2.82	2.25	0.8	-10.2
E	B-19	SP	4	13	9	9	7	0.75	4.19	3.00	1.5	-13.2
E	B-19	SP	4	5	3	3	3	0.64	5.46	2.50	1.6	-16.2
E	B-19	SP	4	14	9	9	7	0.54	4.13	2.00	1.0	-18.2
E	B-19	SP	4	12	7	7	6	0.63	4.44	2.50	1.3	-20.2
E	B-19	SP	4	15	9	9	8	0.76	4.07	2.00	1.0	-23.2
E	B-19	SP	4	15	9	9	8	0.73	4.08	1.50	0.7	-24.2
E	B-19	SP	4	22	14	14	11	1.15	0.59	2.00	0.1	-26.2
E	B-19	SM	24	20	13	19	16	0.41	2.58	2.00	0.6	-28.2
E	B-19	SM	24	9	5	10	8	0.74	3.89	3.00	1.4	-30.2
E	B-19	SM	24	19	12	17	15	5.27	0.00	4.80	0.0	-34.2
Total Set.											10.8	

E	B-24	SP	4	30	24	24	20	1.39	0.22	1.00	0.0	3.8
E	B-24	SP	4	18	13	13	10	1.14	0.64	2.00	0.2	-10.2
E	B-24	SP	4	18	11	11	9	1.11	0.73	8.20	0.7	-26.2
E	B-24	SP	4	17	10	10	8	5.19	0.00	5.00	0.0	-30.2
E	B-24	SM	24	51	41	49	41	5.24	0.00	4.00	0.0	-36.2
E	B-24	SM	24	54	44	53	44	5.27	0.00	3.80	0.0	-38.2
Total Set.											0.9	

SOARCA Study

Mw = 5.8, PGA = 0.4g, GWT Elev. = 5 ft

FSAR Sampler Size Correction

Table 1: Liquefaction induced settlement for a magnitude 5.8 earthquake, 0.4 pga, and groundwater table at 5 ft mean sea level

Section	Boring	Soil Type	Fines Content	N	(N ₁) ₆₀	(N ₁) _{60cs}	(N ₁) _{72cs}	FS	Vol. Strain %	Thickness ft	Settlement in	Elevation ft
E	B-9	SM	24	12	9	14	12	1.31	0.36	5.20	0.2	-6.7
E	B-9	SP	4	53	42	42	35	5.61	0.00	5.00	0.0	-10.7
E	B-9	SP	4	25	17	17	14	0.97	1.26	4.00	0.6	-16.7
E	B-9	SP	4	23	15	15	13	1.08	0.75	3.00	0.3	-18.7
E	B-9	SM	24	13	8	14	11	0.63	3.24	4.50	1.7	-22.7
E	B-9	SM	24	23	16	22	18	0.59	2.35	5.50	1.6	-27.7
E	B-9	SM	24	40	30	37	31	5.24	0.00	4.80	0.0	-33.7
Total Set.											4.4	
F	B-16	SW	4	57	45	45	38	0.35	1.29	6.50	1.0	-12.9
F	B-16	SP	4	12	10	10	8	1.09	0.80	7.00	0.7	-30.9
Total Set.											1.7	
F	B-8	SP	4	11	9	9	7	5.88	0.00	1.10	0.0	-4
F	B-8	SP	4	35	29	29	24	2.41	0.00	2.60	0.0	-4.2
F	B-8	SP	4	24	18	18	15	5.71	0.00	3.30	0.0	-9.2
F	B-8	SM	24	8	5	10	8	0.88	3.92	12.00	5.6	-24
Total Set.											5.6	

SOARCA Study
Surry Nuclear Power Plant
Liquefaction Induced Settlement Calculations

Calculations By: T. Weaver
Date: 10/27/2011

Notes:

- Ishihara and Yoshimine (1992) method used to calculate settlement.
- The FSAR N-value sampler correction, C_s , was used.
- Factor of safety against liquefaction was computed using the procedure recommended by Youd et al. (2001).
- Magnitude, $M_w = 6.5$
- Peak ground acceleration, $p_g = 0.75g$
- Ground water table, Elev = 5 ft
- Silty sand were assumed to have a fines content of 24%

Table 2: Liquefaction induced settlement for a magnitude 6.5 earthquake, 0.75 pga, and groundwater table at 5 ft mean sea level

Section	Boring	Soil Type	Fines Content	N	(N ₁) ₆₀	(N ₁) _{60CS}	(N ₁) _{72CS}	FS	Vol. Strain %	Thickness ft	Settlement in	Elevation ft
A	B-11	SP	4	19	15	15	13	0.40	2.94	6.60	2.3	-4.6
A	B-11	SP	4	45	38	38	33	2.23	0.00	7.40	0.0	-8.6
A	B-11	SP	4	13	8	8	7	0.24	4.22	6.00	3.0	-29.6
Total Set.											5.4	

A	B-17	SP	4	49	39	39	33	2.29	0.00	8.00	0.0	-6.3
A	B-17	SP/ML	4	20	12	12	11	0.31	3.36	5.00	2.0	-36.3
Total Set.											2.0	Fill

A	B-22	SM-ML	24	34	29	36	31	2.90	0.00	2.50	0.0	4.5
A	B-22	SP	4	24	19	19	16	0.55	2.51	3.00	0.9	0.5
A	B-22	SP	4	28	22	22	19	0.60	2.29	7.00	1.9	-1.5
Total Set.											2.8	

Table 2: Liquefaction induced settlement for a magnitude 6.5 earthquake, 0.75 pga, and groundwater table at 5 ft mean sea level

Section	Boring	Soil Type	Fines Content	N	(N ₁) ₆₀	(N ₁) _{60cs}	(N ₁) _{72cs}	FS	Vol. Strain %	Thickness ft	Settlement in	Elevation ft
A	B-27	SP	4	37	30	30	25	1.31	0.21	1.50	0.0	4.5
A	B-27	SP	4	69	61	61	52	2.73	0.00	2.00	0.0	2.5
A	B-27	SP	4	26	21	21	18	0.60	2.38	4.00	1.1	0.5
A	B-27	SP	4	53	43	43	37	2.29	0.00	4.50	0.0	-5.5
A	B-27	SM-ML	24	14	8	13	11	0.34	3.21	6.00	2.3	-35.5
A	B-27	SW	4	37	23	23	19	0.58	2.22	3.00	0.8	-40.5
Total Set.											4.3	
C	B-12	SP	4	28	24	24	20	0.64	2.08	1.30	0.3	-6.7
C	B-12	SP	4	24	20	20	17	0.51	2.43	3.25	0.9	-7.9
C	B-12	SP	4	24	19	19	16	0.46	2.53	3.00	0.9	-13.2
C	B-12	SP	4	29	23	23	20	0.58	2.17	2.35	0.6	-13.9
C	B-12	SM	24	9	7	12	10	0.30	3.51	5.00	2.1	-17.9
C	B-12	SM	24	19	14	20	17	0.46	2.45	5.00	1.5	-23.9
C	B-12	SM	24	18	13	18	16	0.44	2.57	5.00	1.5	-27.9
C	B-12	SM	24	17	12	17	15	0.41	2.69	4.10	1.3	-33.9
Total Set.											9.2	
C	B-15	SP	4	48	38	38	33	2.29	0.00	8.00	0.0	-6.3
C	B-15	SM	24	17	12	17	15	0.41	2.68	6.30	2.0	-26.3
C	B-15	SM	24	20	14	19	17	0.46	2.49	7.20	2.1	-30.3
Total Set.											4.2	
C	B-20	SP	4	19	15	15	13	0.46	3.01	1.90	0.7	4.1
C	B-20	SP	4	17	13	13	12	0.40	3.20	2.00	0.8	2.1
C	B-20	SP	4	25	20	20	17	0.56	2.45	2.25	0.7	0.1
C	B-20	SP	4	15	11	11	10	0.32	3.58	1.25	0.5	-2.4
C	B-20	SM-ML	24	11	7	12	10	0.30	3.46	4.40	1.8	-24.9
C	B-20	SM-ML	24	19	13	18	16	0.43	2.59	2.50	0.8	-25.9
C	B-20	SP	4	8	4	4	4	0.16	5.20	5.00	3.1	-29.9
C	B-20	SP	4	52	35	35	30	2.15	0.00	3.00	0.0	-35.9
Total Set.											8.4	

Table 2: Liquefaction induced settlement for a magnitude 6.5 earthquake, 0.75 pga, and groundwater table at 5 ft mean sea level

Section	Boring	Soil Type	Fines Content	N	(N ₁) ₆₀	(N ₁) _{60cs}	(N ₁) _{72cs}	FS	Vol. Strain %	Thickness ft	Settlement in	Elevation ft
C	B-25	SP	4	33	31	31	27	4.45	0.00	0.00	0.0	20.3
C	B-25	SW	4	45	41	41	35	3.63	0.00	0.00	0.0	14.3
C	B-25	SW	4	32	27	27	23	1.09	0.00	0.00	0.0	10.3
C	B-25	SP	4	25	19	19	17	0.61	2.48	2.70	0.8	4.3
C	B-25	SP	4	50	42	42	36	2.57	0.00	5.00	0.0	0.3
C	B-25	SW	4	62	51	51	44	2.29	0.00	3.00	0.0	-5.7
Total Set.											0.8	
D	B-13	SP	4	19	14	14	12	0.37	3.04	0.95	0.3	-7.7
D	B-13	SP	4	65	55	55	47	2.23	0.00	2.50	0.0	-8.2
D	B-13	SP	4	26	19	19	17	0.48	2.49	2.25	0.7	-12.7
D	B-13	SP	4	20	15	15	12	0.36	3.03	3.00	1.1	-12.7
D	B-13	SM-ML	24	7	5	9	8	0.25	3.98	5.00	2.4	-18.7
D	B-13	SM-ML	24	12	8	13	11	0.33	3.25	5.00	2.0	-22.7
D	B-13	SM-ML	24	15	10	15	13	0.37	2.94	5.00	1.8	-28.7
D	B-13	SM-ML	24	10	6	11	9	0.29	3.64	4.80	2.1	-32.7
Total Set.											10.3	
D	B-18	SP	4	41	33	33	28	2.25	0.00	2.00	0.0	-9.6
D	B-18	SP	4	36	27	27	23	0.77	1.38	5.00	0.8	-13.6
D	B-18	SP	4	24	17	17	14	0.40	2.72	4.00	1.3	-19.6
D	B-18	SM	24	17	12	17	15	0.41	2.66	2.00	0.6	-21.6
D	B-18	SM	24	15	10	16	13	0.37	2.88	4.00	1.4	-23.6
D	B-18	SM	24	13	8	13	11	0.34	3.21	5.00	1.9	-29.6
D	B-18	SM	24	17	11	16	14	0.40	2.75	4.90	1.6	-33.6
Total Set.											7.7	
D	B-23	SP	4	36	29	29	25	1.11	0.42	3.50	0.2	-26.1
D	B-23	SP	4	24	15	15	13	0.37	2.94	4.05	1.4	-29.6
D	B-23	SP	4	14	8	8	7	0.23	4.24	2.00	1.0	-30.1
D	B-23	SM	24	17	11	16	14	0.39	2.78	2.00	0.7	-30.1
D	B-23	SM	24	68	61	72	62	2.07	0.00	2.95	0.0	-33.6
Total Set.											3.3	

Fill

Table 2: Liquefaction induced settlement for a magnitude 6.5 earthquake, 0.75 pga, and groundwater table at 5 ft mean sea level

Section	Boring	Soil Type	Fines Content	N	(N ₁) ₆₀	(N ₁) _{60cs}	(N ₁) _{72cs}	FS	Vol. Strain %	Thickness ft	Settlement in	Elevation ft
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D	B-28	SP	4	26	24	24	20	0.71	2.02	4.30	1.0	0.7
D	B-28	SP	4	40	34	34	29	2.33	0.00	5.00	0.0	-5.3
D	B-28	SP	4	13	11	11	9	0.29	3.69	8.70	3.8	-9.3

Total Set. 4.9

E	B-14	SP	4	5	3	3	3	0.15	5.46	4.40	2.9	-6.9
E	B-14	SM-ML	24	57	51	61	52	2.17	0.00	2.94	0.0	-10.9
E	B-14	SM-ML	24	18	13	19	16	0.45	2.54	3.00	0.9	-12.78
E	B-14	SM-ML	24	10	7	12	10	0.30	3.50	3.00	1.3	-16.9
E	B-14	SM-ML	24	26	19	25	22	0.64	1.91	2.00	0.5	-18.78
E	B-14	SM-ML	24	12	8	13	11	0.32	3.28	4.06	1.6	-20.9
E	B-14	SM-ML	24	9	5	10	9	0.27	3.78	5.00	2.3	-26.9
E	B-14	SM-ML	24	9	5	10	9	0.27	3.82	4.10	1.9	-30.9

Total Set. 11.3

E	B-19	SM	24	12	9	14	12	0.45	3.04	2.00	0.7	3.8
E	B-19	SM	24	24	19	26	22	0.72	1.75	2.95	0.6	-3.7
E	B-19	SP	4	42	33	33	28	2.29	0.00	2.50	0.0	-7.2
E	B-19	SP	4	14	10	10	8	0.27	3.90	1.50	0.7	-8.7
E	B-19	SP	4	18	13	13	11	0.32	3.34	2.25	0.9	-10.2
E	B-19	SP	4	13	9	9	7	0.24	4.14	3.00	1.5	-13.2
E	B-19	SP	4	5	3	3	3	0.14	5.46	2.50	1.6	-16.2
E	B-19	SP	4	14	9	9	8	0.24	4.08	2.00	1.0	-18.2
E	B-19	SP	4	12	7	7	6	0.21	4.40	2.50	1.3	-20.2
E	B-19	SP	4	15	9	9	8	0.25	4.01	2.00	1.0	-23.2
E	B-19	SP	4	15	9	9	8	0.25	4.03	1.50	0.7	-24.2
E	B-19	SP	4	22	14	14	12	0.34	3.16	2.00	0.8	-26.2
E	B-19	SM	24	20	13	19	16	0.44	2.54	2.00	0.6	-28.2
E	B-19	SM	24	9	5	10	9	0.27	3.83	3.00	1.4	-30.2
E	B-19	SM	24	19	12	17	15	0.42	2.66	4.80	1.5	-34.2

Total Set. 14.3

Table 2: Liquefaction induced settlement for a magnitude 6.5 earthquake, 0.75 pga, and groundwater table at 5 ft mean sea level

Section	Boring	Soil Type	Fines Content	N	(N ₁) ₆₀	(N ₁) _{60cs}	(N ₁) _{72cs}	FS	Vol. Strain %	Thickness ft	Settlement in	Elevation ft
E	B-24	SP	4	30	24	24	20	0.77	1.82	1.00	0.2	3.8
E	B-24	SP	4	18	13	13	11	0.32	3.34	2.00	0.8	-10.2
E	B-24	SP	4	18	11	11	9	0.29	3.63	8.20	3.6	-26.2
E	B-24	SP	4	17	10	10	9	0.27	3.84	5.00	2.3	-30.2
E	B-24	SM	24	51	41	49	42	2.09	0.00	4.00	0.0	-36.2
E	B-24	SM	24	54	44	53	45	2.10	0.00	3.80	0.0	-38.2
Total Set.											6.9	
E	B-9	SM	24	12	9	14	12	0.36	3.11	5.20	1.9	-6.7
E	B-9	SP	4	53	42	42	36	2.18	0.00	5.00	0.0	-10.7
E	B-9	SP	4	25	17	17	15	0.42	2.68	4.00	1.3	-16.7
E	B-9	SP	4	23	15	15	13	0.38	2.90	3.00	1.0	-18.7
E	B-9	SM	24	13	8	14	12	0.33	3.18	4.50	1.7	-22.7
E	B-9	SM	24	23	16	22	19	0.51	2.30	5.50	1.5	-27.7
E	B-9	SM	24	40	30	37	32	2.07	0.00	4.80	0.0	-33.7
Total Set.											7.5	
F	B-16	SW	4	57	45	45	39	2.14	0.00	6.50	0.0	-12.9
F	B-16	SP	4	12	10	10	8	0.27	3.87	7.00	3.3	-30.9
Total Set.											3.3	
F	B-8	SP	4	11	9	9	7	0.25	4.14	1.10	0.5	-4
F	B-8	SP	4	35	29	29	25	0.99	0.63	2.60	0.2	-4.2
F	B-8	SP	4	24	18	18	16	0.46	2.57	3.30	1.0	-9.2
F	B-8	SM	24	8	5	10	8	0.27	3.86	12.00	5.6	-24
Total Set.											7.3	