

PIANO NAZIONALE DI RIPRESA E RESILIENZA (PNRR)

Missione 2 - Componente 4 - Sub-investimento 2.1b

ACCORDO AI SENSI DELL'ART. 15, DELLA LEGGE 241/1990 PER LA REALIZZAZIONE DEL SUB-INVESTIMENTO 2.1b «finanziato dall'Unione europea - NextGenerationEU»

“Misure per la gestione del rischio alluvione e per la riduzione del rischio idrogeologico”

ACCORDO QUADRO LAVORI FINALIZZATI ALLA MANUTENZIONE DEI CORSI D'ACQUA AFFERENTI AL TERRITORIO DI COMPETENZA DELL'UFFICIO TERRITORIALE DI PIACENZA E DELL'UFFICIO TERRITORIALE DI REGGIO EMILIA. ANNUALITÀ 2023-2025

LOTTO 1 PIACENZA (BACINI TREBBIA E ARDA) (CIG ACCORDO QUADRO 9492599481)

Codice Intervento: 17751

Titolo: PNRR M2C4 INVESTIMENTO 2.1B Interventi di ripristino, recupero ed integrazione delle opere di difesa idraulica dell'alveo del fiume Trebbia in corrispondenza del nodo idraulico di Perino, a monte e valle della briglia. Loc. Poggio Paione, comuni di Travo e Coli (PC)

Capitolo di spesa: U21301 (2023) **Importo finanziamento:** € 2,500,000.00

CUP: F18H22000530004

PROGETTO ESECUTIVO

relativo al Contratto Attuativo n° 4

Allegato n.
3.9

VERIFICHE A LIQUEFAZIONE

Gruppo di progettazione:

Dott. Ing. Cristina FRANCA
(Responsabile del progetto e D.L.)

R.T.P.

 **STUDIO POLARIS** Studio POLARIS STP S.r.l.
(mandataria-capogruppo)

 **EOS** EOS – INGEGNERIA
(mandante)

 **ENGEO S.r.l.**
(mandante)

Visto di validazione
Il Responsabile Unico del Procedimento
Arch. Cristian Ferrarini



V_s BASED LIQUEFACTION ANALYSIS REPORT

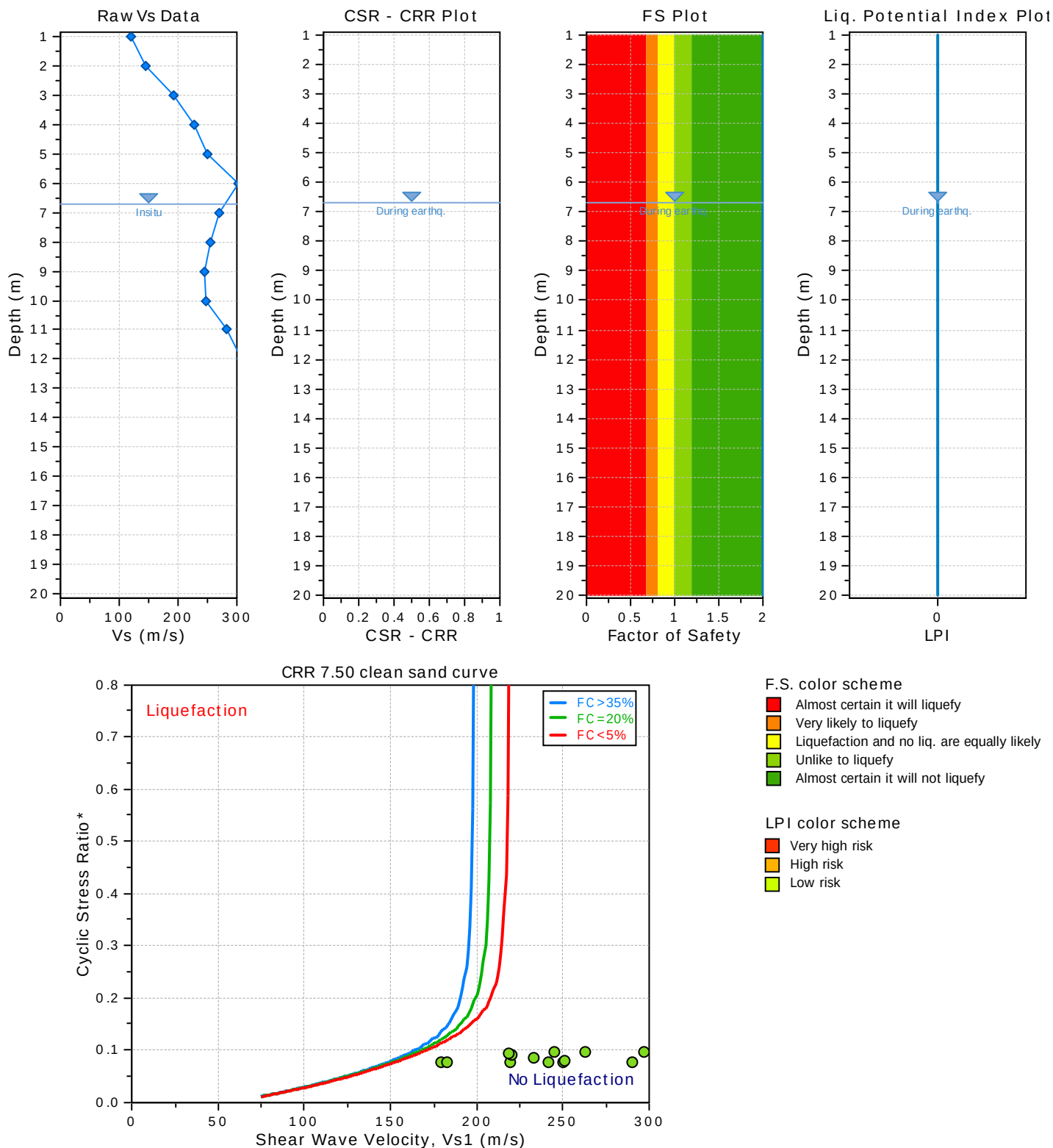
Project title : Briglia Rondanera

V_s Name: Sc-Sx

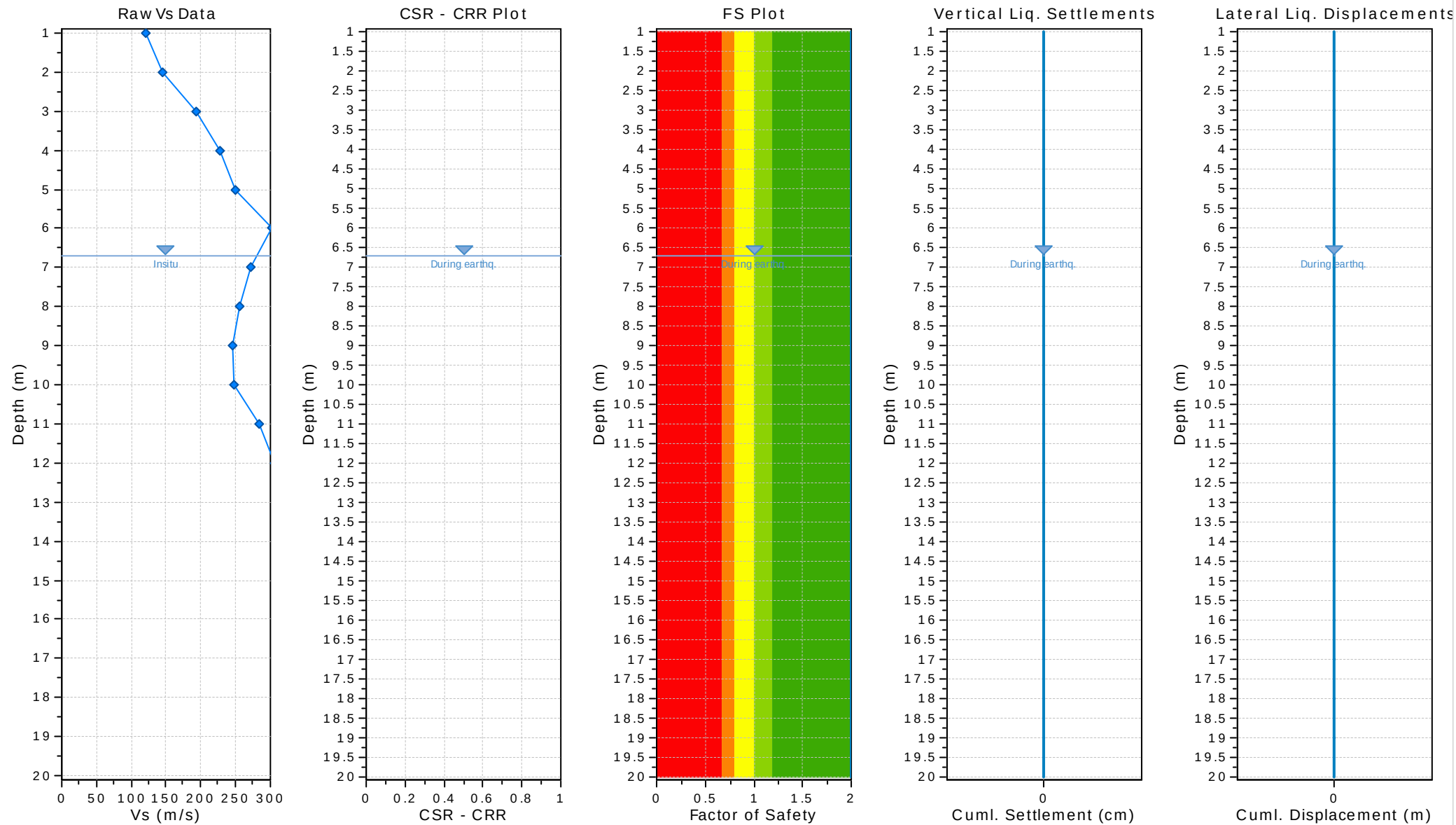
Location : F. Trebbia

:: Input parameters and analysis properties ::

Analysis method: NCEER 1998 (Youd et al. 2001)
G.W.T. (in-situ): 6.70 m
G.W.T. (earthq.): 6.70 m
Earthquake magnitude M_w: 5.50
Peak ground acceleration: 0.22 g
Eq. external load: 0.00 kPa



:: Overall Liquefaction Assessment Analysis Plots ::



:: Field input data ::					
Test Depth (m)	V _s Field Value (m/s)	Fines Content (%)	Unit Weight (kN/m ³)	Infl. Thickness (m)	Can Liquefy
1.00	120.00	0.00	20.00	0.00	Yes
2.00	145.00	0.00	20.00	0.00	Yes
3.00	193.00	0.00	20.00	0.00	Yes
4.00	228.00	0.00	20.00	0.00	Yes
5.00	250.00	0.00	20.00	0.00	Yes
6.00	303.00	0.00	20.00	0.00	Yes
7.00	271.00	0.00	20.00	0.00	Yes
8.00	256.00	0.00	20.00	0.00	Yes
9.00	246.00	0.00	20.00	0.00	Yes
10.00	248.00	0.00	20.00	0.00	Yes
11.00	283.00	0.00	20.00	0.00	Yes
12.00	307.00	0.00	20.00	0.00	Yes
13.00	352.00	0.00	20.00	0.00	Yes
14.00	448.00	0.00	20.00	0.00	Yes
15.00	450.00	0.00	20.00	0.00	Yes
16.00	452.00	0.00	20.00	0.00	Yes
17.00	545.00	0.00	20.00	0.00	Yes
18.00	567.00	0.00	20.00	0.00	Yes
19.00	803.00	0.00	20.00	0.00	Yes
20.00	821.00	0.00	20.00	0.00	Yes

Abbreviations

Depth: Depth at which test was performed (m)
 Vs Field Value: Measured shear waves velocity (m/s)
 Fines Content: Fines content at test depth (%)
 Unit Weight: Unit weight at test depth (kN/m³)
 Infl. Thickness: Thickness of the soil layer to be considered in settlements analysis (m)
 Can Liquefy: User defined switch for excluding/including test depth from the analysis procedure

:: Cyclic Resistance Ratio (CRR) calculation data ::									
Depth (m)	V _s Field Value (m/s)	Unit Weight (kN/m ³)	σ _v (kPa)	u _o (kPa)	σ' _{vo} (kPa)	Norm. Factor	V _{s1} (m/s)	V _{s1} * (m/s)	CRR _{7.5}
1.00	120.00	20.00	20.00	0.00	20.00	1.50	180.03	215.00	4.000
2.00	145.00	20.00	40.00	0.00	40.00	1.26	182.93	215.00	4.000
3.00	193.00	20.00	60.00	0.00	60.00	1.14	220.01	215.00	4.000
4.00	228.00	20.00	80.00	0.00	80.00	1.06	241.88	215.00	4.000
5.00	250.00	20.00	100.00	0.00	100.00	1.00	250.82	215.00	4.000
6.00	303.00	20.00	120.00	0.00	120.00	0.96	290.45	215.00	4.000
7.00	271.00	20.00	140.00	2.94	137.06	0.93	251.29	215.00	4.000
8.00	256.00	20.00	160.00	12.75	147.25	0.91	233.16	215.00	4.000
9.00	246.00	20.00	180.00	22.56	157.44	0.90	220.34	215.00	4.000
10.00	248.00	20.00	200.00	32.37	167.63	0.88	218.67	215.00	4.000
11.00	283.00	20.00	220.00	42.18	177.82	0.87	245.88	215.00	4.000
12.00	307.00	20.00	240.00	51.99	188.01	0.86	263.04	215.00	4.000
13.00	352.00	20.00	260.00	61.80	198.20	0.85	297.64	215.00	4.000
14.00	448.00	20.00	280.00	71.61	208.39	0.84	374.10	215.00	4.000
15.00	450.00	20.00	300.00	81.42	218.58	0.83	371.31	215.00	4.000
16.00	452.00	20.00	320.00	91.23	228.77	0.82	368.74	215.00	4.000
17.00	545.00	20.00	340.00	101.04	238.96	0.81	439.79	215.00	4.000

:: Cyclic Resistance Ratio (CRR) calculation data ::									
Depth (m)	V _s Field Value (m/s)	Unit Weight (kN/m ³)	σ _v (kPa)	u _o (kPa)	σ' _{vo} (kPa)	Norm. Factor	V _{s1} (m/s)	V _{s1} * (m/s)	CRR _{7.5}
18.00	567.00	20.00	360.00	110.85	249.15	0.80	452.79	215.00	4.000
19.00	803.00	20.00	380.00	120.66	259.34	0.79	634.86	215.00	4.000
20.00	821.00	20.00	400.00	130.47	269.53	0.78	642.87	215.00	4.000

Abbreviations

σ_v: Total stress during SPT test (kPa)
 u_o: Water pore pressure during SPT test (kPa)
 σ'_{vo}: Effective overburden pressure during SPT test (kPa)
 Norm. Factor: overburden-stress correction factor
 V_{s1}: Overburden-stress corrected shear wave velocity
 V_{s1}*: Limiting upper value of V_{s1}
 CRR_{7.5}: Cyclic resistance ratio for M=7.5

:: Cyclic Stress Ratio calculation (CSR fully adjusted and normalized) ::													
Depth (m)	Unit Weight (pcf)	σ _{v,eq} (kPa)	u _{o,eq} (kPa)	σ' _{vo,eq} (kPa)	r _d	α	CSR	MSF	CSR _{eq,M=7.5}	K _{sigma}	CSR*	FS	
1.00	20.00	20.00	0.00	20.00	0.99	1.00	0.142	2.21	0.064	1.00	0.093	2.000	●
2.00	20.00	40.00	0.00	40.00	0.99	1.00	0.141	2.21	0.064	1.00	0.092	2.000	●
3.00	20.00	60.00	0.00	60.00	0.98	1.00	0.140	2.21	0.063	1.00	0.091	2.000	●
4.00	20.00	80.00	0.00	80.00	0.97	1.00	0.139	2.21	0.063	1.00	0.091	2.000	●
5.00	20.00	100.00	0.00	100.00	0.97	1.00	0.138	2.21	0.062	1.00	0.090	2.000	●
6.00	20.00	120.00	0.00	120.00	0.96	1.00	0.137	2.21	0.062	0.97	0.092	2.000	●
7.00	20.00	140.00	2.94	137.06	0.95	1.00	0.139	2.21	0.063	0.94	0.096	2.000	●
8.00	20.00	160.00	12.75	147.25	0.94	1.00	0.146	2.21	0.066	0.93	0.102	2.000	●
9.00	20.00	180.00	22.56	157.44	0.92	1.00	0.151	2.21	0.068	0.92	0.107	2.000	●
10.00	20.00	200.00	32.37	167.63	0.90	1.00	0.154	2.21	0.070	0.90	0.111	2.000	●
11.00	20.00	220.00	42.18	177.82	0.88	1.00	0.156	2.21	0.071	0.89	0.114	2.000	●
12.00	20.00	240.00	51.99	188.01	0.86	1.00	0.156	2.21	0.071	0.88	0.115	2.000	●
13.00	20.00	260.00	61.80	198.20	0.83	1.00	0.155	2.21	0.070	0.87	0.116	2.000	●
14.00	20.00	280.00	71.61	208.39	0.79	1.00	0.153	2.21	0.069	0.87	0.115	2.000	●
15.00	20.00	300.00	81.42	218.58	0.76	1.00	0.149	2.21	0.068	0.86	0.113	2.000	●
16.00	20.00	320.00	91.23	228.77	0.73	1.00	0.146	2.21	0.066	0.85	0.112	2.000	●
17.00	20.00	340.00	101.04	238.96	0.70	1.00	0.142	2.21	0.064	0.84	0.110	2.000	●
18.00	20.00	360.00	110.85	249.15	0.67	1.00	0.138	2.21	0.062	0.83	0.108	2.000	●
19.00	20.00	380.00	120.66	259.34	0.64	1.00	0.134	2.21	0.061	0.83	0.106	2.000	●
20.00	20.00	400.00	130.47	269.53	0.62	1.00	0.131	2.21	0.059	0.82	0.104	2.000	●

Abbreviations

σ_{v,eq}: Total overburden pressure at test point, during earthquake (kPa)
 u_{o,eq}: Water pressure at test point, during earthquake (kPa)
 σ'_{vo,eq}: Effective overburden pressure, during earthquake (kPa)
 r_d: Nonlinear shear mass factor
 α: Improvement factor due to stone columns
 CSR: Cyclic Stress Ratio
 MSF: Magnitude Scaling Factor
 CSR_{eq,M=7.5}: CSR adjusted for M=7.5
 K_{sigma}: Effective overburden stress factor
 CSR*: CSR fully adjusted (user FS applied)***
 FS: Calculated factor of safety against soil liquefaction

*** User FS: 1.20

:: Liquefaction potential according to Iwasaki ::

Depth (m)	FS	F	wz	Thickness (m)	I _L
1.00	2.000	0.00	9.50	1.00	0.00
2.00	2.000	0.00	9.00	1.00	0.00
3.00	2.000	0.00	8.50	1.00	0.00
4.00	2.000	0.00	8.00	1.00	0.00
5.00	2.000	0.00	7.50	1.00	0.00
6.00	2.000	0.00	7.00	1.00	0.00
7.00	2.000	0.00	6.50	1.00	0.00
8.00	2.000	0.00	6.00	1.00	0.00
9.00	2.000	0.00	5.50	1.00	0.00
10.00	2.000	0.00	5.00	1.00	0.00
11.00	2.000	0.00	4.50	1.00	0.00
12.00	2.000	0.00	4.00	1.00	0.00
13.00	2.000	0.00	3.50	1.00	0.00
14.00	2.000	0.00	3.00	1.00	0.00
15.00	2.000	0.00	2.50	1.00	0.00
16.00	2.000	0.00	2.00	1.00	0.00
17.00	2.000	0.00	1.50	1.00	0.00
18.00	2.000	0.00	1.00	1.00	0.00
19.00	2.000	0.00	0.50	1.00	0.00
20.00	2.000	0.00	0.00	1.00	0.00

Overall potential I_L : 0.00I_L = 0.00 - No liquefactionI_L between 0.00 and 5 - Liquefaction not probableI_L between 5 and 15 - Liquefaction probableI_L > 15 - Liquefaction certain

:: Vertical settlements estimation for dry sands ::

Depth (m)	V _{s1,cs} (ft/s)	(N ₁) _{60,cs}	τ _{av}	p	G _{max} (MPa)	a	b	γ	ε ₁₅	N _c	ε _{Nc} (%)	Δh (m)	ΔS (cm)
1.00	180.03	17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000
2.00	182.93	18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000
3.00	220.01	38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000
4.00	241.88	50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000
5.00	250.82	50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000
6.00	290.45	50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000

Cumulative settlements: 0.000

Abbreviations

V_{s1,cs}: Normalized shear wave velocity clean sand equivalent
 (N₁)_{60,cs}: Estimated normalized corrected clean sand SPT
 τ_{av}: Average cyclic shear stress
 p: Average stress
 G_{max}: Maximum shear modulus (MPa)
 a, b: Shear strain formula variables
 γ: Average shear strain
 ε₁₅: Volumetric strain after 15 cycles
 N_c: Number of cycles
 ε_{Nc}: Volumetric strain for number of cycles N_c (%)
 Δh: Thickness of soil layer (cm)
 ΔS: Settlement of soil layer (cm)

:: Vertical settlements estimation for saturated sands ::

Depth (m)	$V_{s1,cs}$ (m/s)	$q_{t1N,cs}$	e_v weight factor	e_v (%)	Δh (m)	s (cm)
7.00	251.29	410.19	1.00	0.00	0.00	0.000
8.00	233.16	296.63	1.00	0.00	0.00	0.000
9.00	220.34	232.20	1.00	0.00	0.00	0.000
10.00	218.67	224.70	1.00	0.00	0.00	0.000
11.00	245.88	373.31	1.00	0.00	0.00	0.000
12.00	263.04	499.94	1.00	0.00	0.00	0.000
13.00	297.64	853.63	1.00	0.00	0.00	0.000
14.00	374.10	2296.70	1.00	0.00	0.00	0.000
15.00	371.31	2223.51	1.00	0.00	0.00	0.000
16.00	368.74	2157.55	1.00	0.00	0.00	0.000
17.00	439.79	4626.41	1.00	0.00	0.00	0.000
18.00	452.79	5248.28	1.00	0.00	0.00	0.000
19.00	634.86	22668.86	1.00	0.00	0.00	0.000
20.00	642.87	23932.78	1.00	0.00	0.00	0.000

Cumulative settlements: 0.000

Abbreviations

$V_{s1,cs}$: Normalized shear wave velocity clean sand equivalent
 $q_{t1N,cs}$: Estimated normalized corrected clean sand cone resistance
 e_v : Post liquefaction volumetric strain (%)
 Δh : Thickness of soil layer to be considered (m)
s: Estimated settlement (cm)