COMUNE DI NONANTOLA

PIANO PARTICOLAREGGIATO DI INIZIATIVA PRIVATA "COMPARTO C.2V2" LOCALITA' REDU'

SPAZIO RISERVATO ALL'UFFICIO TECNICO

ARTECH STUDIO ASSOCIATO

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OGGETTO TAVOLA :

RELAZIONE GEOLOGICA, GEOTECNICA, SISMICA

ELABORATO

TAV.11

SCALA

EMISSIONE DEL

REV.

COMUNE DI NONANTOLA
PROVINCIA DI MODENA

PIANO PARTICOLAREGGIATO DI INIZIATIVA PRIVATA “COMPARTO C.2V2” LOCALITÀ REDÙ

SOGGETTO REALIZZATORE

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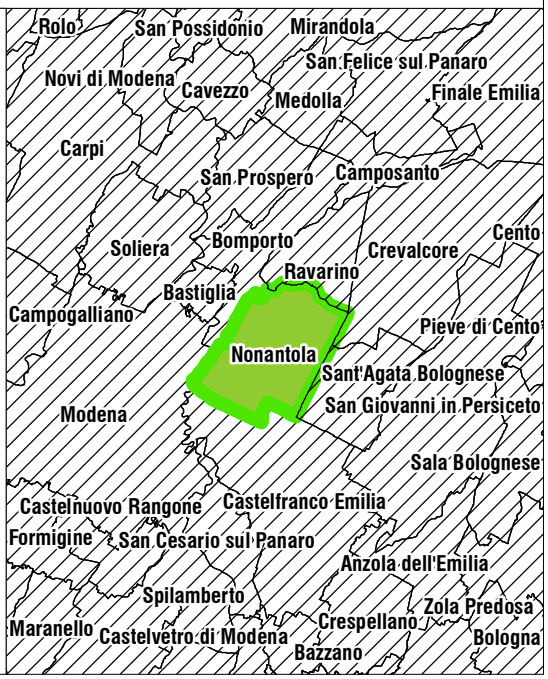

RELAZIONE GEOLOGICA PER LA MICROZONAZIONE SISMICA DEL SITO

Codice commessa : 1193/21 | Data DICEMBRE 2021

revisione	data	descrizione	redatto	controllato	approvato
1	DIC 2021	RELAZIONE GEOLOGICA			

GEO GROUP
GEOLOGIA E AMBIENTE

COMUNE DI NONANTOLA

PROVINCIA DI MODENA

Contenuti

MICROZONAZIONE SISMICA DEL SITO
(ai sensi delle DGR 630/2019, DGR 476/2021 e DGR 566/2021) con verifica del coefficiente di amplificazione del moto sismico secondo approccio descritto nella normativa della Regione Emilia-Romagna, verifica dei fenomeni di liquefazione e dei cedimenti post-sismici.

OGGETTO

PIANO PARTICOLAREGGIATO DI INIZIATIVA PRIVATA "COMPARTO C.2V2" LOCALITÀ REDÙ

Rif. n. 1193/21

LOCALITÀ

Redù di Nonantola

COMMITTENTE

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SOMMARIO

TAVOLE

ALLEGATI

1. PREMESSA

Nel mese di Dicembre 2021 è stata eseguita l'analisi di pericolosità sismica locale in prospettiva di microzonazione sismica a supporto della progettazione urbanistica di un nuovo piano particolareggiato d'iniziativa privata, secondo le disposizioni indicate dalle normative regionali DGR 630/19, DGR 476/2021 e DGR 566/2021.

La presente analisi geologica è relativa ad un'area sita in corrispondenza della località di Redù, nel territorio comunale di Nonantola.

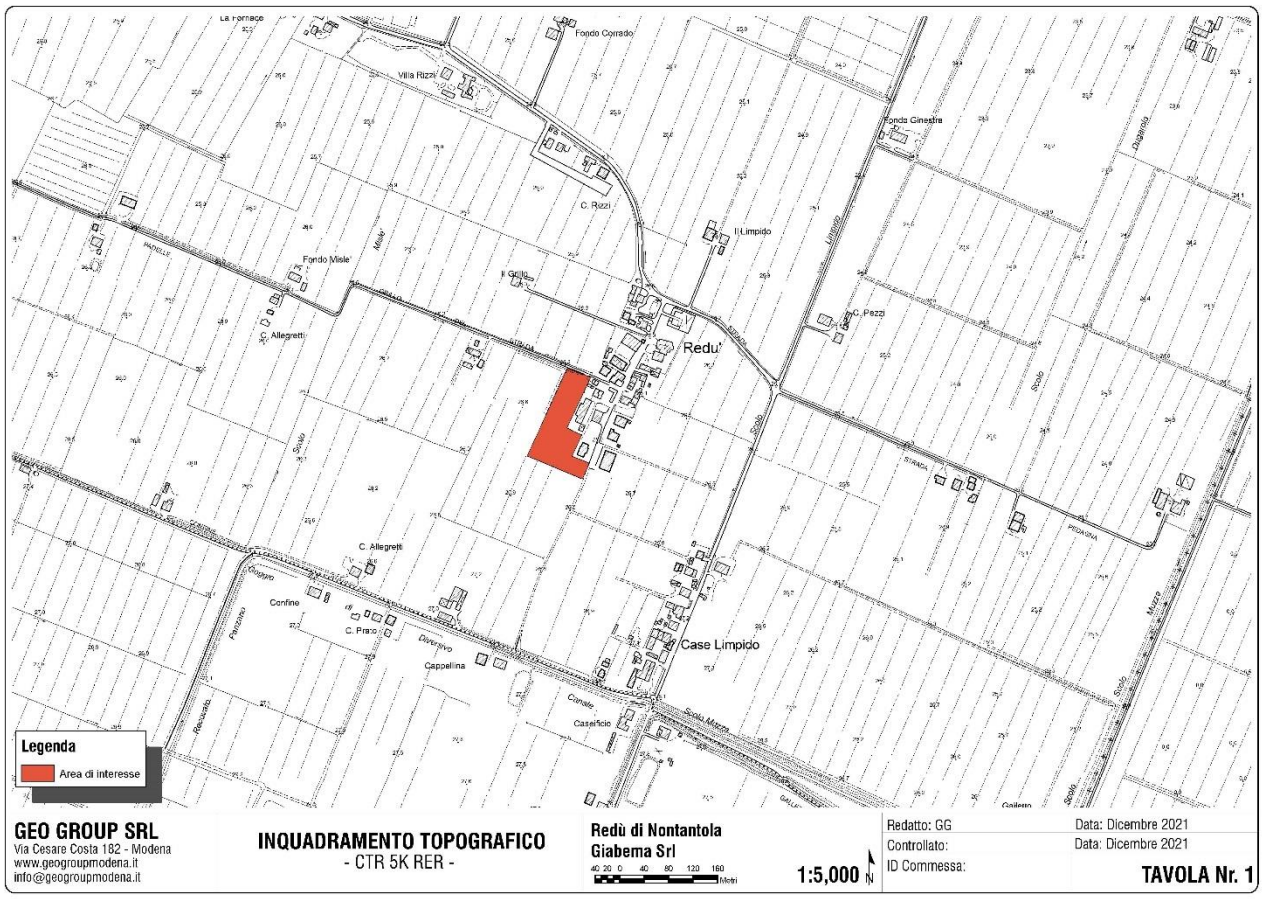


Fig. n. 1.1 – Inquadramento area di studio su base di cartografia CTR

1.1. Riferimenti normativi

La presente relazione geologica viene redatta ai fini della procedura di variante urbanistica prevista. La normativa regionale di riferimento è la seguente:

- **DGR 630/2019**
  ATTO DI COORDINAMENTO TECNICO SUGLI STUDI DI MICROZONAZIONE SISMICA PER LA PIANIFICAZIONE TERRITORIALE E URBANISTICA (ARTT. 22 E 49, L.R . N. 24/2017).;

- **DGR n. 476/2021**
  AGGIORNAMENTO DELL'"ATTO DI COORDINAMENTO TECNICO SUGLI STUDI DI MICROZONAZIONE SISMICA PER LA PIANIFICAZIONE TERRITORIALE E URBANISTICA (ARTT. 22 E 49, L.R. N. 24/2017)" DI CUI ALLA DELIBERAZIONE DELLA GIUNTA REGIONALE 29 APRILE 2019, N. 630.

- **DGR n. 566/2021**
  APPROVAZIONE DEI CRITERI PER L'ATTRIBUZIONE, LA CONCESSIONE E LA LIQUIDAZIONE DI CONTRIBUTI PER STUDI DI MICROZONAZIONE SISMICA E ANALISI DELLA CONDIZIONE LIMITE PER L'EMERGENZA NEI COMUNI CARATTERIZZATI DA UNA PERICOLOSITÀ SISMICA AG INFERIORE A 0,125G.

2. INQUADRAMENTO GENERALE

2.1. Aspetti geologici generali

L'area in analisi è sita nella media-bassa pianura, in un contesto geologico superficiale di piana alluvionale. La geologia di superficie è rappresentata dall'unità AES8 (Subsintema di Ravenna), nella facies di terreni appartenenti alla categoria dei limi-sabbiosi.

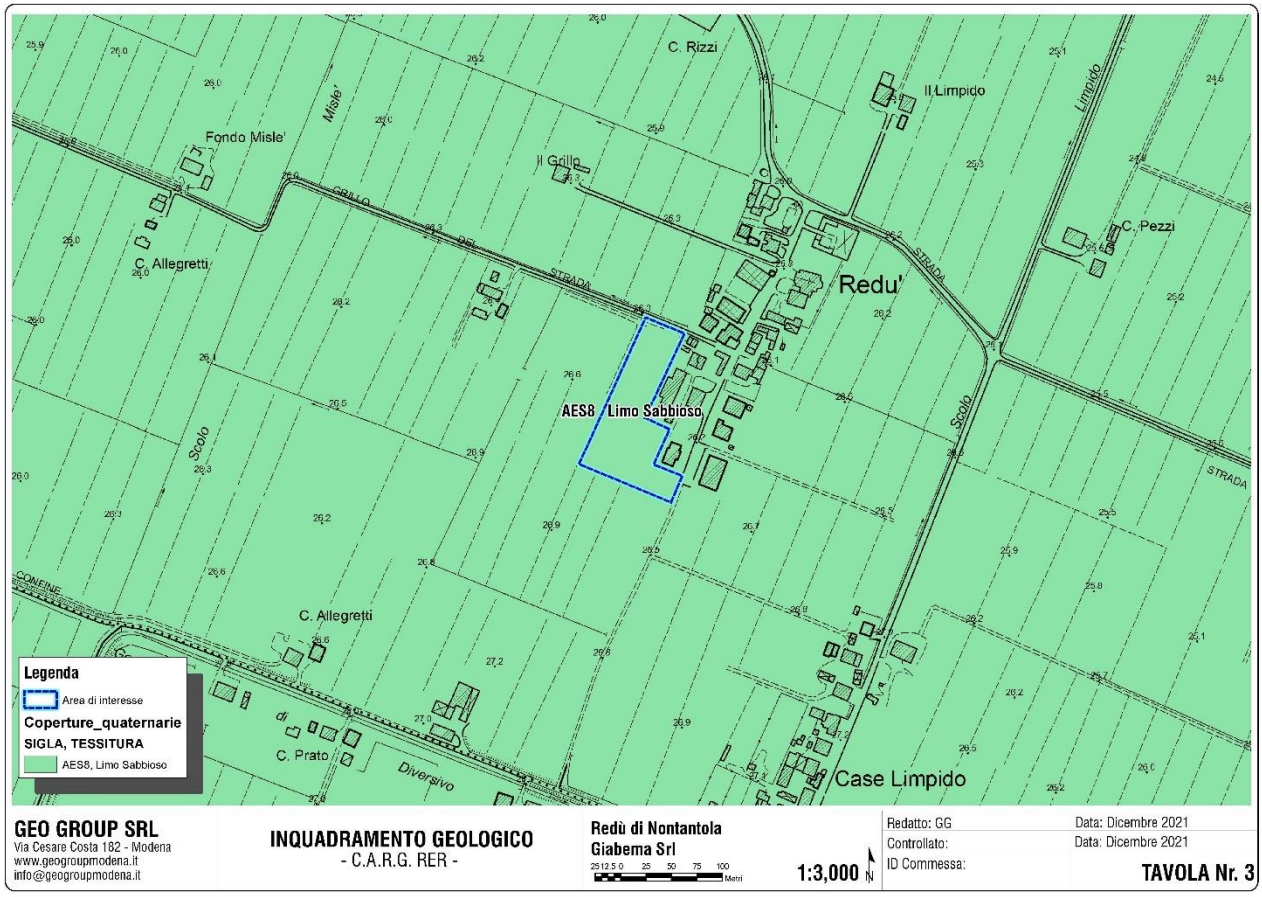
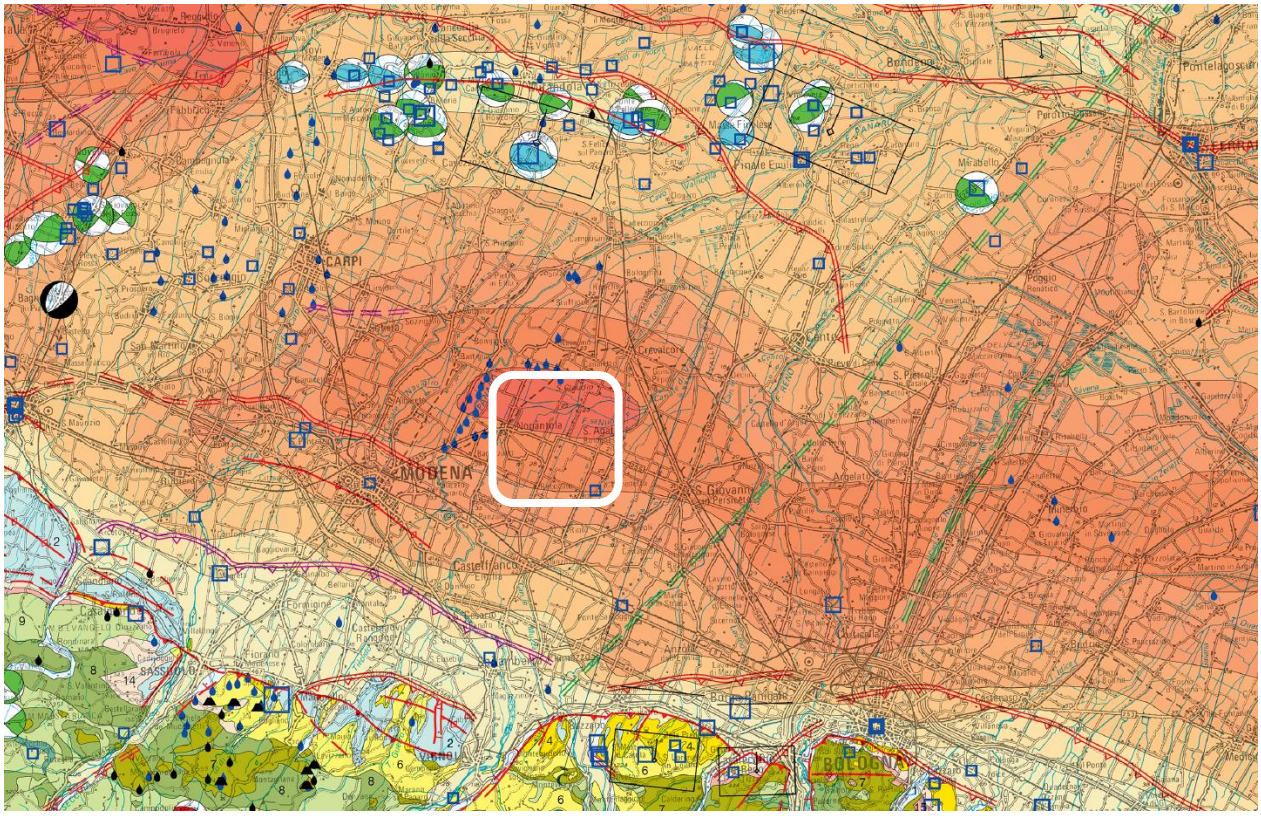


Fig. n. 2.1 – Estratto cartografia geologica della Regione Emilia Romagna

L'assetto geologico profondo è determinato dalla presenza del substrato rigido (Miocene e Evaporiti Messiniane) posto alla profondità di circa -6000 m rispetto al piano campagna (Dati RER) come visibile nell'interpolazione in Fig. n. 2.2.. La base del Sintema Emiliano-Romagnolo Superiore si attesta alla quota di -300/-350 metri rispetto al livello medio del mare.



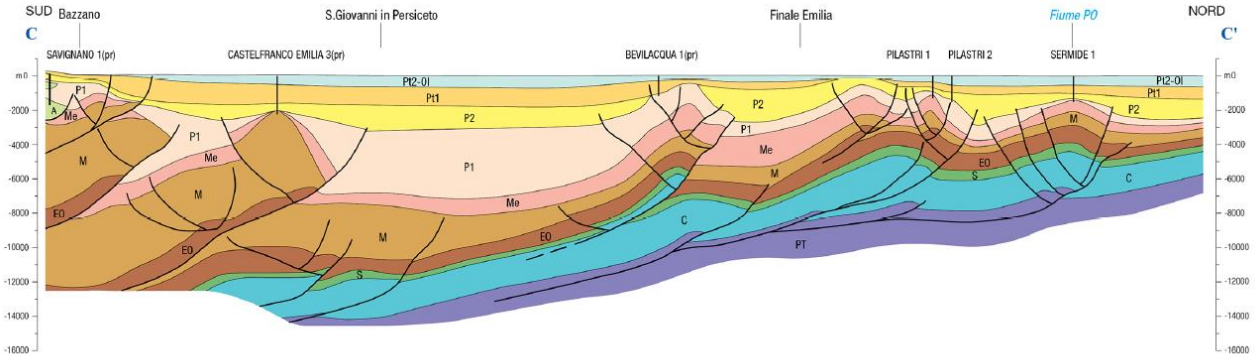
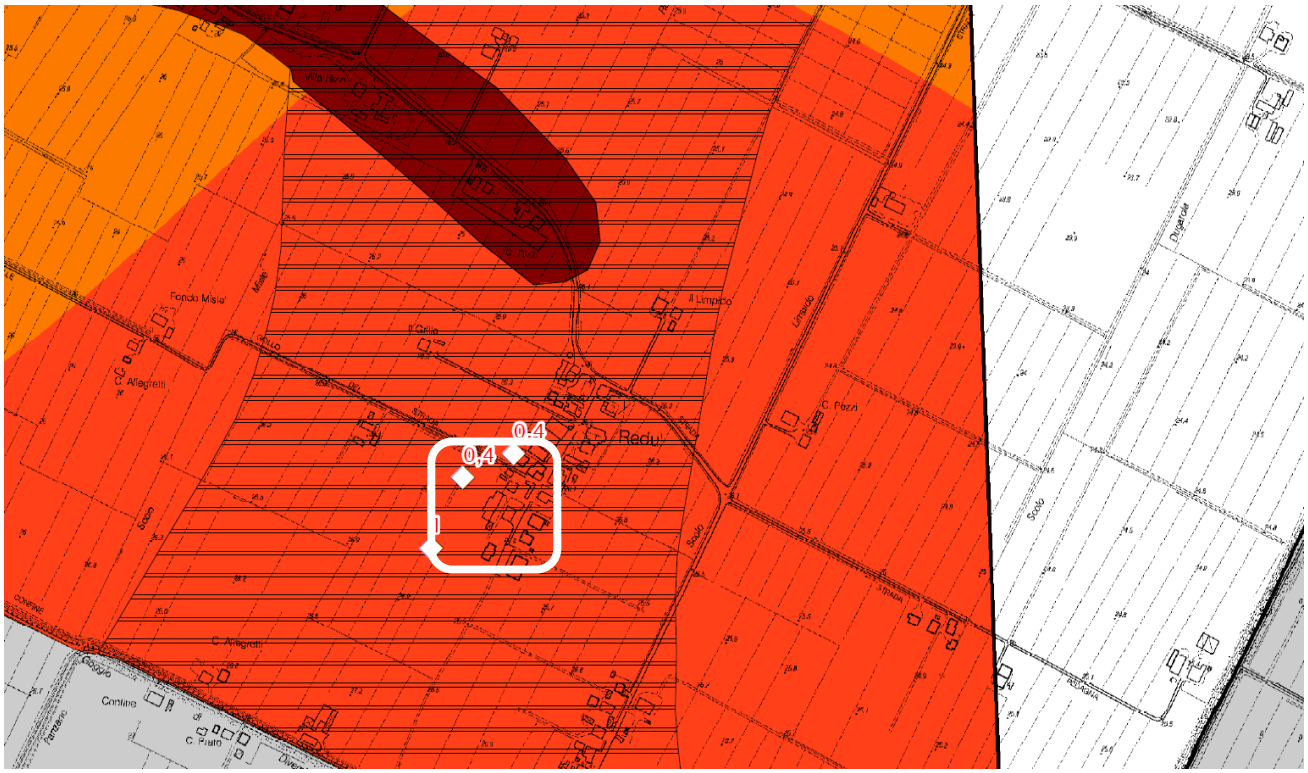


Fig. n. 2.2 – Estratti dalla "Carta Sismotettonica della Regione Emilia-Romagna e Aree Limitrofe"

2.2. Inquadramento rispetto agli studi MS

Dalla consultazione della cartografia relativa al piano di microzonazione sismica MS del Comune di Nonantola si evince come l'area in oggetto ricada in corrispondenza di depositi suscettibili a potenziali fenomeni di liquefazione. Data l'instabilità attesa, il presente studio verrà condotto secondo il III livello di approfondimento.



Legenda

Zone stabili suscettibili di amplificazioni locali

Fattori di amplificazione della P.G.A.

- F.a. P.G.A. = 1,3 – 1,4
- F.a. P.G.A. = 1,5 – 1,6
- F.a. P.G.A. = 1,7 – 1,8
- F.a. P.G.A. = 1,9 – 2,0

Zone suscettibili di instabilità

Aree soggette ad approfondimenti di III° livello

Potenziale liquefazione: $0 < IL \leq 2$; $2 < IL \leq 5$

Valore dell'indice di Liquefazione (IL: classificazione secondo Sonmez, 2003) (stima IL 15 m).

- 0,2 Rischio di liquefazione basso ($0 < IL \leq 2$)
- 3,2 Rischio di liquefazione moderato ($2 < IL \leq 5$)
- Potenziali cedimenti differenziali
- Zona suscettibile di sovrapposizione di instabilità differenti

Altri elementi rappresentati

- Limite di Comune

Fig. n. 2.2 – Estratto cartografia Carta di microzonazione sismica livello 2 (FPGA)

2.3. Inquadramento pericolosità di base

In accordo con la normativa regionale DGR 630 del 29/04/2019 è stata identificata la pericolosità sismica di base specifica di sito. La pericolosità viene espressa mediante il parametro Acceleration Spectrum Intensity (ASIUHS) che rappresenta l'integrale dello spettro di riferimento di accelerazione calcolato per l'intervallo di periodi 0.1 s ≤ T ≤ 0.5 s. Il valore di ASIUHS diviso per l'intervallo di periodo ΔT viene fornito da INGV per l'intero territorio nazionale mediante apposita griglia georeferenziata.

Successivamente (fig. 2.3) si illustra l'interpolazione discreta della suddetta griglia in riferimento all'area di interesse. Il valore di ASIUHS/ΔT(0.1 s ≤ T ≤ 0.5 s) specifico di sito risulta essere pari a 349 cm/sec2.

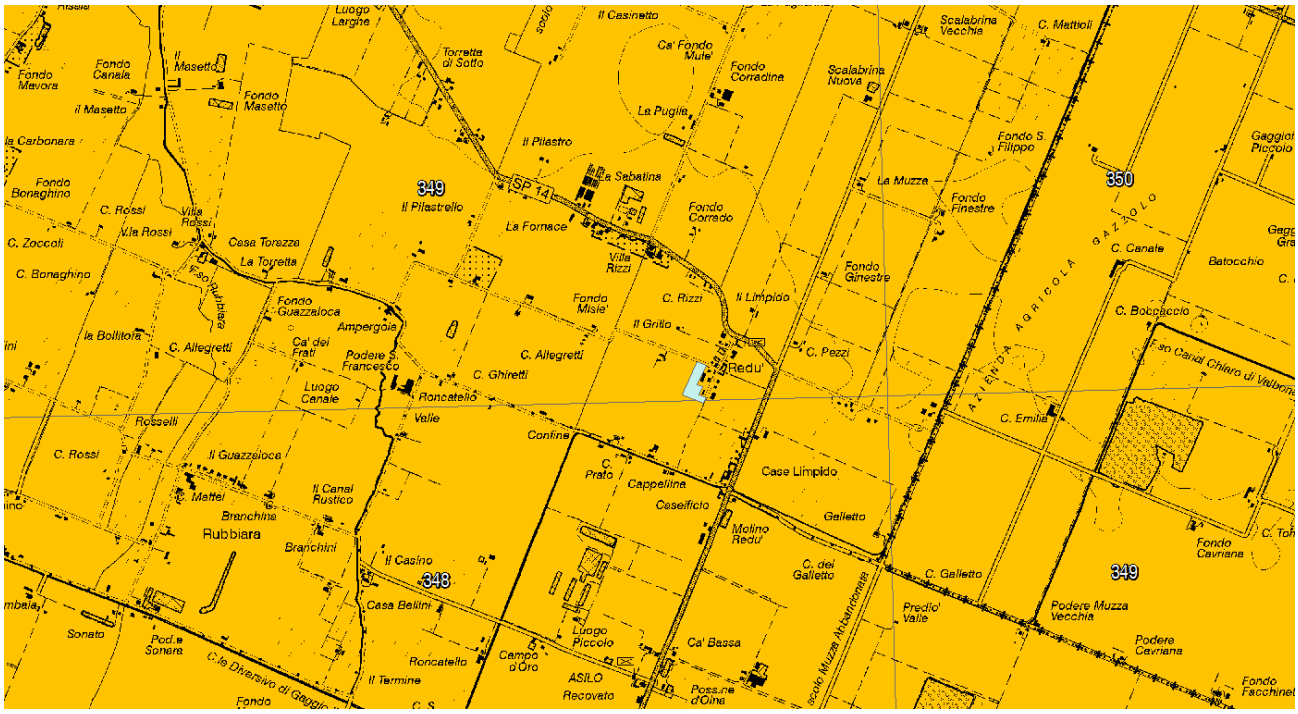


Fig. 2.3 – Interpolazione dei valori ASI derivanti dalla griglia fornita dalla Regione Emilia-Romagna (DGR 630/2019)

3. INDAGINI GEOGNOSTICHE

3.1. Campagna geognostica

Con la finalità di definire il modello stratigrafico, geotecnico e sismico dei terreni che compongono l'areale in oggetto è stata considerata la seguente campagna geognostica:

CAMPAGNA GEOGNOSTICA: SETTEMBRE 2021	
Indagini	
Descrizione	Numero
Prove penetrometriche statiche con punta elettrica CPTU	3
Indagini sismiche passive HVSR	2

Alla tavola n. 4 è illustrata la planimetria di dettaglio relativa al posizionamento planimetrico delle indagini sopracitate.

3.2. Metodologie di indagine

PROVE PENETROMETRICHE STATICHE CON PUNTA ELETTRICA E PIEZOCONO CPTU

Le specifiche tecniche della strumentazione impiegata per l'esecuzione delle seguenti indagini sono illustrate in allegato, a corredo dell'interpretazione delle stesse. Le indagini penetrometriche sono state spinte fino alla profondità di -20.00 metri da piano campagna.

ACQUISIZIONE DI RUMORE SISMICO MEDIANTE STAZIONE VELOCIMETRICA TRIASSIALE (METODOLOGIA HVSR)

Per la definizione delle frequenze naturali di vibrazione dei depositi superficiali presenti, è stata svolta una campagna di acquisizione di rumore sismico naturale disperso mediante registrazionI a stazione singola velocimetrica triassiale (Strumentazione TROMINO 3G MOHO). La durata delle acquisizioni eseguite è pari a T = 1200 s in conformità a quanto esposto nelle linee guida "Guideline for the implementation of the H/V spectral ratio technique on ambient vibrations" imposte dal SESAME European research project (2004).

La tecnica HVSR è una metodologia di rilievo geofisico che consente di valutare alcune caratteristiche di depositi sedimentari. Tale tecnica è risultata idonea per valutare il periodo fondamentale di depositi sedimentari, in modo particolare quando l'impedenza di questi è in grande contrasto con l'impedenza del bedrock. La principale applicazione della tecnica del rapporto spettrale H/V è quindi quella di consentire in modo semplice e veloce l'identificazione della frequenza fondamentale f0 del sito.

La tecnica HVSR consente quindi di valutare la frequenza fondamentale di risonanza di uno strato soffice a partire dalle sole registrazioni del rumore in superficie. Se si considera la struttura geologica tipica di un deposito sedimentario, il tremore registrato in superficie è assimilabile alla composizione di onde superficiali e di onde di volume. Tali onde verranno modificate dall'azione filtrante dello strato soffice. Si possono definire due spettri relativi alle misure del moto superficiale orizzontale (Hf) e verticale (Vf); tali spettri sono legati agli spettri delle onde di volume e di quelle di superficie dalle seguenti formule:

$$V_f = A_v * V_h + V_s$$

$$H_f = A_h * H_b + H_s$$

dove Ah e Av sono i fattori di amplificazione del moto orizzontale e verticale delle onde di volume; Hb e Vb sono gli spettri orizzontale e verticale del moto nel bedrock e Hs e Vs sono gli spettri del moto orizzontale e verticale delle onde di superficie. Nella tecnica HVSR il rapporto H/V è esprimibile come:

$$\frac{H}{V} = \frac{H_f}{V_f} = \frac{H_b}{V_b} * \frac{A_b + \frac{H_s}{H_h}}{A_v + \frac{V_s}{V_b}}$$

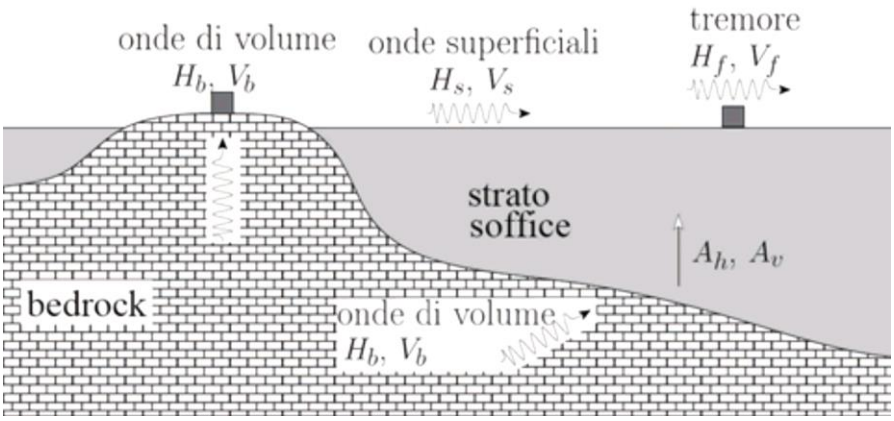


Fig. n. 3.1 – Struttura geologica di un deposito sedimentario

Per basse frequenze (f<(2-3)f0) non c'è amplificazione significativa del moto verticale; inoltre, gli spettri Hb e Vb nel bedrock non hanno ancora ricevuto alcuna rilevante amplificazione. Con l'ulteriore ipotesi di predominanza delle onde provenienti dal bedrock su quelle superficiali si può dimostrare che il rapporto H/V è una approssimazione per difetto del fattore di amplificazione orizzontale Ah cercato

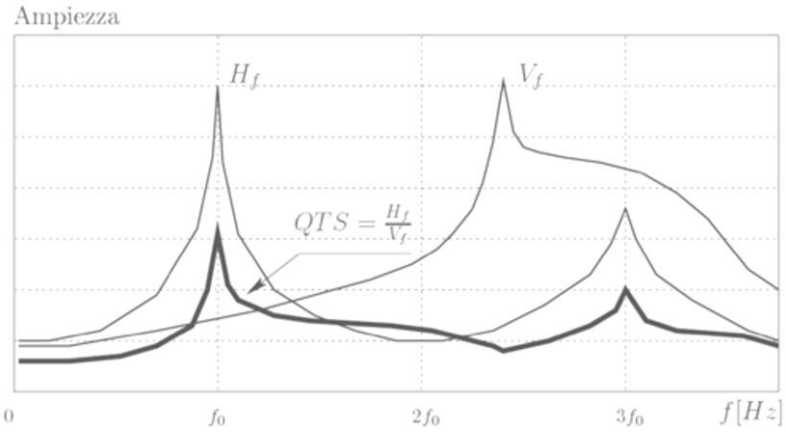


Fig. n. 3.2 – Confronto schematico tra gli spettri orizzontale (Hf) e verticale (Vf), ed il rapporto H/V=Hf/Vf

Si consideri ancora il sito ideale caratterizzato dalla presenza di uno strato soffice posto sopra il bedrock (fig. 3.4). Quando un'onda sismica proveniente dal bedrock passa attraverso lo strato soffice per giungere in superficie, viene modificata in base alle caratteristiche dello strato. Se si suppone che lo strato soffice ideale sia omogeneo ed elastico, risulta possibile calcolare la frequenza fondamentale di risonanza secondo la legge del quarto d'onda:

$$f_0 = \frac{4C_s}{H}$$

dove Cs è la velocità delle onde S e H è la profondità dello strato soffice.

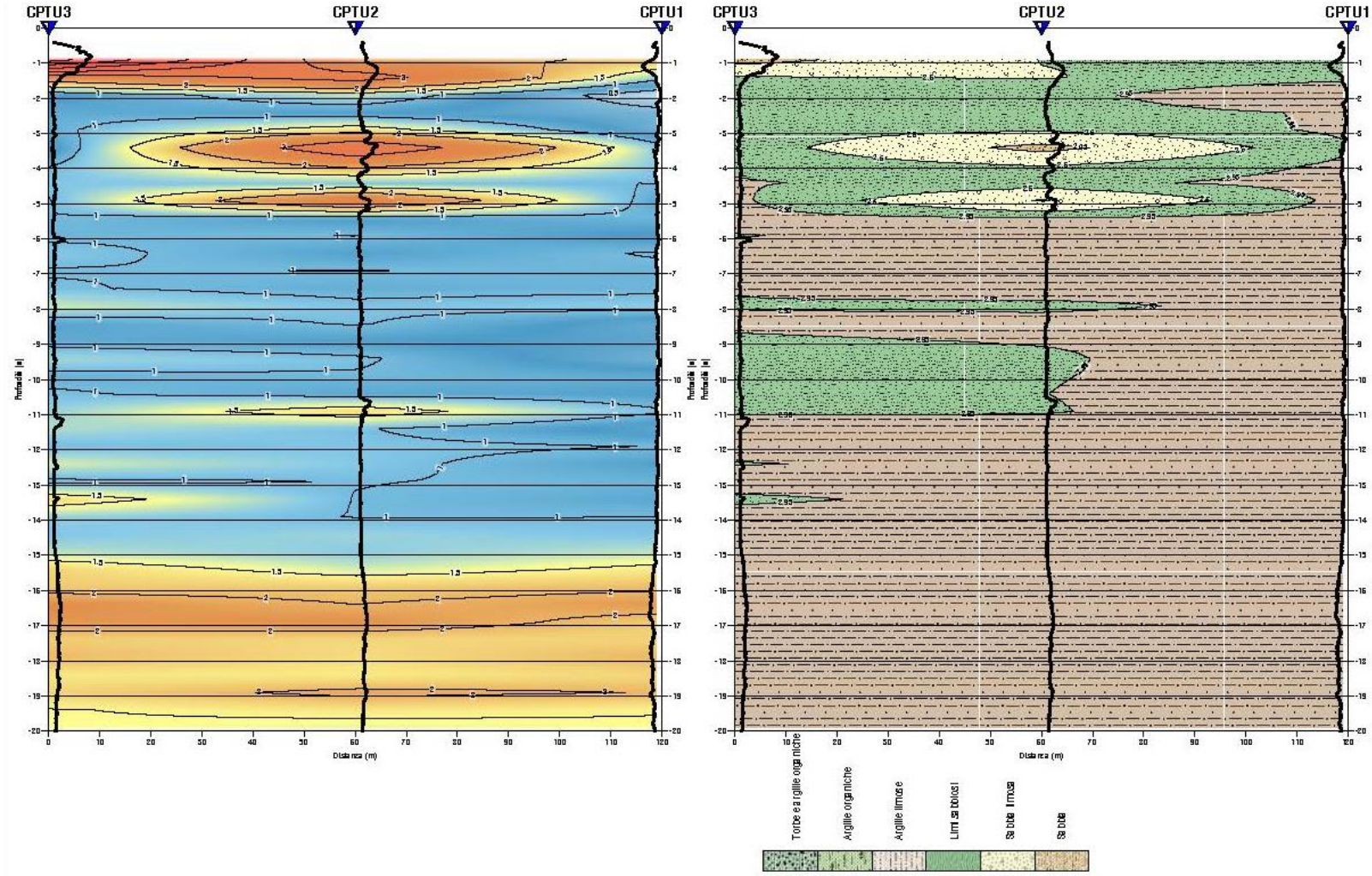
4. MODELLO GEOLOGICO

4.1. Risultati indagini geognostiche e modello geologico

Il modello geologico è stato ricostruito attraverso le indagini eseguite in sito. In allegato, alla tavola n. 5, vengono restituite le sezioni geologiche/geotecniche ricostruite sulla base delle indagini geognostiche. Si illustra successivamente il modello stratigrafico medio che descrive l'andamento delle unità che definiscono il sottosuolo dell'area di interesse.

MODELLO GEOLOGICO MEDIO			
Campagna indagini SETTEMBRE 2020			
Unità	**Quota base strato (m da p.c.)**	**Unità lito-stratigrafica**	**Falda (m da p.c.)**
A	1.50	Terreni argillosi sovra-consolidati	
B	4.00	Terreni limo-sabbiosi e limo argillosi a media consistenza	2.20
C	15.00	Terreni argillosi a media consistenza	
D	20.00	Terreni argillosi consistenti	

In allegato al presente documento sono illustrate le varie interpretazione delle indagini eseguite.


CPTU3
CPTU2
CPTU1
Profondità (m)
Distanza (m)
Torbe e argille organiche
Argille organiche
Argille limose
Limi sabbiosi
Sabbia limosa
Sabbia

5. MODELLO GEOTECNICO

5.1. Modello geotecnico medio

Sulla scorta della modellazione stratigrafica precedentemente illustrata, si deriva il seguente modello geotecnico di riferimento per le verifiche progettuali delle opere di fondazione.

MODELLO GEOTECNICO MEDIO (PARAMETRI K CARATTERISTICI)											
Campagna indagini SETTEMBRE 2021											
Unità	**Z_{TETTO}**	**Z_{BASE}**	**Spessore**	**Unità geotecnica**	**γNAT γSAT**	**c'**	**Cu**	**Φ'P**	**OCR**	**Es**	**M**
A	0.00	1.30	1.5	Terreni argillosi sovra-consolidati	18/20	7	70	23	8.9	100	100
B	1.50	4.00	2.5	Terreni limo-sabbiosi e limo argillosi a media consistenza	19/21	6	60	23	6	12.5	12.5
C	4.00	15.00	11.0	Terreni argillosi a media consistenza	19/21	7	70	23	2.5	6	6
D	15.00	20.00	5.0	Terreni argillosi consistenti	19/21	10	100	25	3.8	15	15
	Metri da p.c.	*Metri da p.c.*	*Metri*	*Descrizione litologica*	*Peso di volume naturale e saturo (kN/m^3)*	*Coesione efficace (kN/m^2)*	*Coesione non drenata (kN/m^2)*	*Angolo d'attrito efficace di picco (°)*	*Grado di sovranconsolidazione*	*Modulo di elasticità di Young (MPa)*	*Modulo edometrico (MPa)*

Durante l'esecuzione delle indagini dirette nel terreno è stata riscontrata una soggiacenza, relativa alla falda freatica superficiale, pari a -2.20 m da piano campagna.

6. AZIONE SISMICA DI RIFERIMENTO

6.1. Risultati delle indagini geofisiche e identificazione della categoria di sottosuolo

Si illustrano successivamente i risultati ottenuti seguito dell'interpretazione delle indagini eseguite in sito.

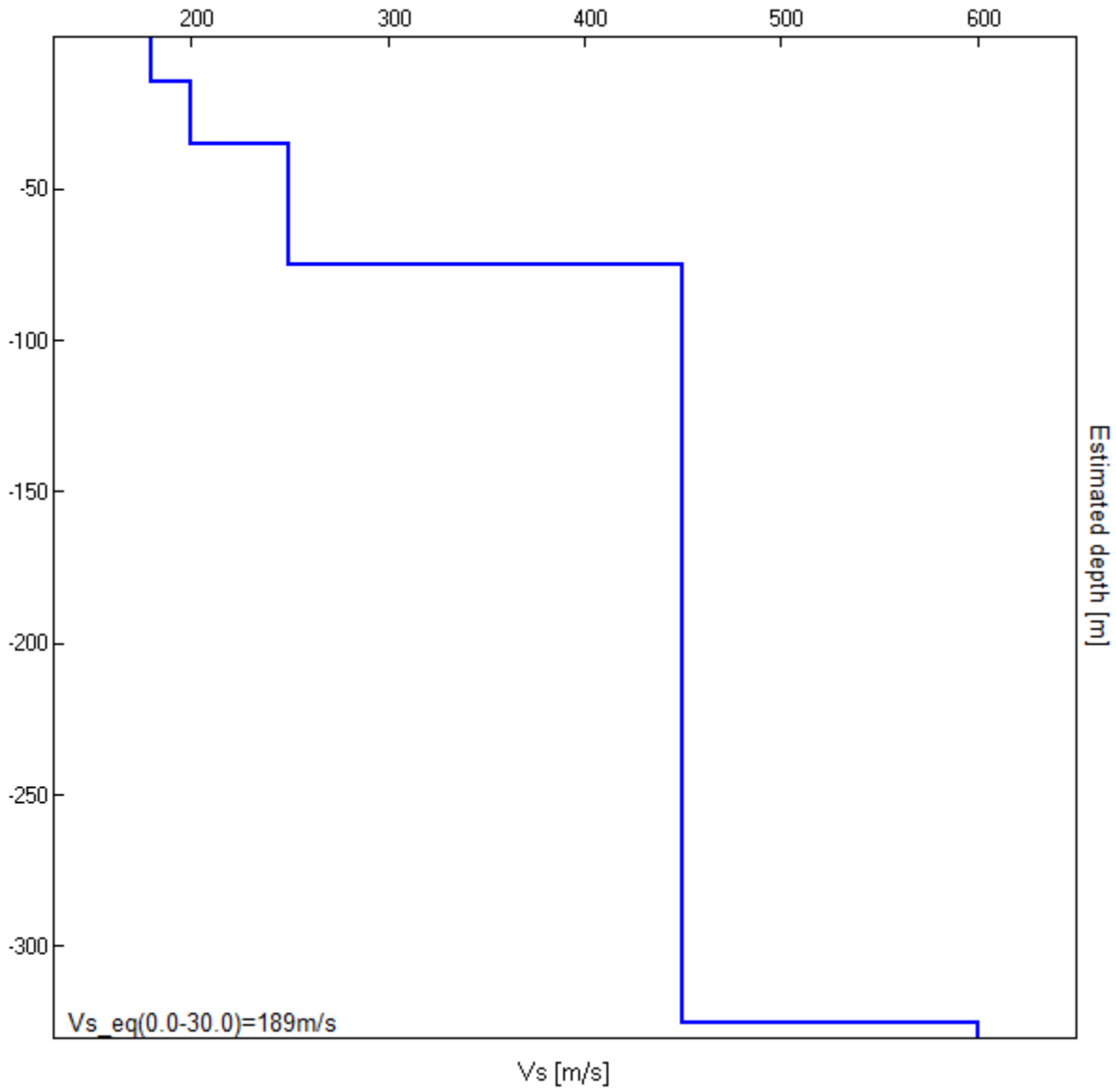


Fig. n. 6.1 – Sintesi del modello di velocità ottenuto dalle indagini sismiche HVSR;

Il modello di velocità ricavato il seguente:

Vs30 189 m/s – Categoria di sottosuolo "C" NTC 2018			
Depth at the bottom of the layer [m]	Thickness [m]	Vs [m/s]	
15.00	15.00	180	
35.00	20.00	200	
75.00	40.00	250	
325.00	250.00	450	
inf.	inf.	600	

Sulla scorta delle velocità derivate dall'indagine sismica HVSR appena illustrata e in riferimento a quanto illustrato nel paragrafo 3.2.2 delle NTC 2018 è possibile definire come le indagini riconducano il terreno a una categoria di sottosuolo B. Dall'analisi delle curve HVSR non è emersa nessuna frequenza fondamentale di sito.

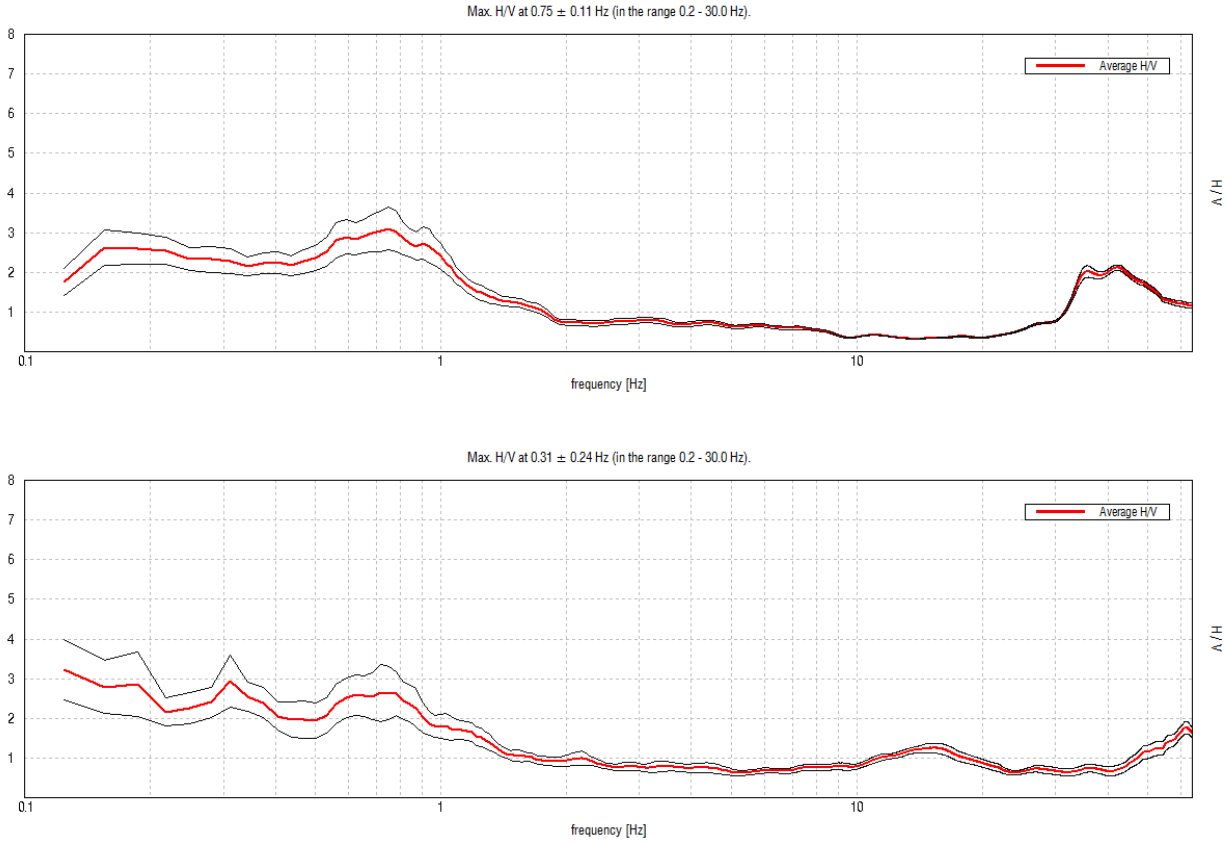


Fig. n. 6.2 – Curve HVSR ottenute dalle acquisizioni eseguite;

6.2. Risposta sismica locale RSL (DGR 630/2019)

Le analisi di risposta sismica locale sono state condotte mediante modelli monodimensionali. Per fare ciò è stato utilizzato come strumento di lavoro il software di calcolo STRATA (University of Texas - Austin) e mediante un modello lineare equivalente.

Utilizzando un modello lineare equivalente è possibile ottenere una soluzione di un modello non lineare, attraverso analisi lineari complete nelle quali, al termine di ogni interazione vengono aggiornati i parametri di rigidezza e smorzamento che sono dipendenti dallo stato di deformazione del terreno. Attraverso un'iterazione di calcoli si raggiunge una convergenza prefissata a monte della fase di computazione.

Il software STRATA è in grado di valutare la risposta sismica di un deposito di terreno, considerando un profilo monodimensionale in cui si propagano linearmente le onde sismiche, in funzione dei parametri dinamici attribuiti al terreno. Il terreno viene schematizzato come un sistema di N strati orizzontali omogenei, isotropi e visco-elastici, sovrastanti un semispazio uniforme, attraversati da un treno di onde di taglio che incidono verticalmente le superfici. Ogni strato è descritto per mezzo dello spessore H, del modulo di taglio massimo Gmax o dalla corrispondente velocità massima Vmax, dal valore dello smorzamento D, dal peso dell'unità di volume γ e dalle curve di decadimento del modulo di rigidezza a taglio normalizzato ($G / G0-\gamma$) e le corrispondenti curve dello smorzamento ($D -\gamma$) con la deformazione di taglio γ. Il modello lineare visco-elastico fa riferimento al modello reologico di Kelvin-Voigt, costituito da una molla e uno smorzatore viscoso in parallelo. Tale modello è descritto quindi dalla rigidezza (G) e dallo smorzamento (D). L'onda monodimensionale viene descritta dall'equazione in cui lo spostamento provocato (u) è funzione della profondità (z) e del tempo (t):

$$u(z,t)=A\exp[i(\omega t+k*z)]+B\exp[i(\omega t-k*z)]$$

Nell'equazione appena presentata A e B rappresentano le corrispettive amplificazioni del tetto e della base dello strato considerato. Il fattore k* risulta dipendente dal modulo di taglio (G), dal grado di smorzamento (D) e dalla densità del terreno (ρ). Le relazioni sono le seguenti:

$$k^* = \frac{\omega}{v_s^*}$$

$$v_s^* = \sqrt{\frac{G^*}{\rho}} \qquad G^* = G\left(1 - 2D^2 + i2D\sqrt{1 - D^2}\right) \simeq G(1 + i2D)$$

Dove G* e v*s rappresentano il modulo di taglio e la velocità di taglio.

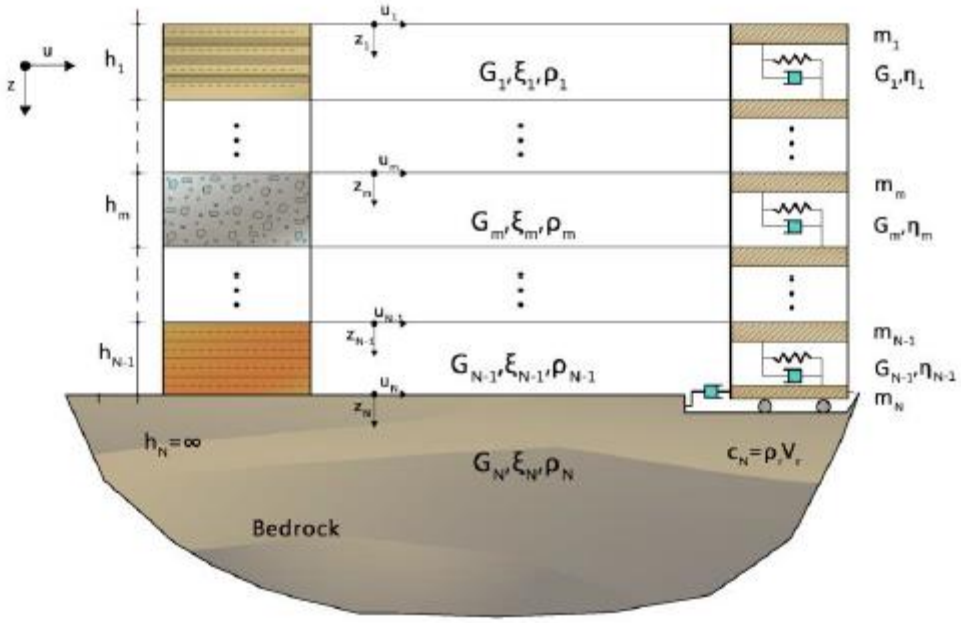


Fig. 6.3 - Modello a strati continui adottato per la simulazione con il codice di calcolo STRATA

Si illustra successivamente il modello adottato per l'analisi RSL in oggetto

z (m)	Vs (m/s)	S (m)	Curva di riferimento
15.0	180.0	15.0	Argilla (Idriss 1990)
35.0	200.0	20.0	Argilla (Idriss 1990)
75.0	250.0	40.0	Sabbia(Idriss 1990)
325.0	450.0	250.0	Sabbia(Idriss 1990)
	600.0		**BEDROCK**

Le curve di decadimento dei moduli G/G0 e del Dumping (D) sono le seguenti:

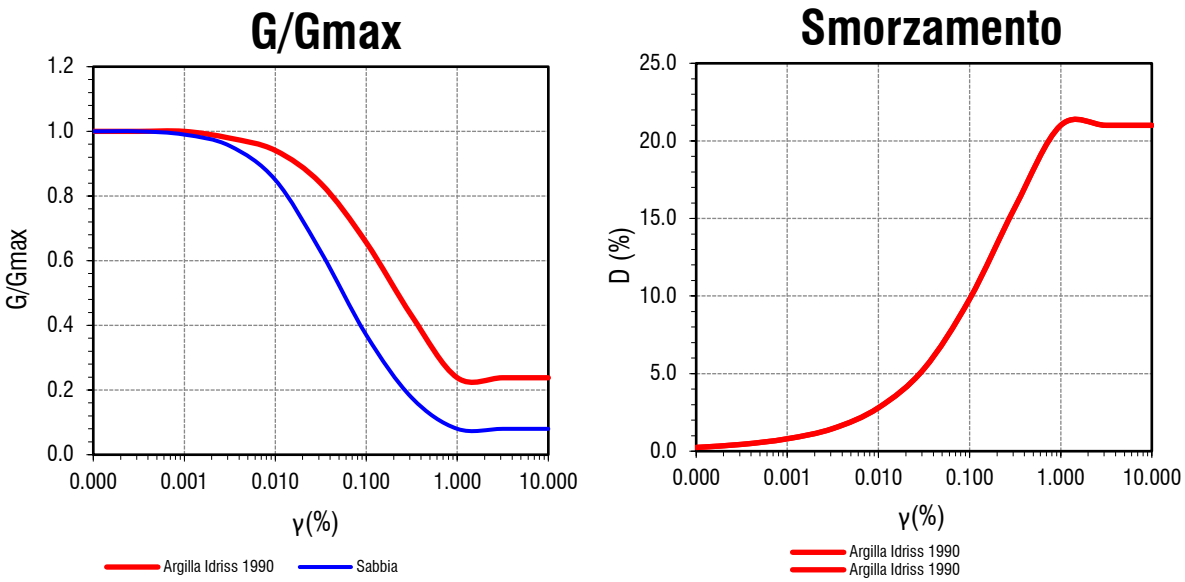
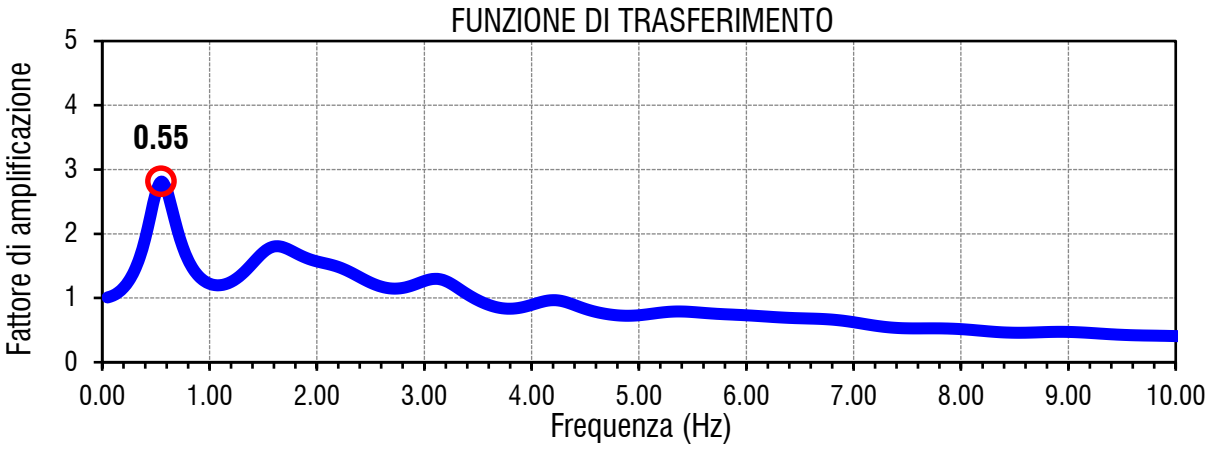


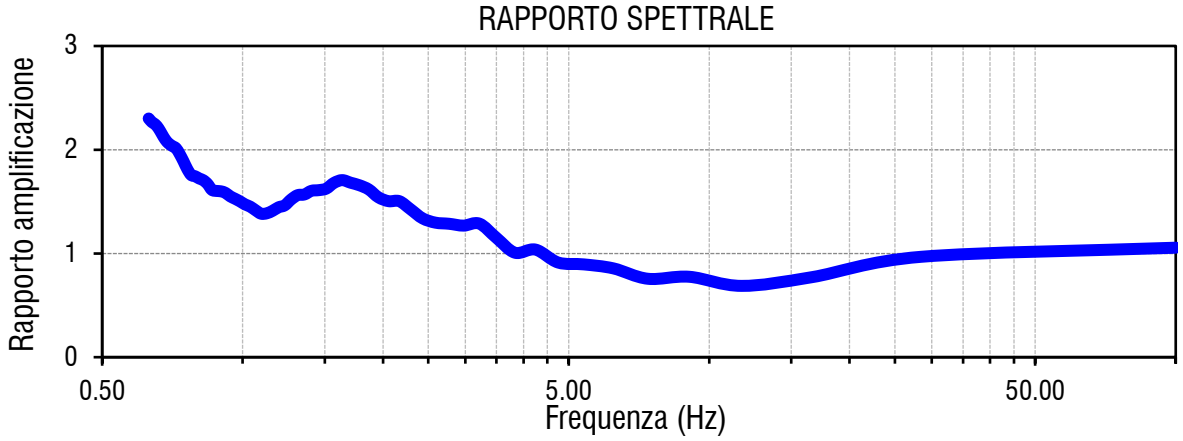
Fig. 6.4 – Curve di decadimento dei terreni analizzati nel calcolo RSL

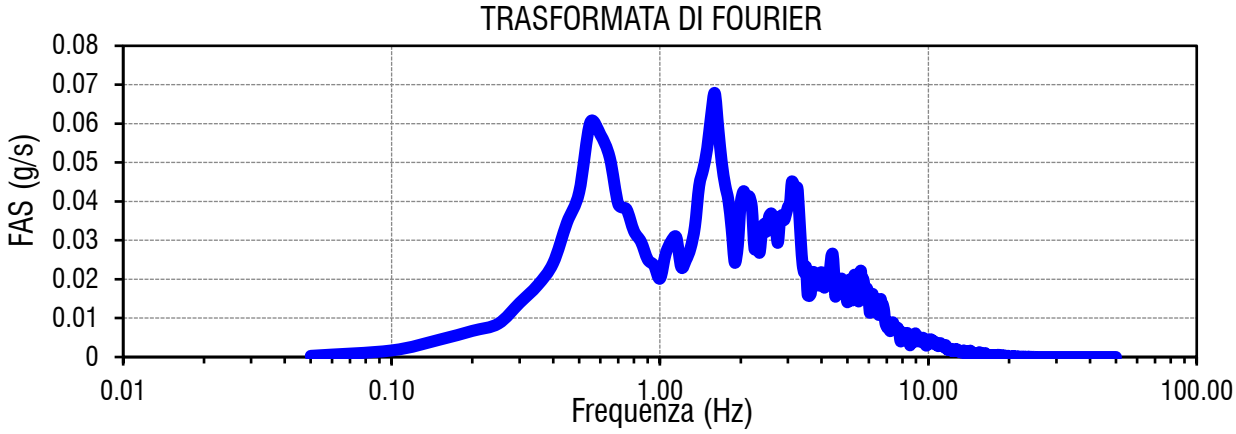
L'input sismico modellato all'interno delle simulazioni RSL deriva dal set accelerometrico (7 segnali) fornito dalla RER come indicato nelle specifiche DGR 476/2021. Le simulazioni sono relative al periodo di ritorno di 475 anni (SLV). Gli accelerogrammi sono stati scalati fino a raggiungere il valore di accelerazione di riferimento per il territorio comunale di Nonantola: considerando quanto illustrato precedente è stato adottato il valore di 0.162 g descrittivo della pericolosità sismica locale.

Si illustrano successivamente gli esiti di ciascuna modellazione eseguita

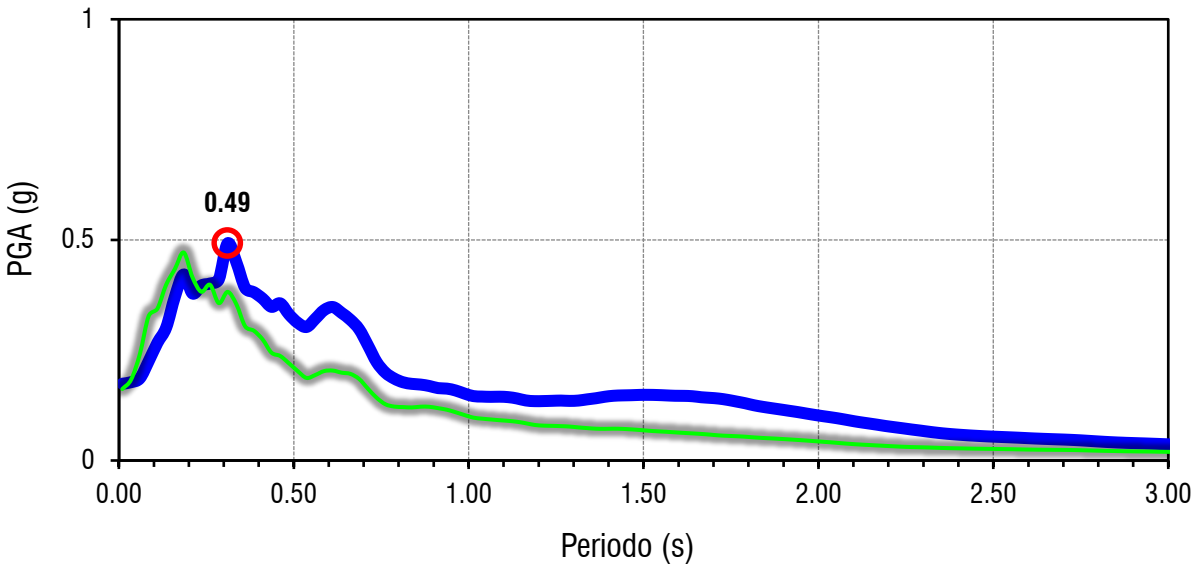
Esiti RSL


FUNZIONE DI TRASFERIMENTO
Fattore di amplificazione
0.55
0
1
2
3
4
5
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
Frequenza (Hz)

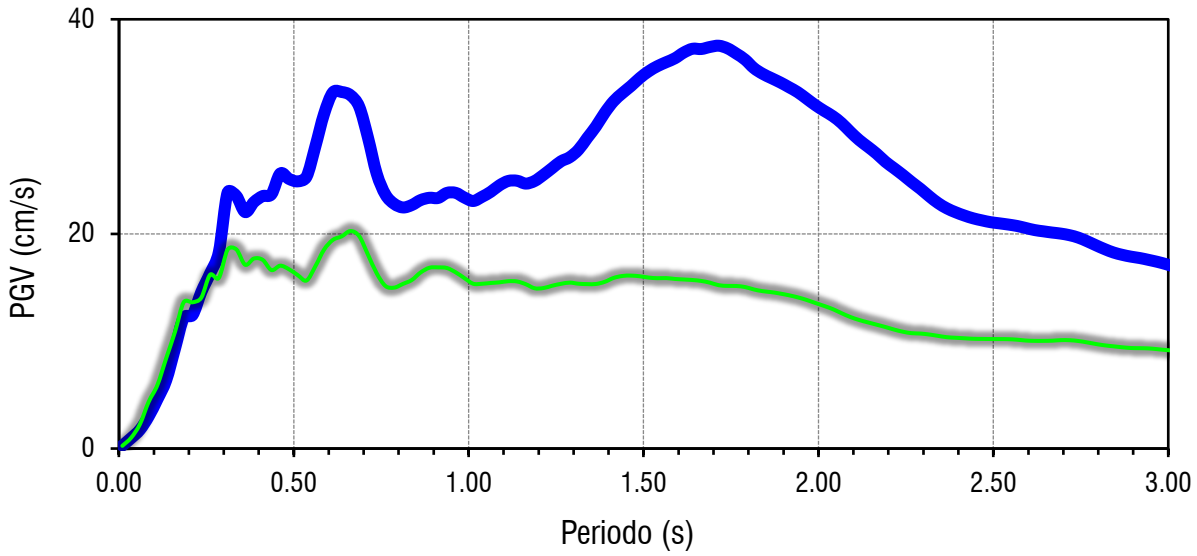

RAPPORTO SPETTRALE
Rapporto amplificazione
0
1
2
3
0.50
5.00
50.00
Frequenza (Hz)


TRASFORMATA DI FOURIER
FAS (g/s)
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.01
0.10
1.00
10.00
100.00
Frequenza (Hz)

Esiti RSL – SPETTRO PSEUDOACCELERAZIONE



Esiti RSL – SPETTRO PSEUDOVELOCITÀ

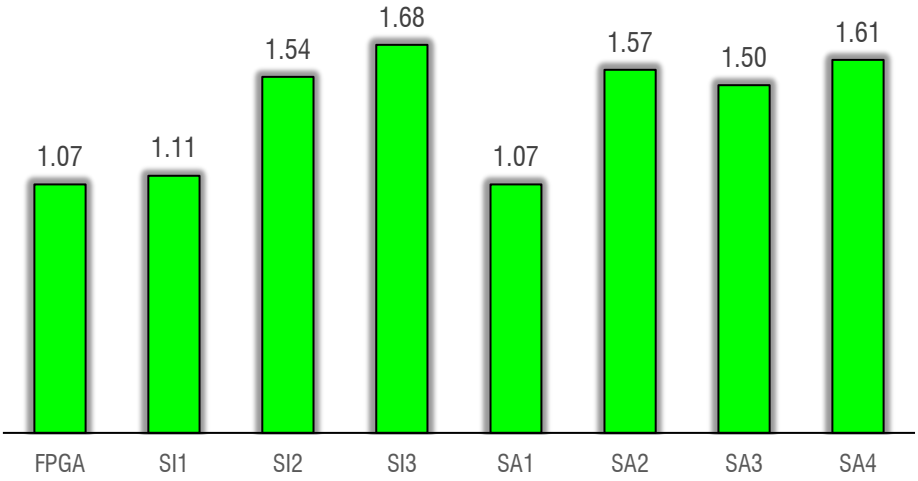


Si illustrano successivamente i principali parametri che descrivono e sintetizzano gli esiti dello studio RSL eseguito. La parametrizzazione fornita risulta adempire le richieste di approfondimento in accordo con le normative regionali precedentemente illustrate.

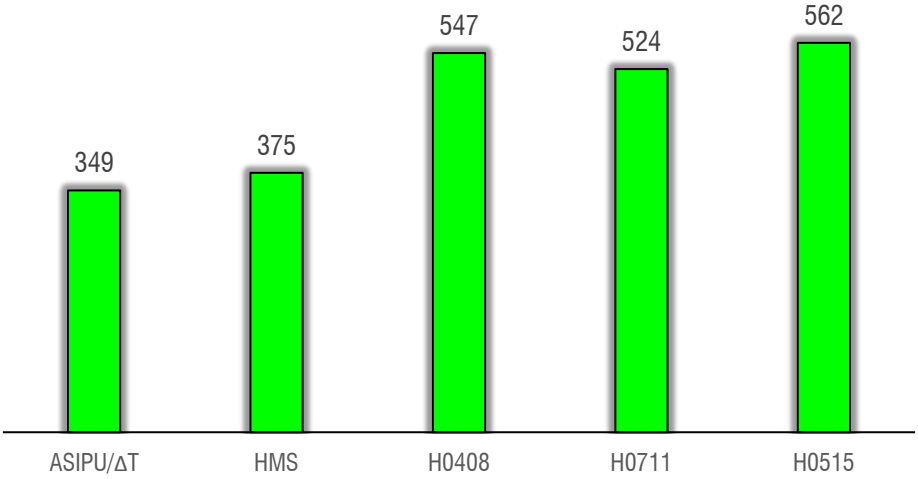
PGA	PGA_0	F_{PGA}	SI1	SI2	SI3	SA1	SA2	SA3	SA4
0.174	**0.162**	1.07	1.11	1.54	1.68	1.07	1.57	1.50	1.61
g	g	-	-	-	-	-	-	-	

$ASI_{PU}/\Delta T$	H_{MS}	H_{0408}	H_{0711}	H_{0515}
349.000	**374.77**	547.467	524.223	562.348
cm/s²	cm/s²	cm/s²	cm/s²	cm/s²

SINTESI ANALISI III LIVELLO DGR 630/2019



SINTESI ANALISI III LIVELLO DGR 630/2019



7. STABILITÀ DEL SITO NEI CONFRONTI DEI FENOMENI CO-SISMICI

7.1. Stima dell'indice potenziale di liquefazione LPI

In accordo con la normativa regionale DGR 630/19 si è proceduto alla verifica della liquefazione per le verticali di prova penetrometriche CPTU.

La valutazione del fenomeno della liquefazione viene svolta attraverso il calcolo del fattore di sicurezza di ciascun livello che compone il sottosuolo analizzato nei confronti del fenomeno stesso. Il fattore di sicurezza è derivato secondo la seguente formulazione:

$$F_L(z) = \frac{CRR_{M=7.5;\sigma'_v=1atm}}{CSR} \cdot MSF \cdot K_\sigma$$

Dove:

CRR è rappresentato dal rapporto di resistenza ciclica

MSF rappresenta il fattore di scala della magnitudo che è funzione della magnitudo stessa, della PGA e del valore di CRR

K_σ è il fattore di correzione che tiene conto della pressione efficace alla profondità a cui la resistenza viene valutata

CSR è il rapporto di tensione ciclica, ovvero la tensione di taglio indotta dall'azione sismica, normalizzata rispetto alla tensione verticale efficace. Tale parametro è derivabile secondo la seguente formulazione:

$$CSR = \frac{\tau_{media}}{\sigma'_{v0}} = 0.65 \cdot \frac{a_{max\,s}}{g} \cdot \frac{\sigma_{v0}}{\sigma'_{v0}} \cdot r_d$$

i termini che compongono la seguente relazione sono rappresentati da a_{max}/g che descrive il valore dell'accelerazione orizzontale a T = 0.00 s, il rapporto della tensione litostatica totale ed efficace, e il coefficiente riduttivo r_d. Quest'ultimo, in accordo con la predetta normativa è stato stimato secondo la seguente formulazione:

$$r_d = \exp\left[\alpha(z) + \beta(z) \cdot M\right]$$

$$\alpha(z) = -1.012 - 1.126 \cdot \mathrm{sen}\left(\frac{z}{11.73} + 5.133\right)$$

$$\beta(z) = 0.106 + 0.118 \cdot \mathrm{sen}\left(\frac{z}{11.28} + 5.142\right)$$

dove M rappresenta il valore di magnitudo di riferimento per il sito in analisi.

Il valore CRR è stato ricavato attraverso la metodologia di calcolo proposta da Boulanger & Idriss 2014. Per le specifiche della procedura di calcolo adottata si faccia riferimento all'allegato A2.2 della DGR 630/2019 della Regione Emilia Romagna. Le analisi di liquefazione sono state eseguite entro i -20.00 m rispetto al piano campagna come prescritto dalla normativa di riferimento.

Le verifiche sono state svolte considerando una magnitudo di riferimento **M = 6.14** (derivante dalla zonazione sismogenetica), una accelerazione massima al suolo **A_{max} = 0.236 g** (NTC 2018 Categoria C in quanto più cautelativa rispetto a quanto derivato da analisi RSL) e con soggiacenza della falda freatica alla profondità di **Dw = -2.20 m da p.c.** .

A seguito dell'identificazione del fattore di sicurezza F_L è stato determinato l'indice potenziale di liquefazione IL (LPI) attraverso il quale è possibile definire l'esposizione del sito al rischio di liquefazione. Il potenziale di liquefazione LPI è stato determinato secondo la seguente formulazione:

$$I_L = \int_0^{z_{crit}} F(z) \cdot w(z) \cdot dz \qquad \text{in cui} \qquad w(z) = \frac{200}{z_{crit}} \cdot \left(1 - \frac{z}{z_{crit}}\right)$$

Dove F(z) viene determinato secondo le formulazioni proposte da Somnez (2003)

$$\begin{aligned} F(z) &= 0 && \text{per} \quad F_L \geq 1.2 \\ F(z) &= 2 \cdot 10^6 \cdot \exp(-18.427 \cdot F_L) && \text{per} \quad 1.2 > F_L \geq 0.95 \\ F(z) &= 1 - F_L && \text{per} \quad F_L \leq 0.95 \end{aligned}$$

In base al valore di LPI ottenuto è possibile fornire un'indicazione del rischio di liquefazione. In considerazione delle linee guida emesse dalla Regione Emilia-Romagna, a seguito degli eventi sismici di Maggio e Giugno 2012, si considera la classificazione di rischio definita da **Sonmez 2003**:

INDICE DI LIQUEFAZIONE	Rischio di liquefazione
LPI=0	Nullo
0<LPI≤2	Basso
2<LPI≤5	Moderato
5<LPI≤10	Alto
15>LPI	Molto alto

Si illustrano successivamente i valori di LPI derivati per ciascuna verticale di prova CPTU considerata ai fini delle analisi del fenomeno di liquefazione:

INDAGINE	INDICE DI LIQUEFAZIONE LPI	RISCHIO
CPT1	**0.000**	BASSO
CPT2	**1.844**	BASSO
CPT3	**0.129**	BASSO

Sulla scorta delle risultanze ottenute dalle verifiche della suscettività del sito al fenomeno di liquefazione emerge che l'areale oggetto di studio risulta esposto a un rischio di liquefazione "basso".

7.2. Verifica dei cedimenti post-sismici (Approccio DGR 630/19)

Per ottemperare alla normativa regionale DGR 630/19 è stata svolta la verifica quantitativa dei cedimenti post-sismici dei livelli granulari saturi, granulari insaturi e dei livelli coesivi soffici. La verifica dei cedimenti è stata eseguita considerando la totalità delle verticali di prova CPTU eseguite. Si illustra successivamente, per via grafica, i risultati dell'analisi.

CEDIMENTI POST-SISMICI – TERRENI GRANULARI SATURI

La stima dei cedimenti dei terreni granulari saturi è stata svolta in relazione alla resistenza alla punta delle indagini CPTU, normalizzata e corretta $(q_{c1N})_{cs}$ e del coefficiente di sicurezza alla liquefazione F_L. Il cedimento post-sismico per ciascuno strato è dato da $\Delta s_i = \varepsilon_{vi}\ \Delta z_i$. La deformazione volumetrica ε_{vi} è stata stimata secondo la metodologia proposta da Idriss e Boulanger (2008) e dettagliata al punto B.1 dell'allegato A2.2 della DGR 630/2019.

CEDIMENTI POST-SISMICI – TERRENI GRANULARI INSATURI

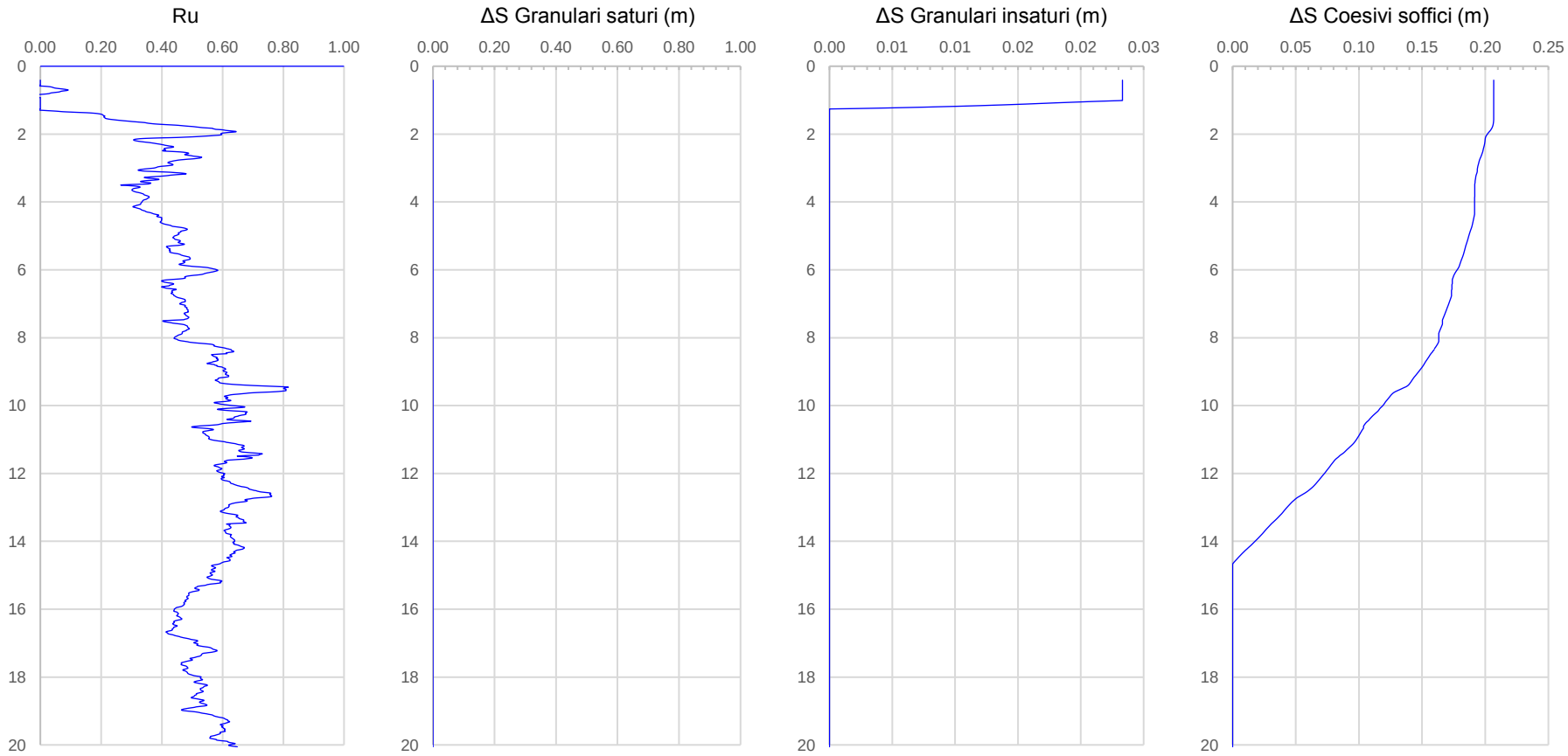
La valutazione della suscettibilità di addensamento dei terreni granulari insaturi e conseguente cedimento è stata calcolata derivando la deformazione volumetrica per un numero di cicli equivalente N_c il cui valore è funzione della magnitudo del terremoto secondo l'equazione $N_c = (M-4)^{2.17}$. La procedura di calcolo completa viene descritta al punto B.2 dell'allegato A2.2 della DGR 630/2019.

CEDIMENTI POST-SISMICI – TERRENI COESIVI SOFFICI

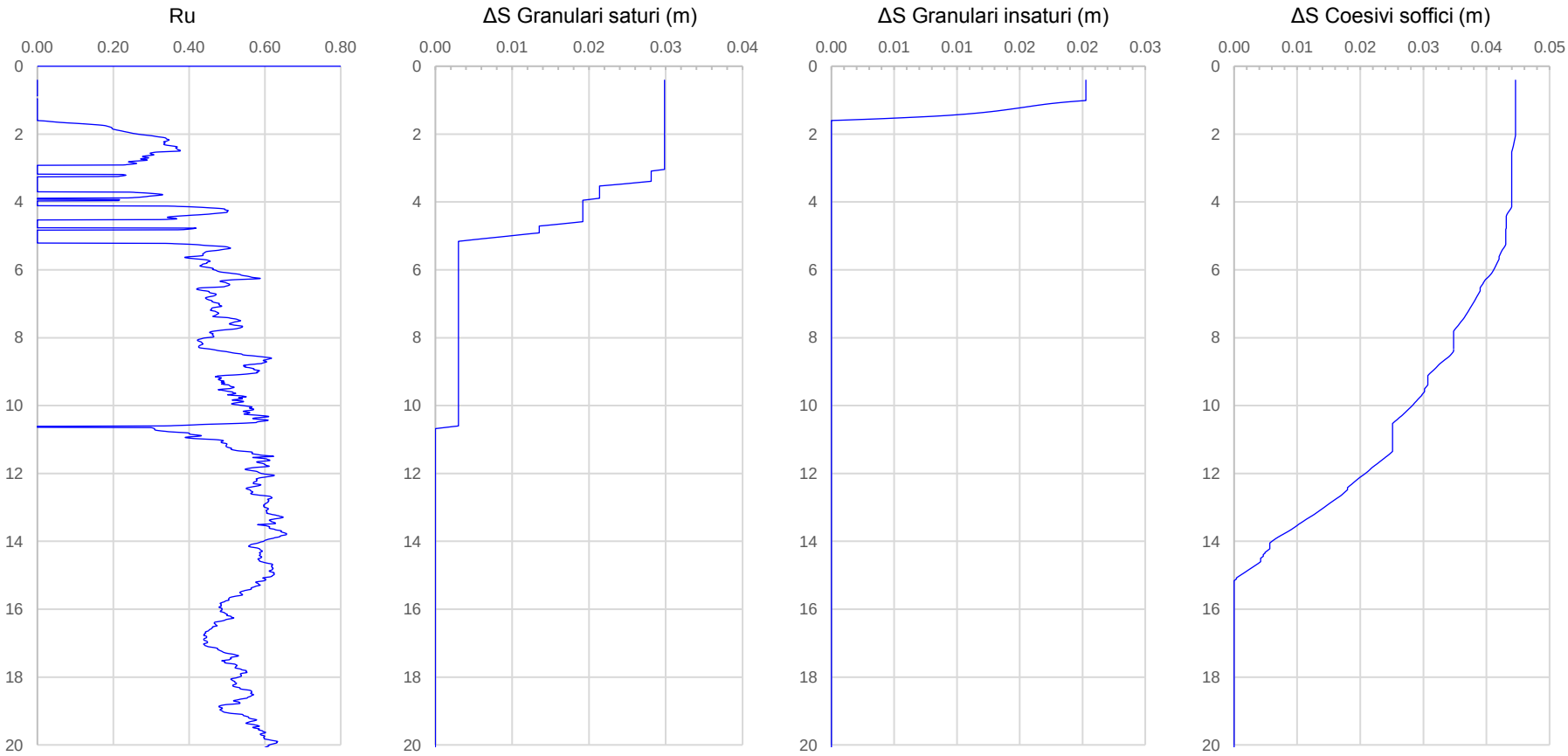
I cedimenti dei livelli coesivi sono stati svolti solamente per gli strati dotati di $c_u < 70$ kPa e Ip > 30 %. L'entità del cedimento di ri-consolidazione conseguente alla dissipazione delle pressioni interstiziali accumulatesi durante il terremoto è stata stimata mediante la formulazione proposta da Yasyhara e Andersen (1991). In tale equazione, descritta dettagliatamente al punto B.3 dell'allegato A2.2 della DGR 630/2019, l'indice di ri-compressione C_r è stato assunto pari all'indice di rigonfiamento C_s, funzione del modulo edometrico. Nel presente caso, sulla scorta dei valori di resistenza alla punta ottenuti a seguito delle prove CPTU eseguite, il modulo edometrico è stato ricavato mediante la relazione proposta da Mitchell & Gardner (1975).

La verifica dei cedimenti sismici è stata svolta considerando una soggiacenza della falda freatica pari a Dw = -2.20 m da p.c. e una magnitudo di riferimento pari a 6.14. Si illustrano successivamente i valori di cedimenti post-sismici per i diversi stati limite considerati:

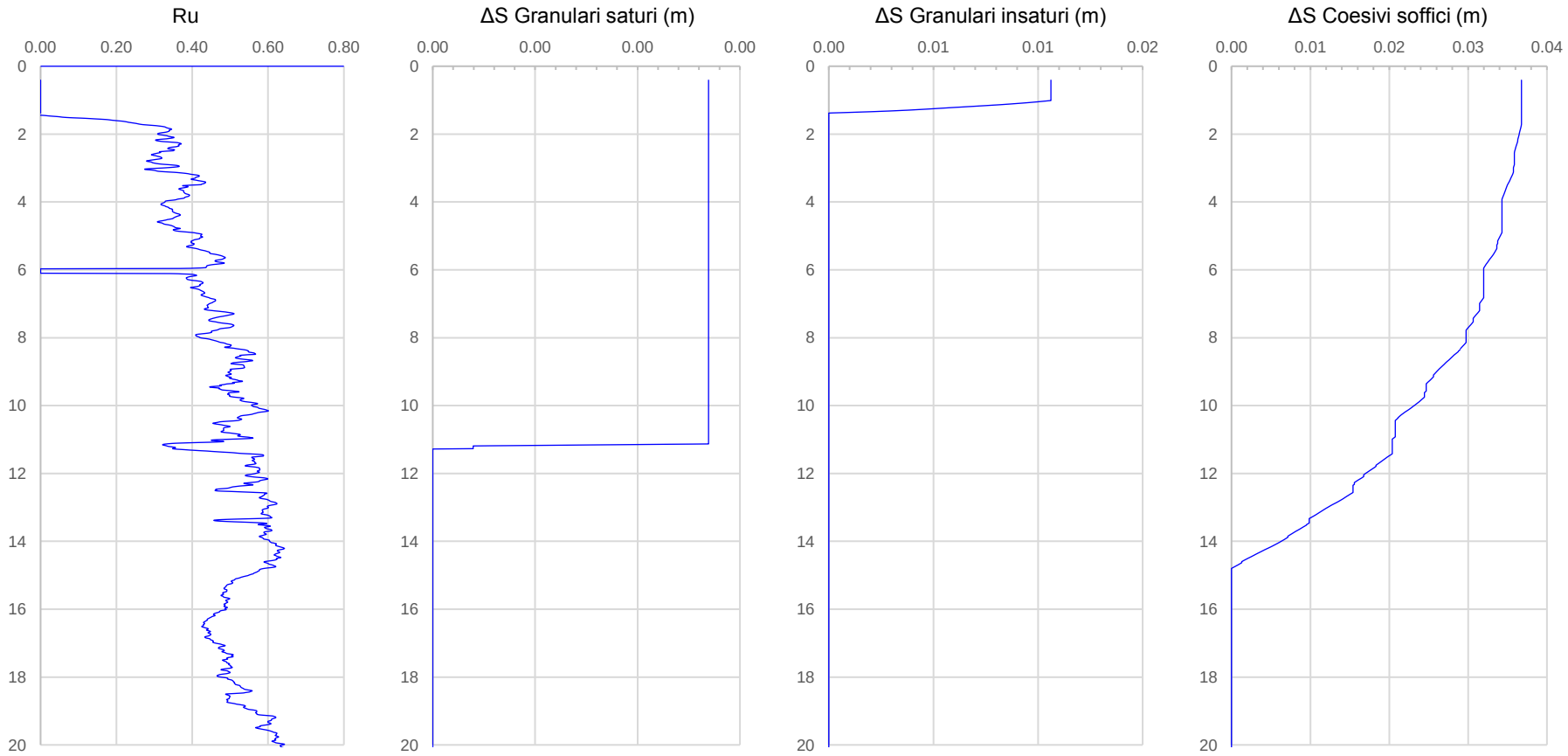
CEDIMENTI POST-SISMICI CPTU1



CEDIMENTI POST-SISMICI CPTU2



CEDIMENTI POST-SISMICI CPTU3



Si riassumono successivamente i valori di cedimento ottenuti a seguito delle analisi eseguite:

CPTU1	Cedimenti S (cm)	Granulari saturi	Granulari insaturi	Coesivi soffici	Cedimento totale
		0.000	2.331	20.671	23.003

CPTU2	Cedimenti S (cm)	Granulari saturi	Granulari insaturi	Coesivi soffici	Cedimento totale
		2.984	2.027	4.460	9.471

CPTU3	Cedimenti S (cm)	Granulari saturi	Granulari insaturi	Coesivi soffici	Cedimento totale
		0.269	1.062	3.677	5.008

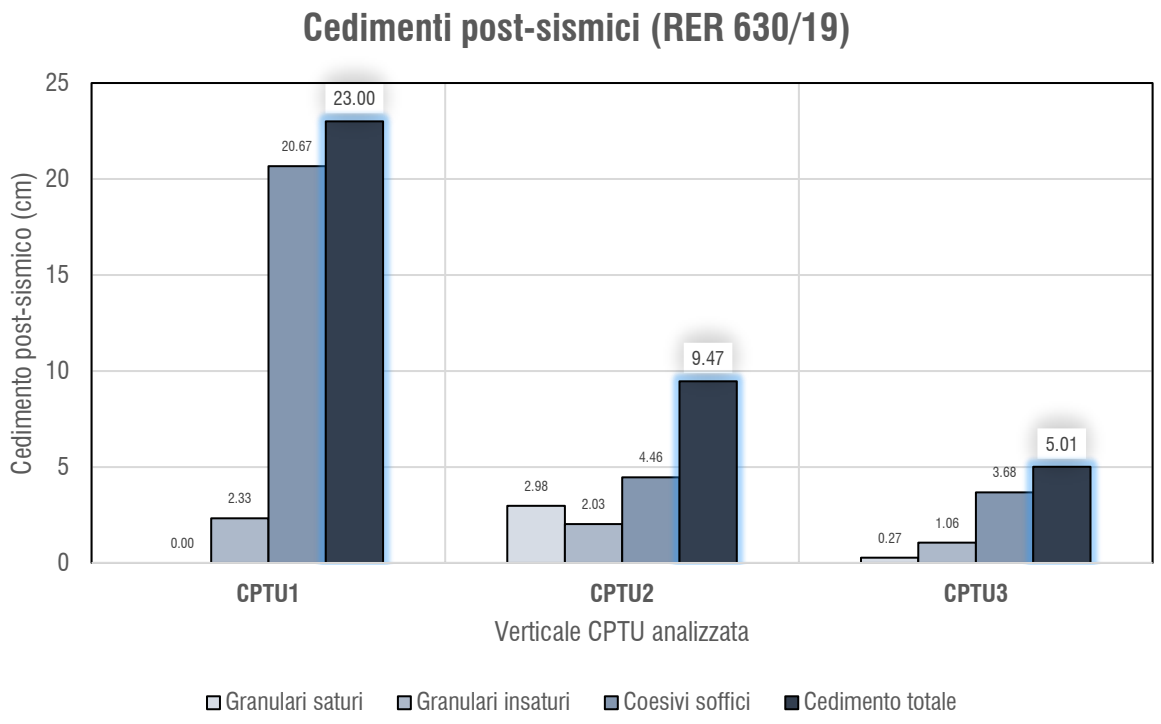


Fig. 6.5 – Sintesi risultati analisi cedimenti sismici;

Per la stima della portata del danneggiamento dovuto al verificarsi dei cedimenti post-sismici è possibile fare riferimento agli autori Ishihara & Yoshimine (Soils and Foundations Vol.32, No. 1, 173-188, Mar 1992 Japanese Society of Soil Mechanics and Foundation Engineering) (Fig. n. 6.6).

Table 1. Relation between damage extent and approximate settlements

Extent of damage	Settlements (cm)	Phenomena on the ground surface
Light to no damage	0~10	Minor cracks
Medium damage	10~30	Small cracks, oozing of sand
Extensive damage	30~70	Large cracks, spouting of sands, large offsets, lateral movement

Fig. 6.6 – Relazione tra la portata del danneggiamento e il valore di cedimento post-sismico Ishihara & Yoshimine (1992);

Facendo riferimento alle casistiche definite dagli autori Ishihara & Yoshimine (1992) e considerati i valori di cedimento post-sismico ottenuti, risulta possibile definire una portata medio-bassa di danneggiamento teorica in condizioni free-field.

8. CONCLUSIONI

Il presente elaborato contiene lo studio di Microzonazione Sismica a supporto della proposta di variante urbanistica relativamente al piano particolareggiato di iniziativa privata "Comparto C.2V2" in località di Redù nel Comune di Nonantola. Lo studio in oggetto è stato eseguito in ottemperanza alla disposizione regionale DGR 630/19 che costituisce la linea guida per la redazione di studi di microzonazione sismica a supporto della progettazione urbanistica.

Lo studio di microzonazione sismica ha previsto l'approfondimento di III livello riguardo alla valutazione degli effetti di amplificazione locale del moto sismico e la stima dei fenomeni co-sismici, quali liquefazione e cedimenti sismo-indotti. L'approccio di studio adottato deriva dalla classificazione attribuita all'area dallo studio di microzonazione sismica del Comune di Nonantola in quanto, nell'area oggetto di studi, viene segnalata potenziale instabilità in prospettiva sismica.

Per quel che concerne la caratterizzazione geotecnica e geofisica del sottosuolo si è fatto riferimento alla campagna indagini espletata da Geo Group Srl nell'anno 2021. Sulla scorta delle risultanze delle indagini è stato possibile ricostruire l'assetto stratigrafico e meccanico delle unità che compongono il sottosuolo di riferimento, congiuntamente alla classificazione geofisica del sottosuolo. L'assetto stratigrafico derivato risulta sufficientemente omogeneo, tale da poter rappresentare l'intera area come una singola microzona a comportamento omogeno in prospettiva sismica.

In ottemperanza della normativa tecnica nazionale (NTC 2018) e in accordo con i risultati ottenuti a seguito delle indagini geofisiche espletate è possibile classificare il terreno di fondazione come appartenente alla categoria C.

A seguito della definizione delle caratteristiche geofisiche del sito è stata condotta un'analisi RSL per la definizione dell'azione sismica di riferimento, secondo approccio di calcolo DGR 630/19. Si riassumono successivamente gli esiti dell'analisi in forma sintetica.

PGA	PGA_0	F_{PGA}	SI1	SI2	SI3	SA1	SA2	SA3	SA4
0.174	**0.162**	1.07	1.11	1.54	1.68	1.07	1.57	1.50	1.61
g	g	-	-	-	-	-	-	-	

$ASI_{PU}/\Delta T$	H_{MS}	H_{0408}	H_{0711}	H_{0515}
349.000	**374.77**	547.467	524.223	562.348
cm/s^2	cm/s^2	cm/s^2	cm/s^2	cm/s^2

L'analisi di risposta sismica locale ha determinato un fattore di amplificazione del moto sismico pari al valore di 1.07. Congiuntamente al valore del fattore di amplificazione è stato derivato il parametro H_{MS} (562.348 cm/s^2): tale parametro risulta di grande interesse per il governo del territorio e per la pianificazione urbanistica in quanto risulta esprimere un valore di accelerazione di riferimento per maggior parte degli edifici civili. In aggiunta a ciò, tale

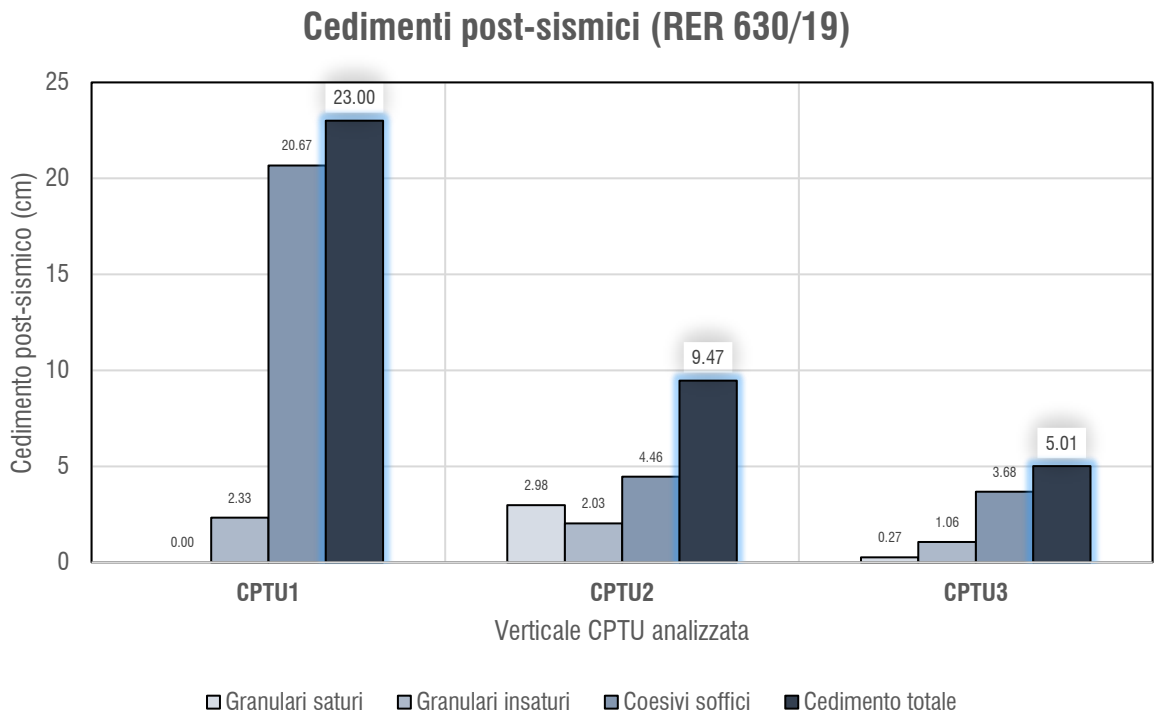
parametro permette di rappresentare in maniera assoluta e più realistica la pericolosità sismica del territorio, tenendo conto sia della pericolosità di base sia degli effetti di sito.

Identificata l'azione sismica di riferimento, si è proceduto alla valutazione e quantificazione dell'instabilità co-sismica derivabile da potenziali fenomeni di liquefazione e cedimenti/addensamenti del sottosuolo per effetto dei carichi sismici.

Si riassumono successivamente i valori di LPI (Indice potenziale di liquefazione) e cedimenti co-sismici derivati:

INDAGINE	INDICE DI LIQUEFAZIONE LPI	RISCHIO
CPT1	0.000	BASSO
CPT2	1.844	BASSO
CPT3	0.129	BASSO

Si riassumono successivamente, per via grafica, i valori di cedimenti post-sismici ottenuti per ciascuna prova.



Facendo riferimento alle casistiche definite dagli autori Ishihara & Yoshimine (1992) e considerati i valori di cedimento post-sismico ottenuti, risulta possibile definire una portata medio-bassa di danneggiamento teorica in condizioni free-field.

Il presente elaborato costituisce l'analisi geologica preliminare a supporto della proposta urbanistica in oggetto; in quanto tale costituisce l'elemento prescrittivo per i futuri approfondimenti in ambito geologico, geotecnico e sismico, propedeutici alle progettazioni esecutive delle opere e degli edifici previsti per l'area in oggetto. Visto e considerato il piano della conoscenza finora raggiunto, si prescrive quanto segue:

1. La seguente relazione geologica ha l'obbiettivo di fornire l'analisi di pericolosità in prospettiva sismica secondo normativa regionale 630/19 in materia urbanistica. Non costituisce pertanto l'elaborato specialistico "Relazione geologica" a supporto della progettazione esecutiva;

2. Gli esiti della campagna geognostica eseguita mostrano una buona consistenza dei terreni che compongono il volume di sottosuolo.

3. Nonostante gli esiti di liquefazione soddisfacenti, si derivano valori di cedimento post-sismico potenziale nell'ordine dei 60/80 cm. Tale evidenza risulta pienamente in accordo con quanto indicato al punto precedente. L'esecuzione di fondazioni profonde per la risoluzione dell'elevata deformabilità del terreno in campo statico potrà ovviare anche alle criticità di deformazione osservate in campo sismico;

4. Sulla scorta dei valori di soggiacenza osservati durante la campagna geognostica (Anno 2020), in riferimento alle strutture e i vani interrati, occorre prevedere l'analisi e l'impiego di idonei sistemi di impermeabilizzazione delle superfici strutturali direttamente al contatto con il mezzo acquifero.

Tanto si doveva

Modena, 14 Dicembre 2021

GEO GROUP S.r.l.

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Email: info@geogroupmodena.it Pec: geo.group@winpec.it Sito: www.geogroupmodena.it
Operatore APR certificato ENAC per operazioni non critiche – Rif. ENAC 18627

TAVOLE

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info@geogroupmodena.it

INQUADRAMENTO TOPOGRAFICO
- CTR 5K RER -

Redù di Nontantola
Giabema Srl

40 20 0 40 80 120 160 Metri

1:5,000

Redatto: GG	Data: Dicembre 2021
Controllato:	Data: Dicembre 2021
ID Commessa:	**TAVOLA Nr. 1**

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Via Cesare Costa 182 - Modena
www.geogroupmodena.it
info@geogroupmodena.it

INQUADRAMENTO AEROFOTOGRAFICO
- CGR 2018 RER -

Redù di Nontantola
Giabema Srl

10 5 0 10 20 30 40 Metri

1:2,000

N

Redatto: GG	Data: Dicembre 2021
Controllato:	Data: Dicembre 2021
ID Commessa:	**TAVOLA Nr. 2**

GEO GROUP SRL
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INQUADRAMENTO GEOLOGICO
- C.A.R.G. RER -

Redù di Nontantola
Giabema Srl

25 12.5 0 25 50 75 100 Metri

1:3,000

Redatto: GG	Data: Dicembre 2021
Controllato:	Data: Dicembre 2021
ID Commessa:	**TAVOLA Nr. 3**

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Via Cesare Costa 182 - Modena
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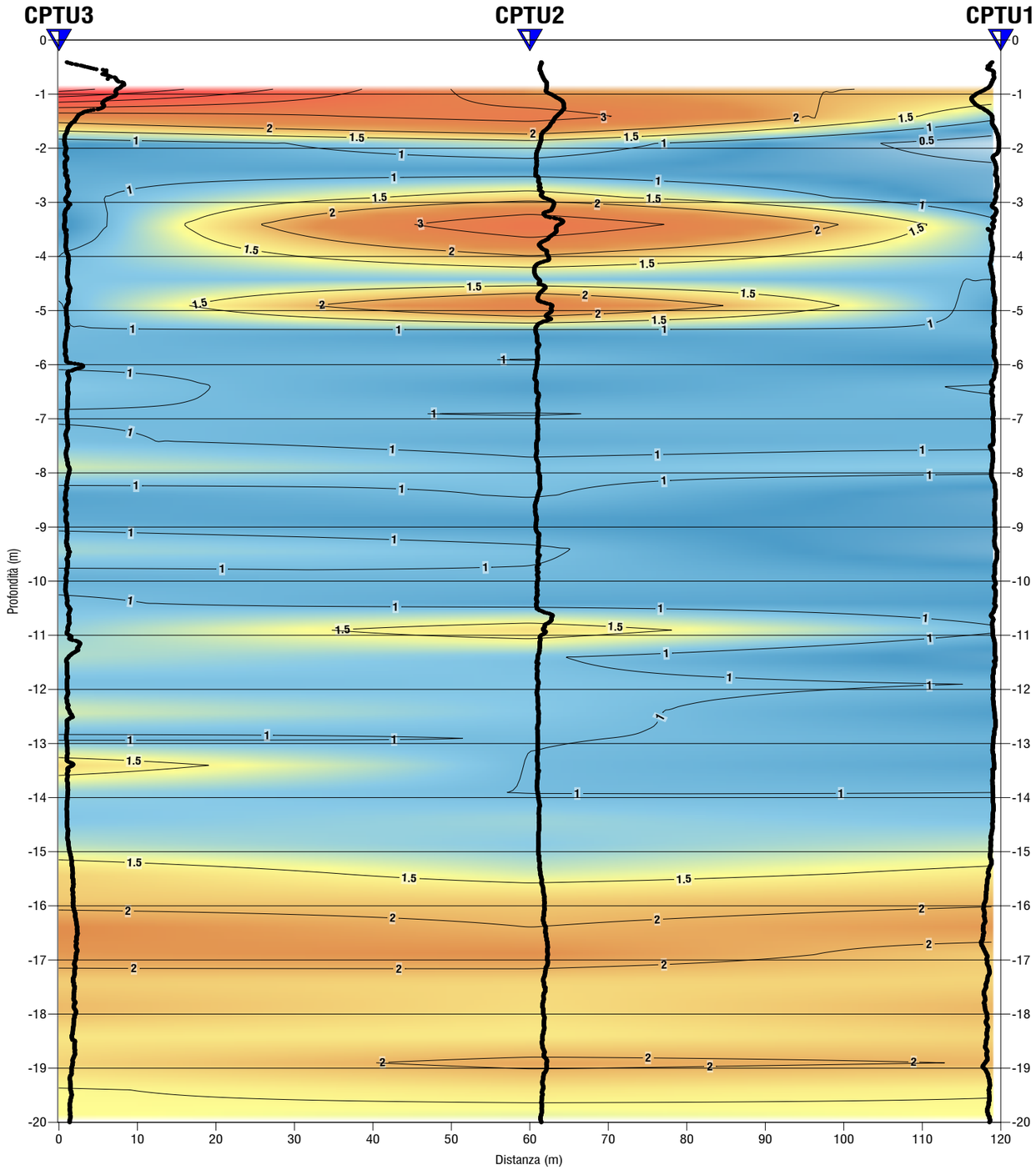
UBICAZIONE INDAGINI
- CAMPAGNA INDAGINI 2021 -

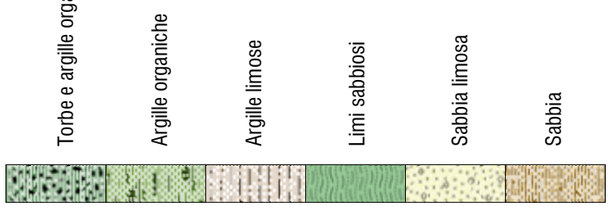
Redù di Nontantola
Giabema Srl

9 4.5 0 9 18 27 36 Metri

1:1,000

Redatto: GG	Data: Dicembre 2021
Controllato:	Data: Dicembre 2021
ID Commessa:	**TAVOLA Nr. 4**





GEO GROUP SRL
Via Cesare Costa 182 - Modena
www.geogroupmodena.it
info@geogroupmodena.it

INTERPRETAZIONE INDAGINI CPTU/CPT RESISTENZA PUNTA / LITOLOGIA

Redù di Nonantola

Redatto: GG	Data: Dicembre 2021
Controllato:	Data: Dicembre 2021
ID Commessa:	**TAVOLA Nr. 5**

UFFICI: via Per Modena, 12 - 41051 Castelnuovo R. (MO) SEDE LEGALE: via C.Costa,182 - 41123 Modena (MO)
tel. 059/3967169; 059/828367 - FAX 059/5960176 p. Iva e C.F.02981500362
Email: info@geogroupmodena.it Pec: geo.group@winpec.it Sito: www.geogroupmodena.it
Operatore APR certificato ENAC per operazioni non critiche – Rif. ENAC 18627

Allegato n.1

Prove penetrometriche statiche con punta elettrica e piezocono CPTU

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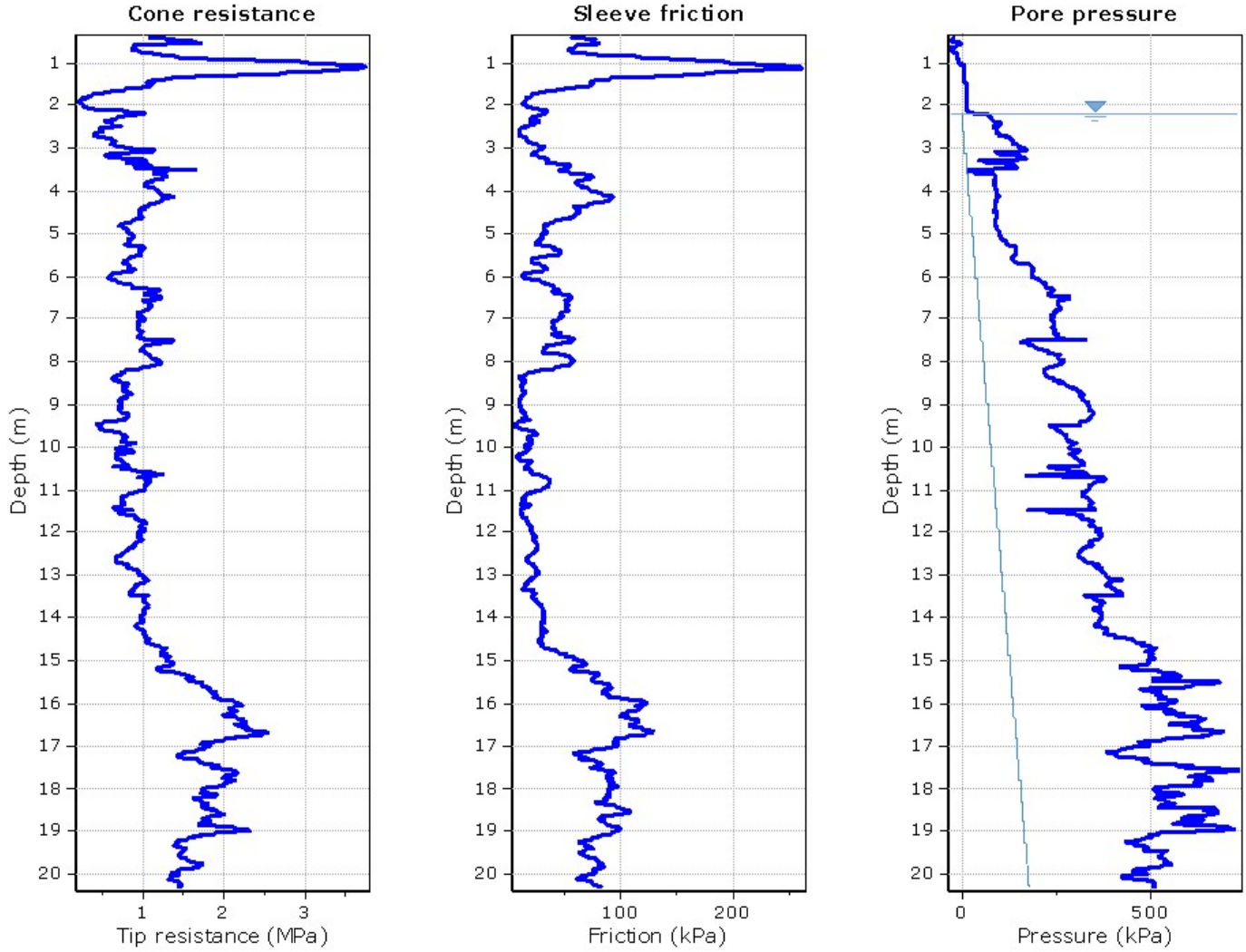
www.geogroupmodena.it

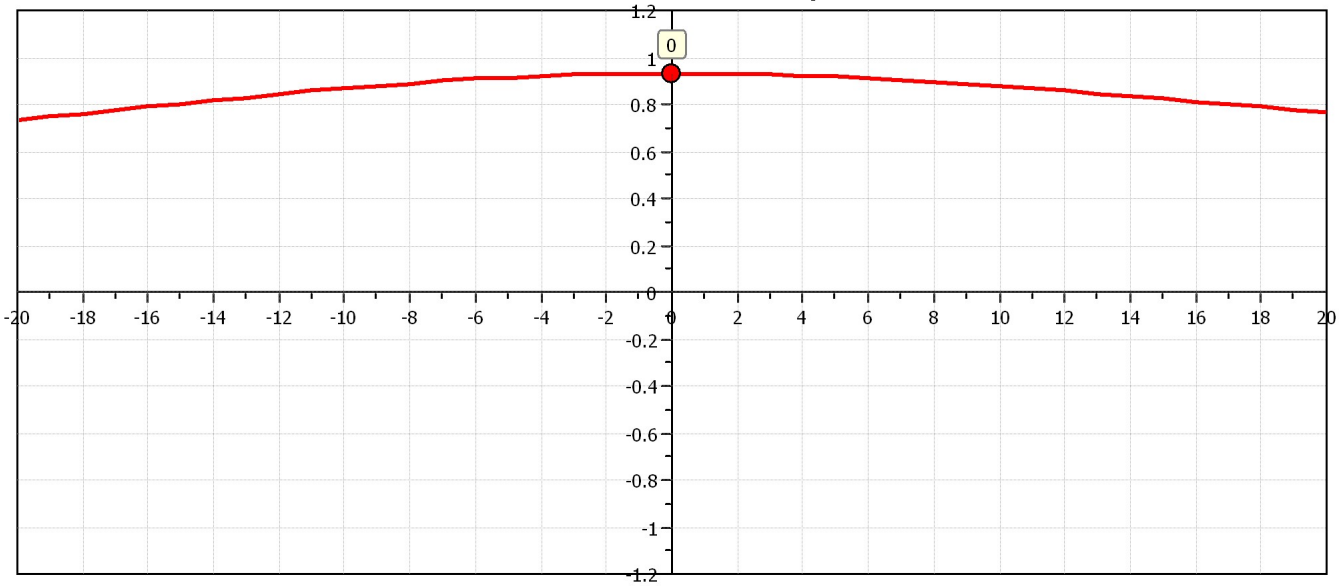
CPT: CPTU1
Total depth: 20.30 m, Date: 09/12/2021
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

Project:
Location:

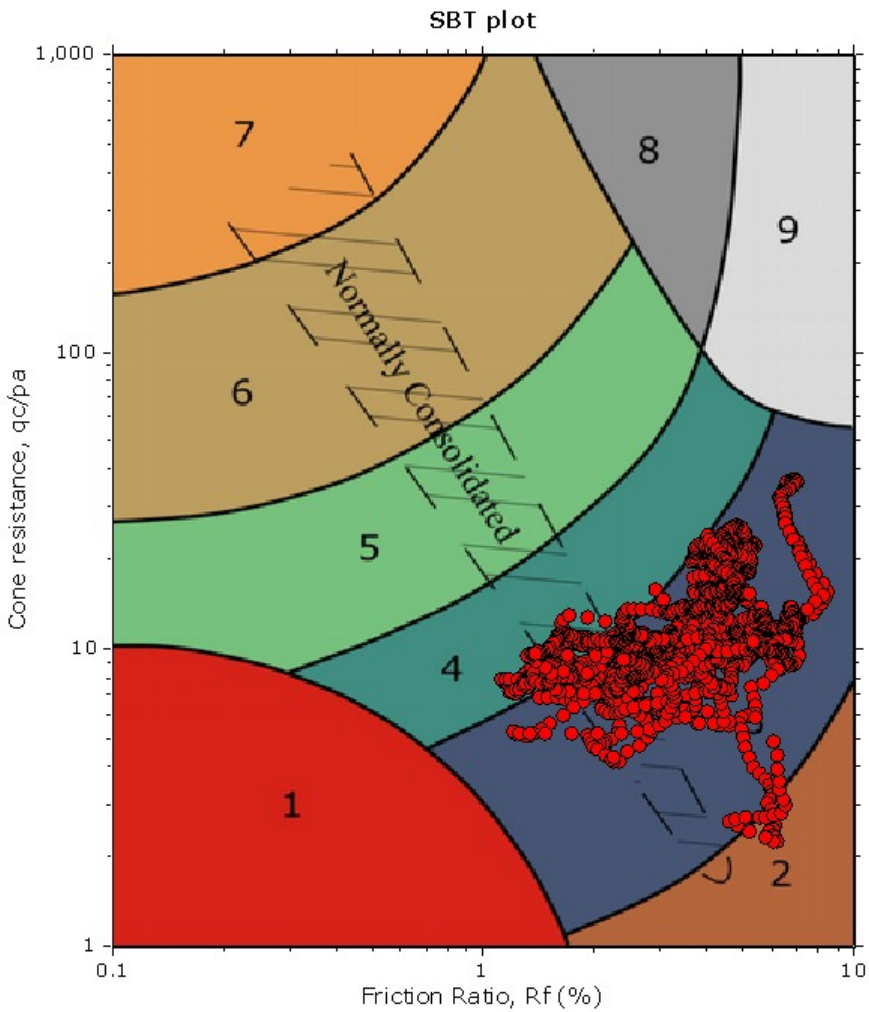


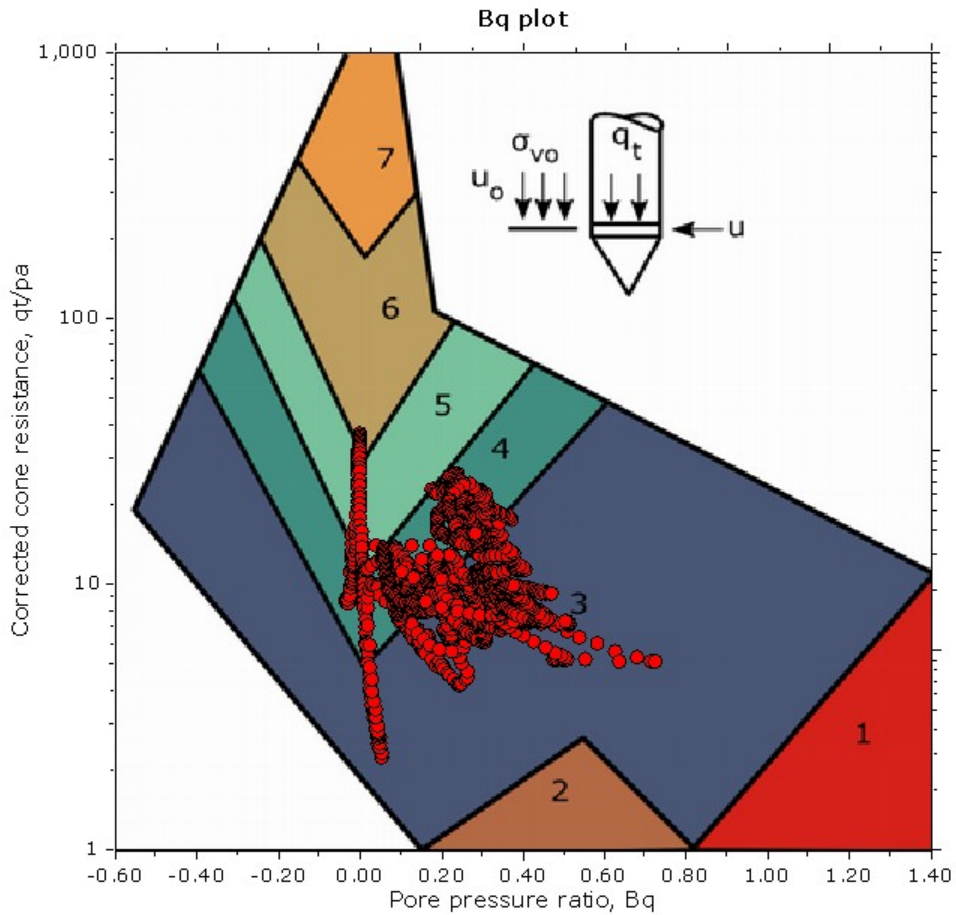
The plot below presents the cross correlation coeficient between the raw qc and fs values (as measured on the field). X axes presents the lag distance (one lag is the distance between two sucessive CPT measurements).

Cross correlation between qc & fs



SBT - Bq plots

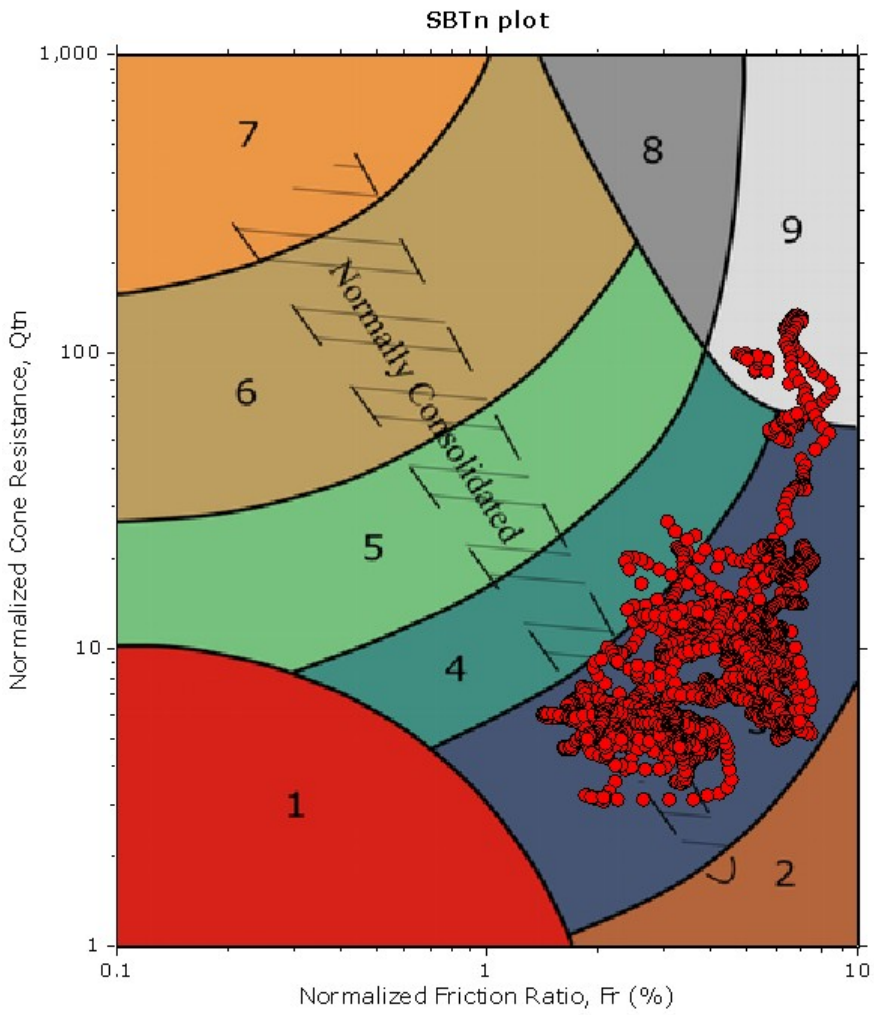


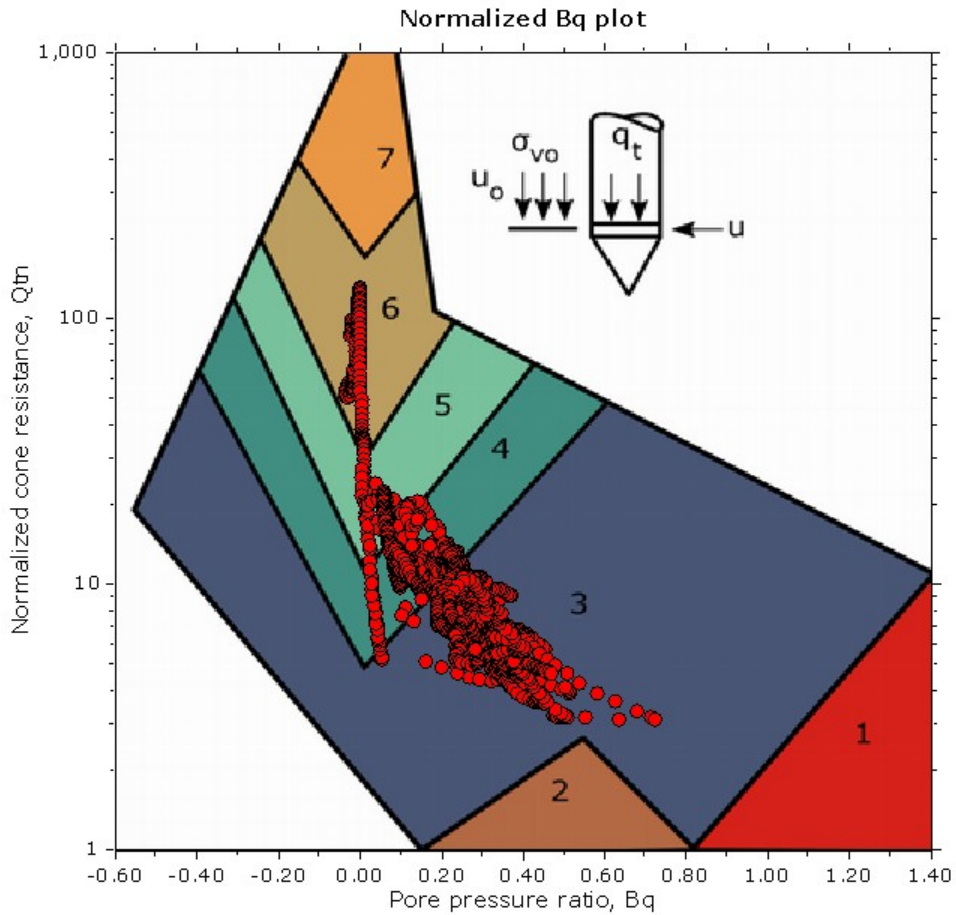


SBT legend

1. Sensitive fine grained
2. Organic material
3. Clay to silty clay
4. Clayey silt to silty clay
5. Silty sand to sandy silt
6. Clean sand to silty sand
7. Gravelly sand to sand
8. Very stiff sand to clayey sand
9. Very stiff fine grained

SBT - Bq plots (normalized)

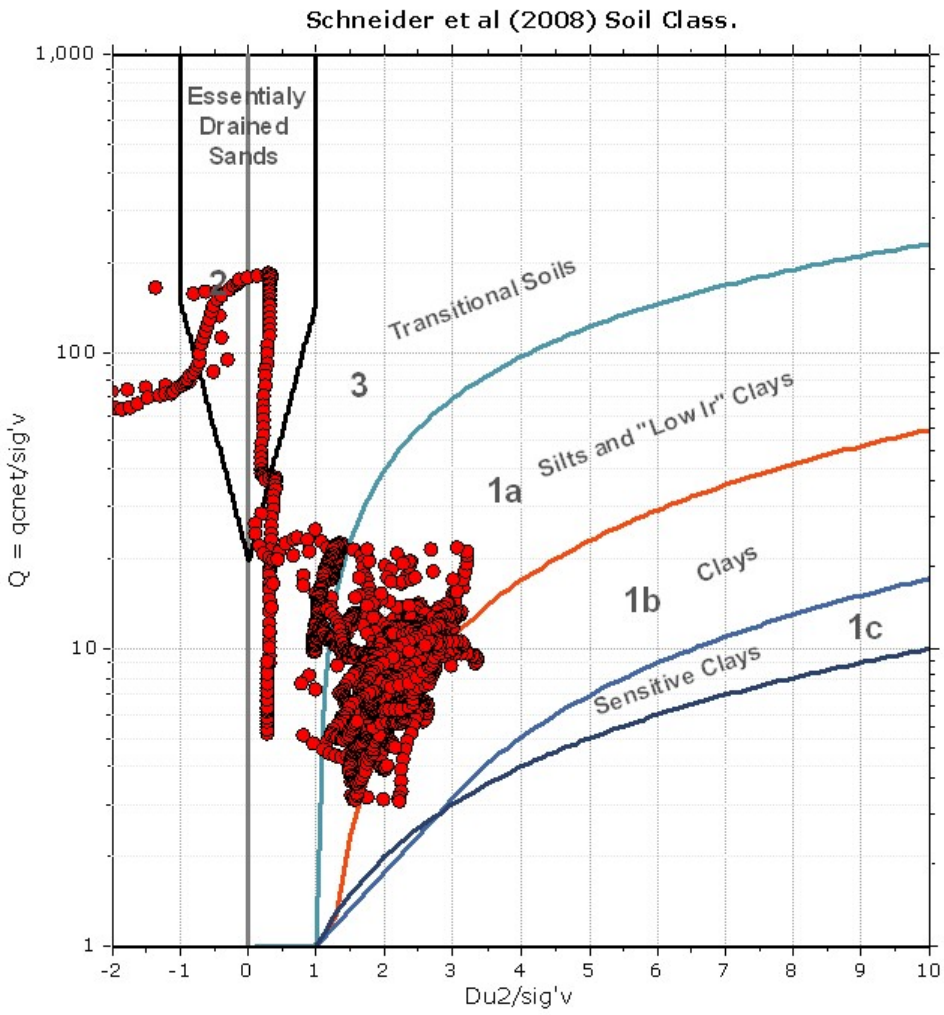


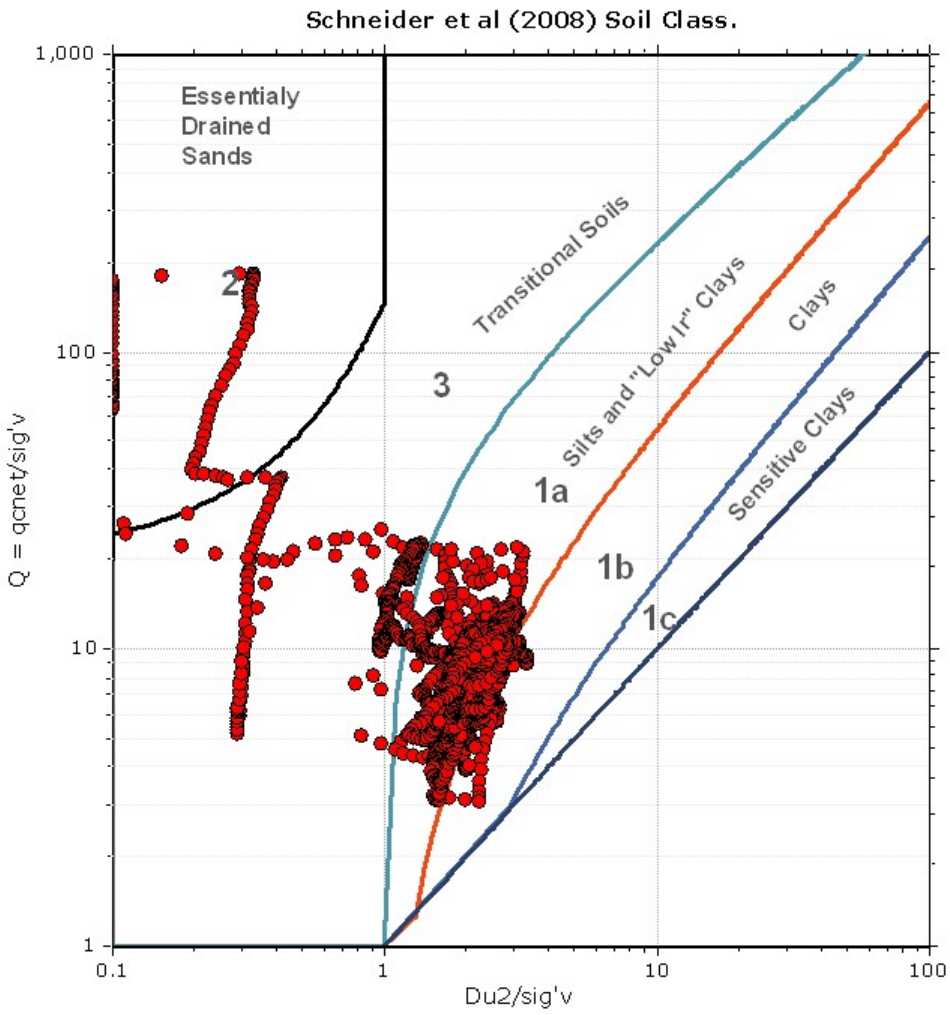


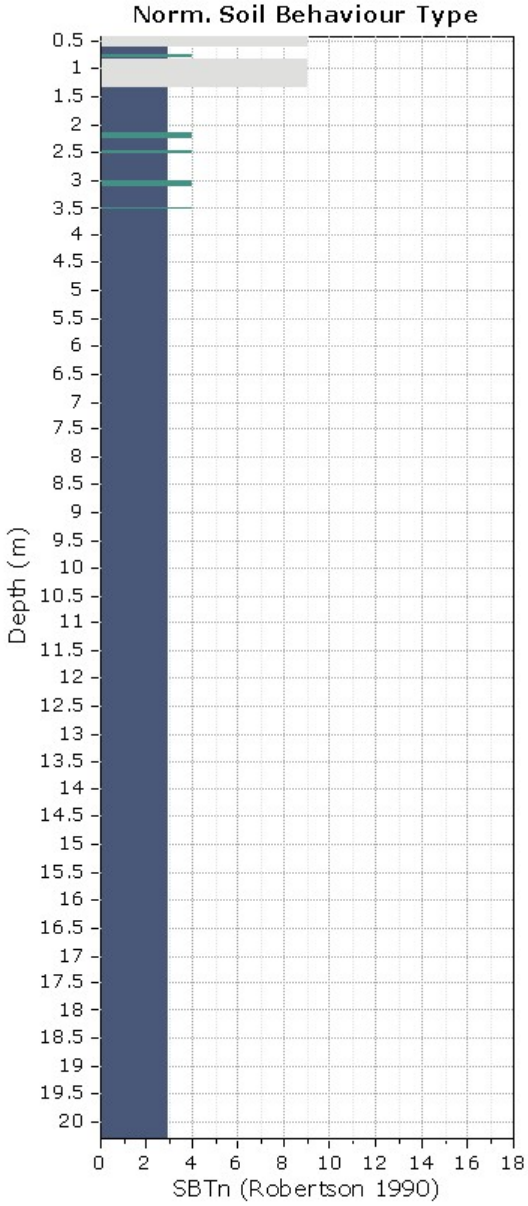
SBTn legend

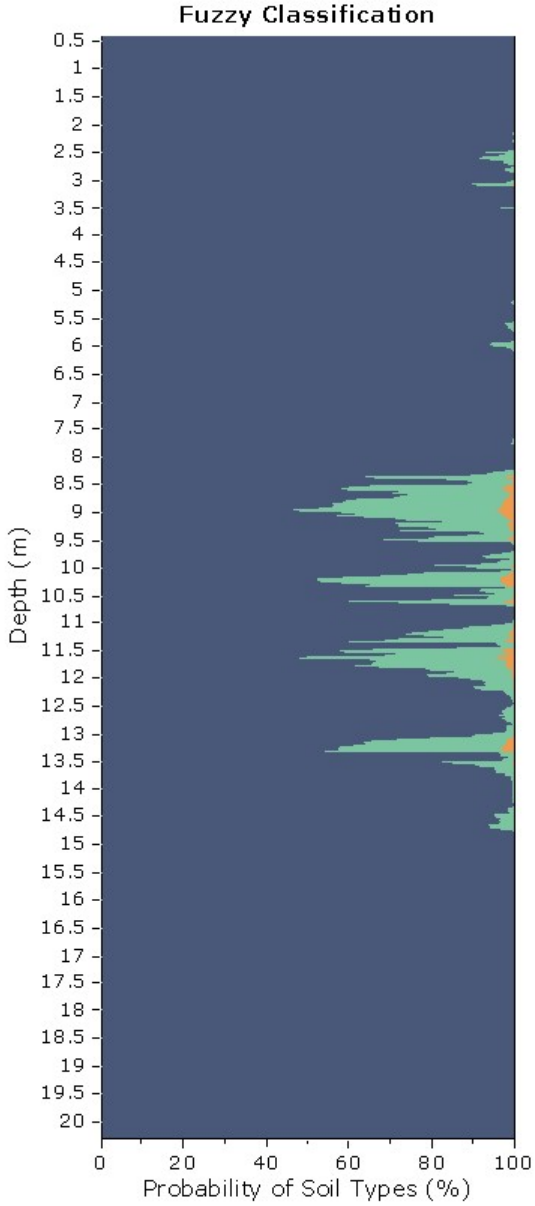
- 1. Sensitive fine grained
- 2. Organic material
- 3. Clay to silty clay
- 4. Clayey silt to silty clay
- 5. Silty sand to sandy silt
- 6. Clean sand to silty sand
- 7. Gravelly sand to sand
- 8. Very stiff sand to clayey sand
- 9. Very stiff fine grained

Bq plots (Schneider)






Norm. Soil Behaviour Type
Depth (m)
SBTn (Robertson 1990)


Fuzzy Classification
Depth (m)
Probability of Soil Types (%)

Geo Group Srl
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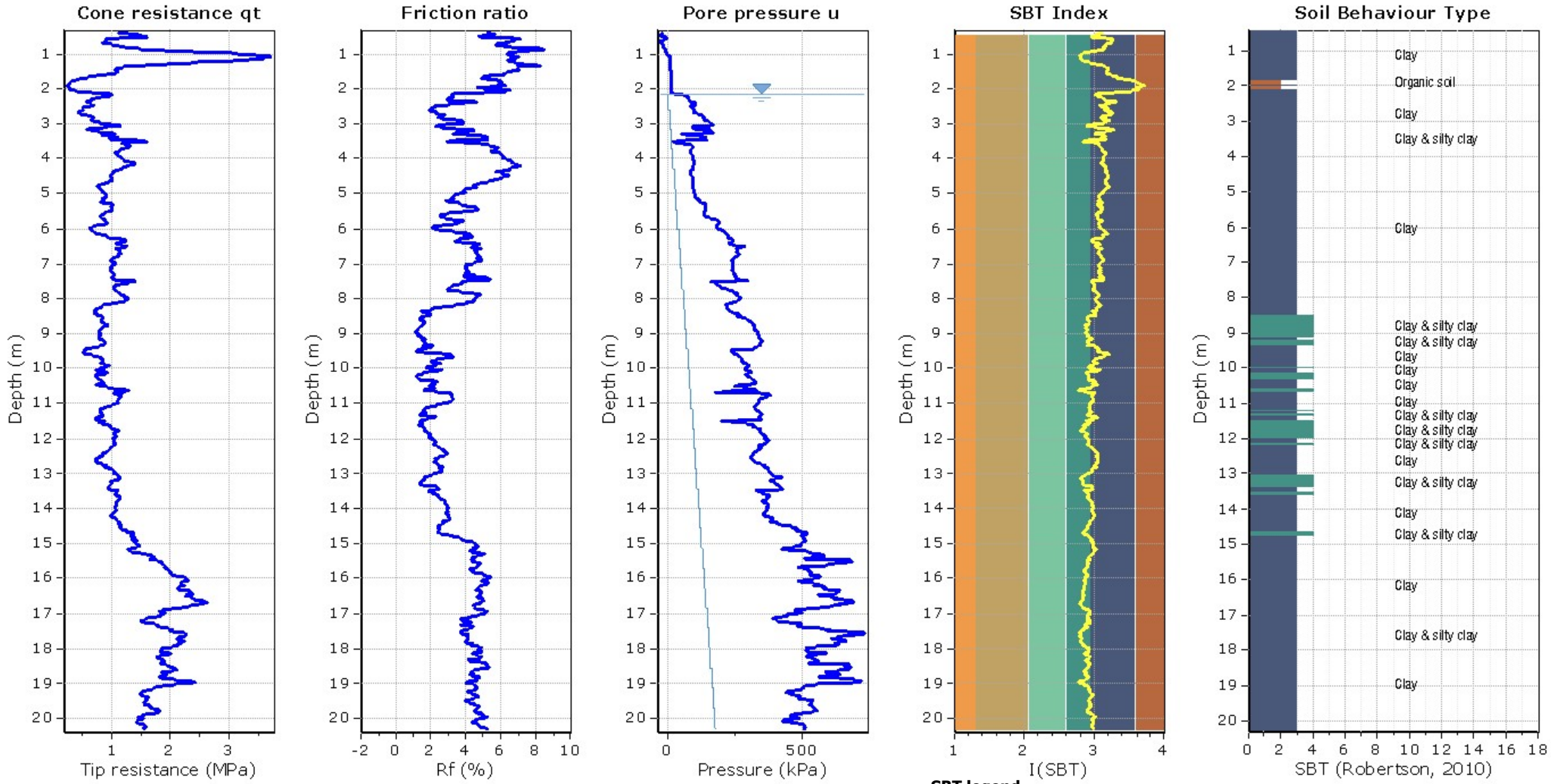
Via Cesare Costa 182
www.geogroupmodena.it

CPT: CPTU1
Total depth: 20.30 m, Date: 09/12/2021
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

Project:
Location:



SBT legend

1. Sensitive fine grained
2. Organic material
3. Clay to silty clay
4. Clayey silt to silty clay
5. Silty sand to sandy silt
6. Clean sand to silty sand
7. Gravely sand to sand
8. Very stiff sand to clayey sand
9. Very stiff fine grained

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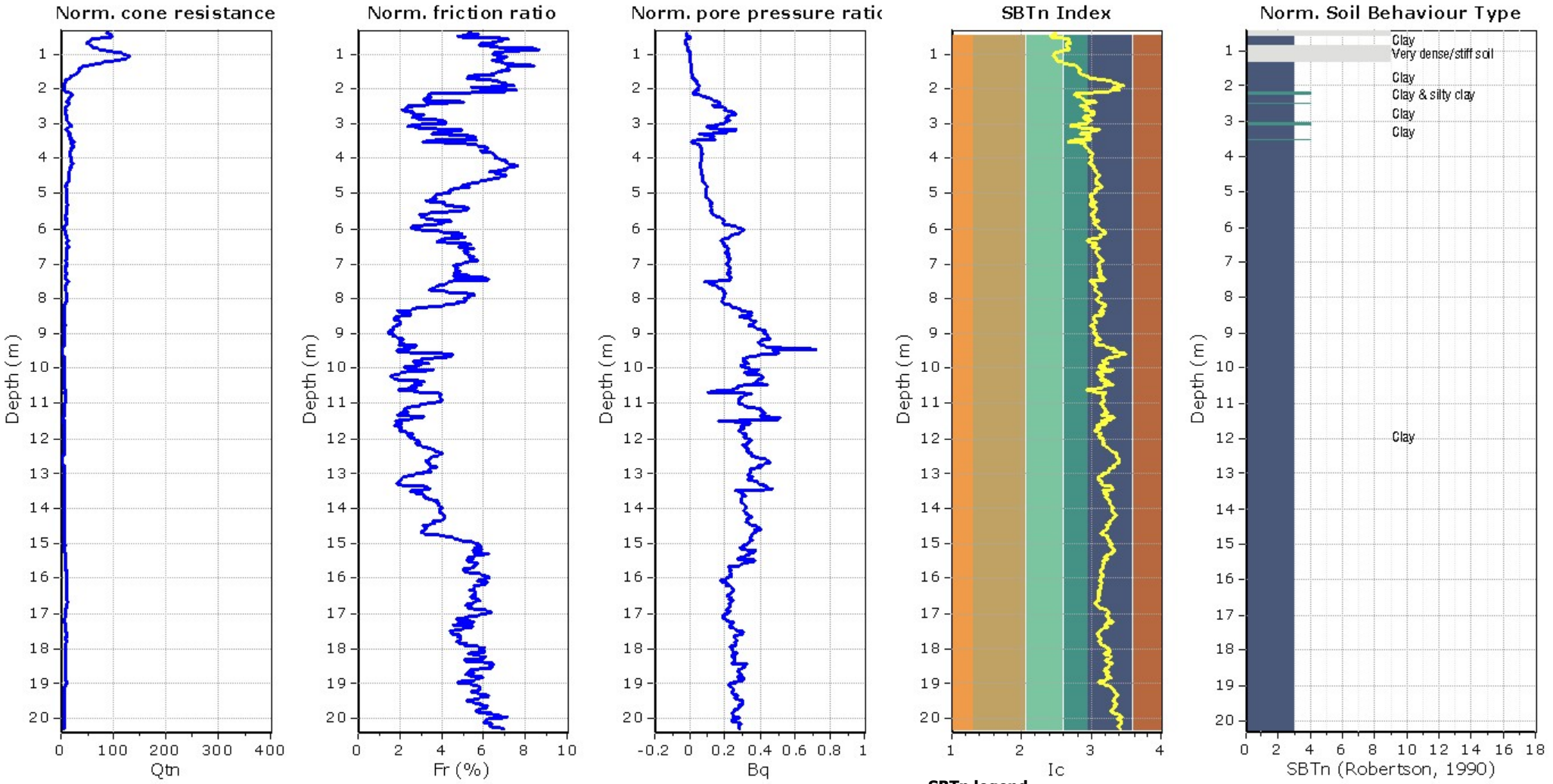
CPT: CPTU1
Total depth: 20.30 m, Date: 09/12/2021
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

Project:
Location:



SBTn legend

1. Sensitive fine grained
2. Organic material
3. Clay to silty clay
4. Clayey silt to silty clay
5. Silty sand to sandy silt
6. Clean sand to silty sand
7. Gravely sand to sand
8. Very stiff sand to clayey sand
9. Very stiff fine grained

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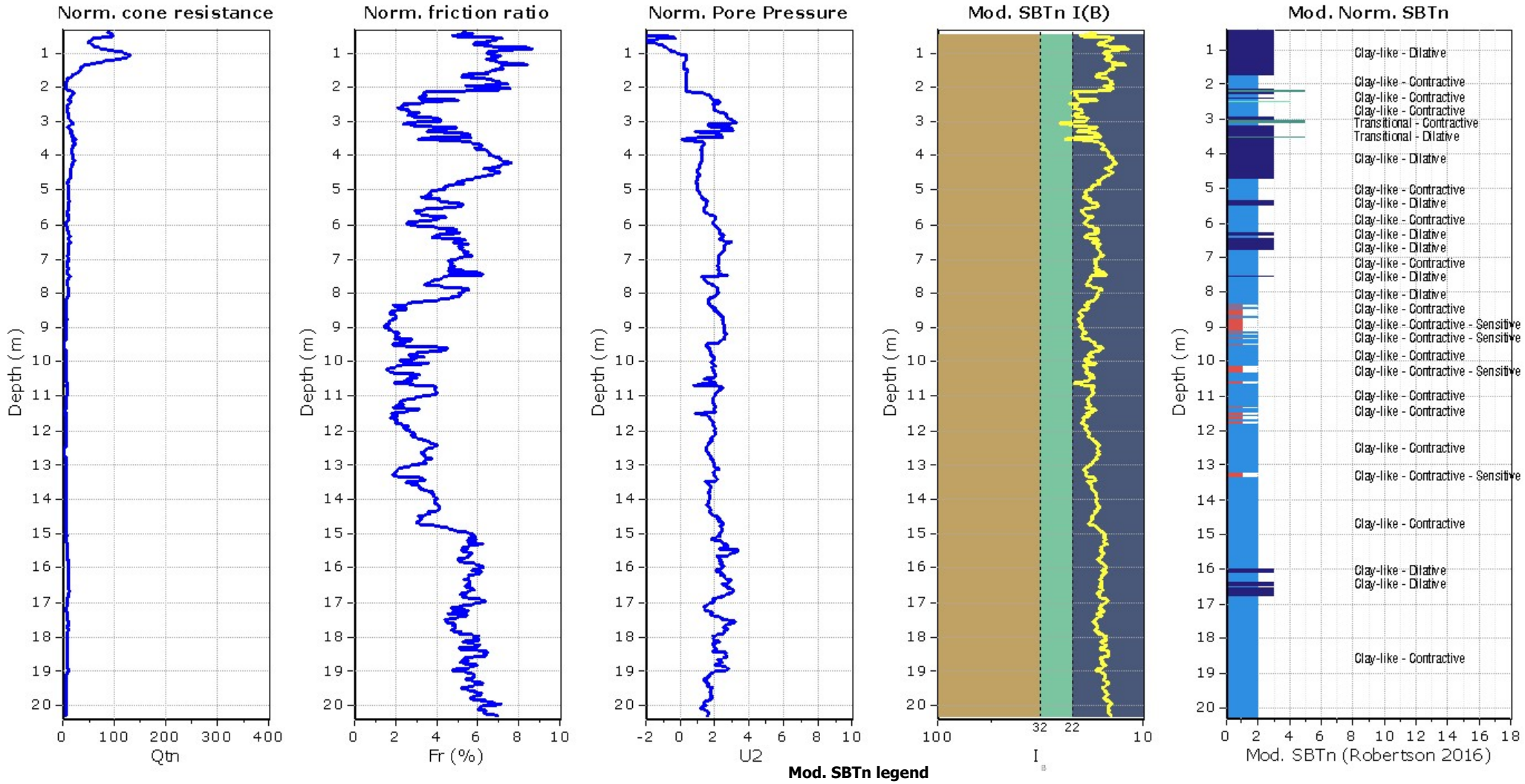
CPT: CPTU1
Total depth: 20.30 m, Date: 09/12/2021
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

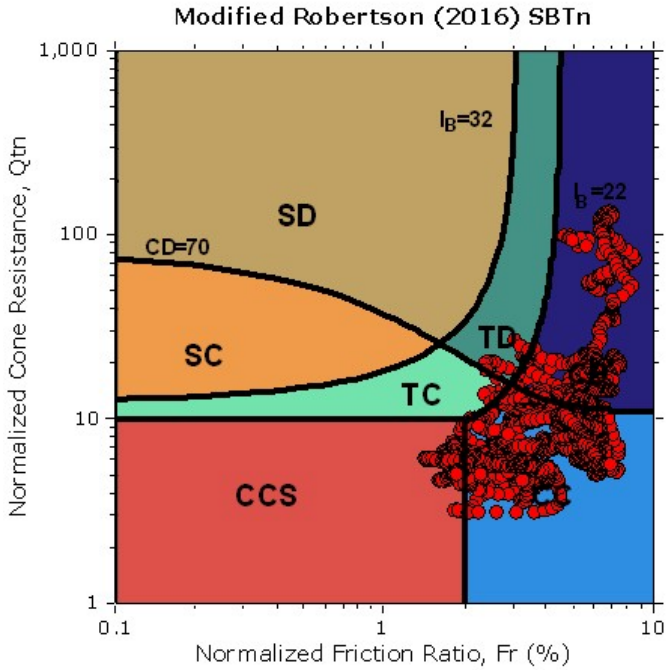
Project:
Location:

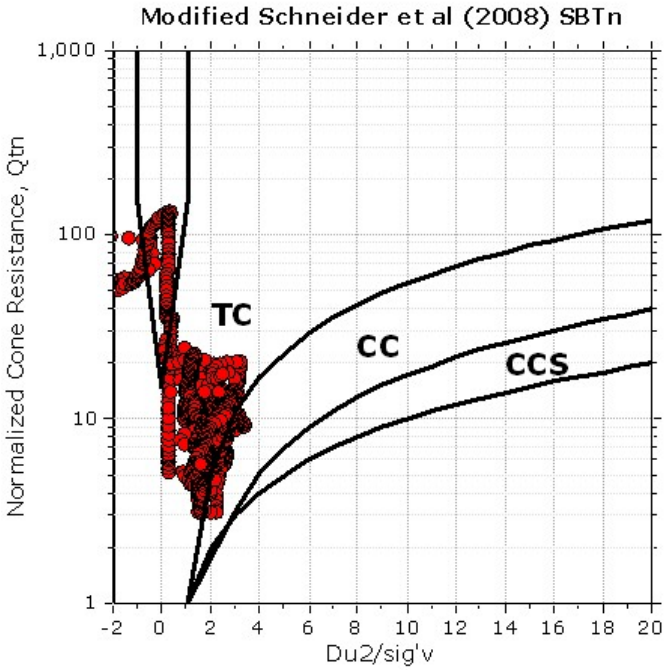


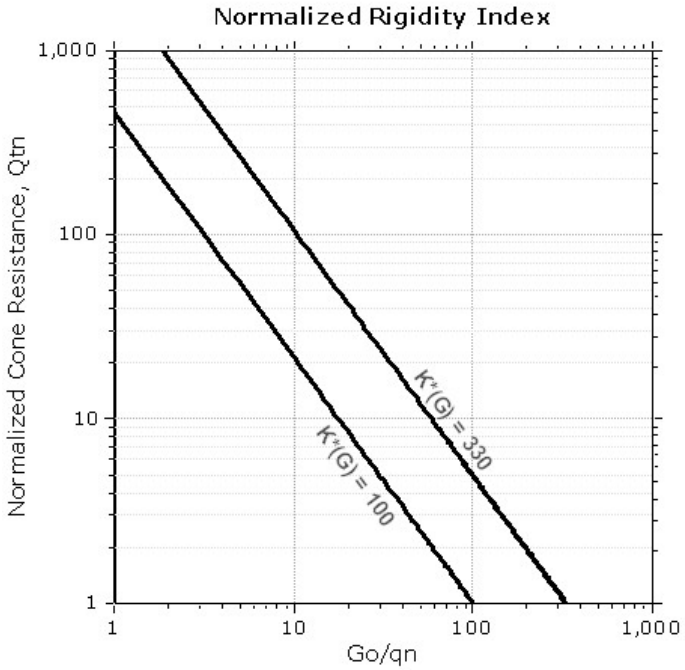
Mod. SBTn legend

1. CCS: ClayLike - Contractive, Sensitive
2. CC: Clay-like - Contractive
3. CD: Clay-Like: Dilative
4. TC: Transitional - Contractive
5. TD: Transitional - Dilative
6. SC: Sand-like - Contractive
7. SD: Sand-like - Dilative

Updated SBTn plots

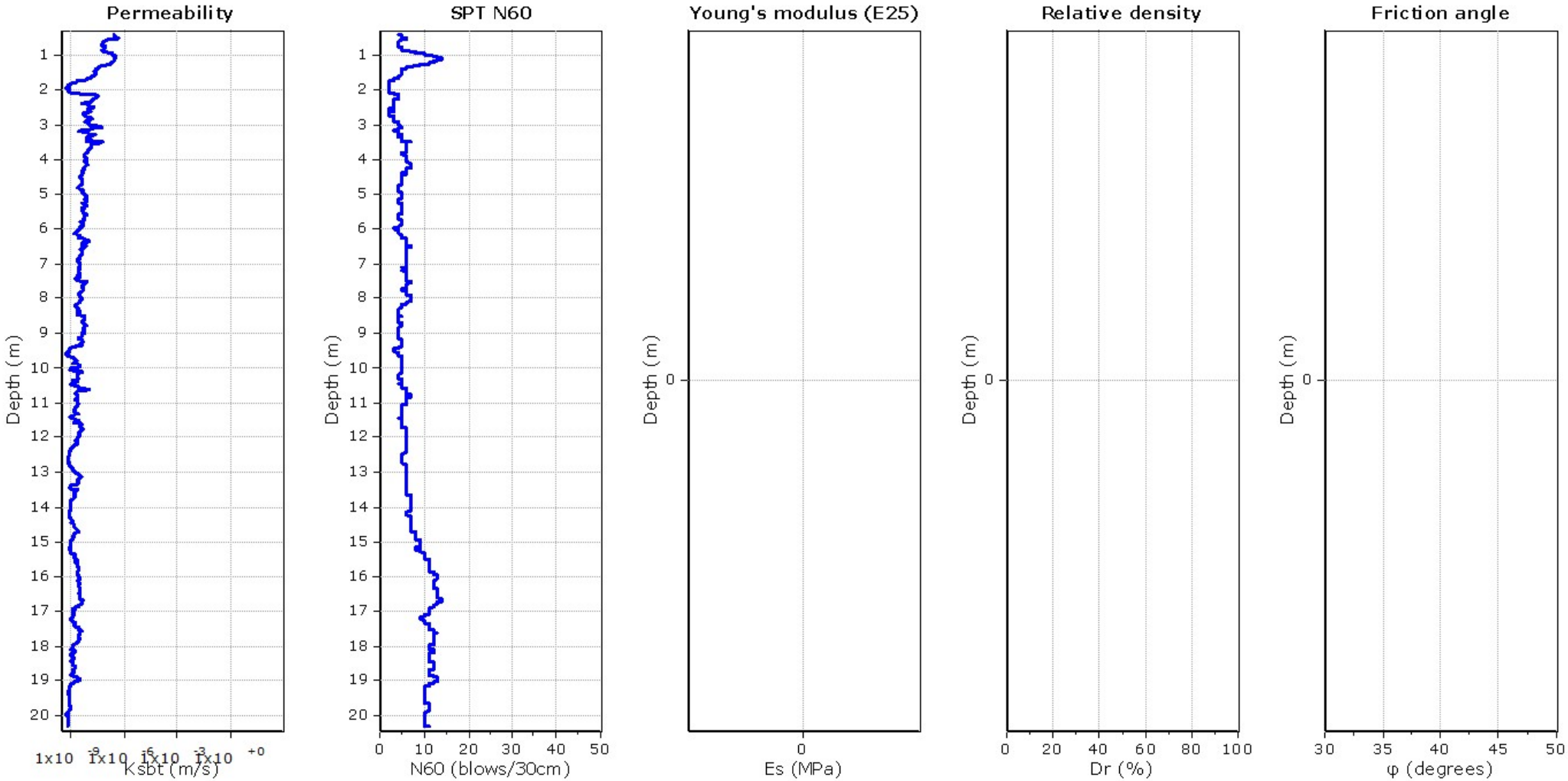






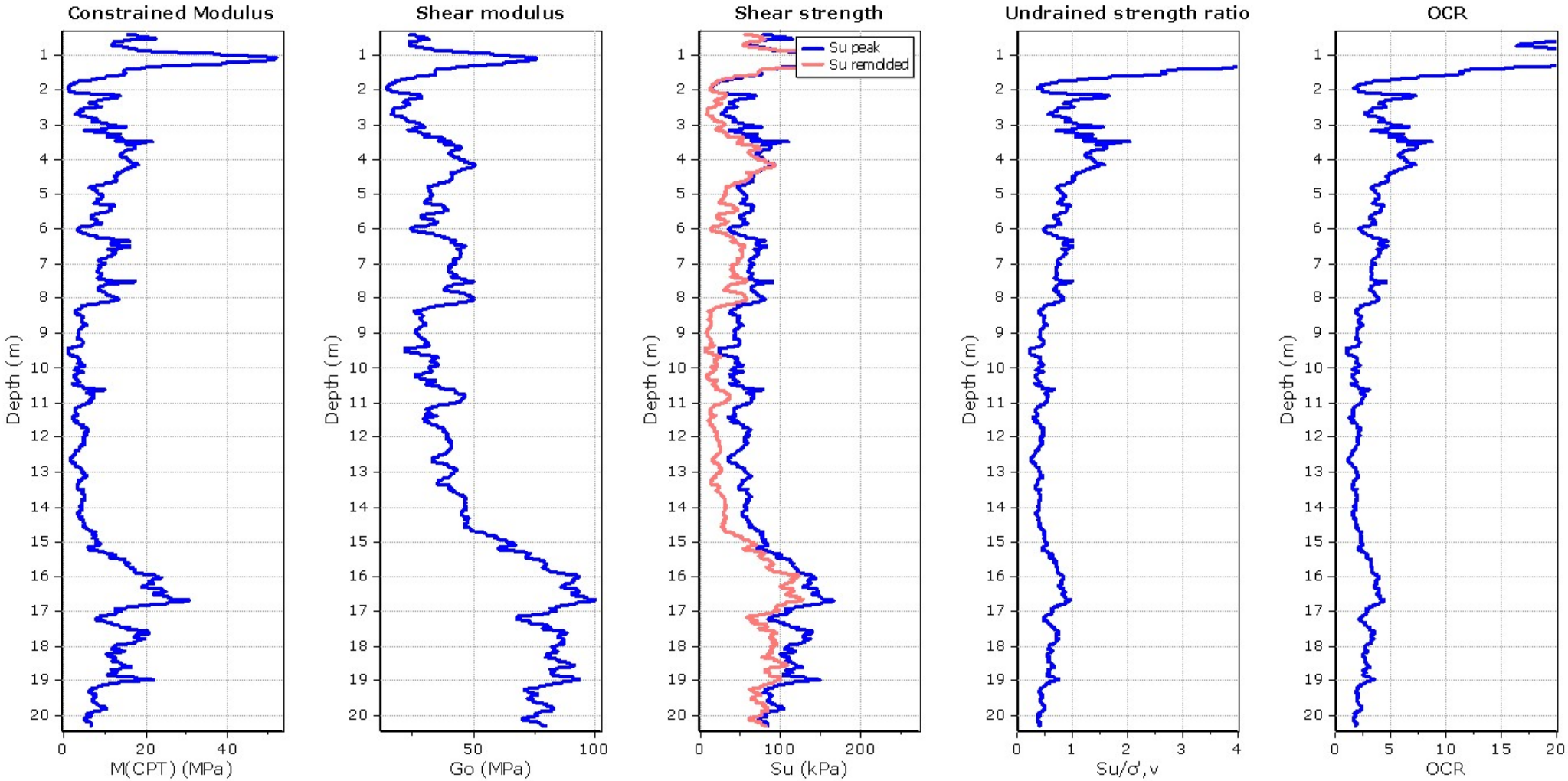
CCS: Clay-like - Contractive - Sensitive
CC: Clay-like - Contractive
CD: Clay-like - Dilative
TC: Transitional - Contractive
TD: Transitional - Dilative
SC: Sand-like - Contractive
SD: Sand-like - Dilative

K(G) > 330: Soils with significant microstructure (e.g. age/cementation)



Calculation parameters

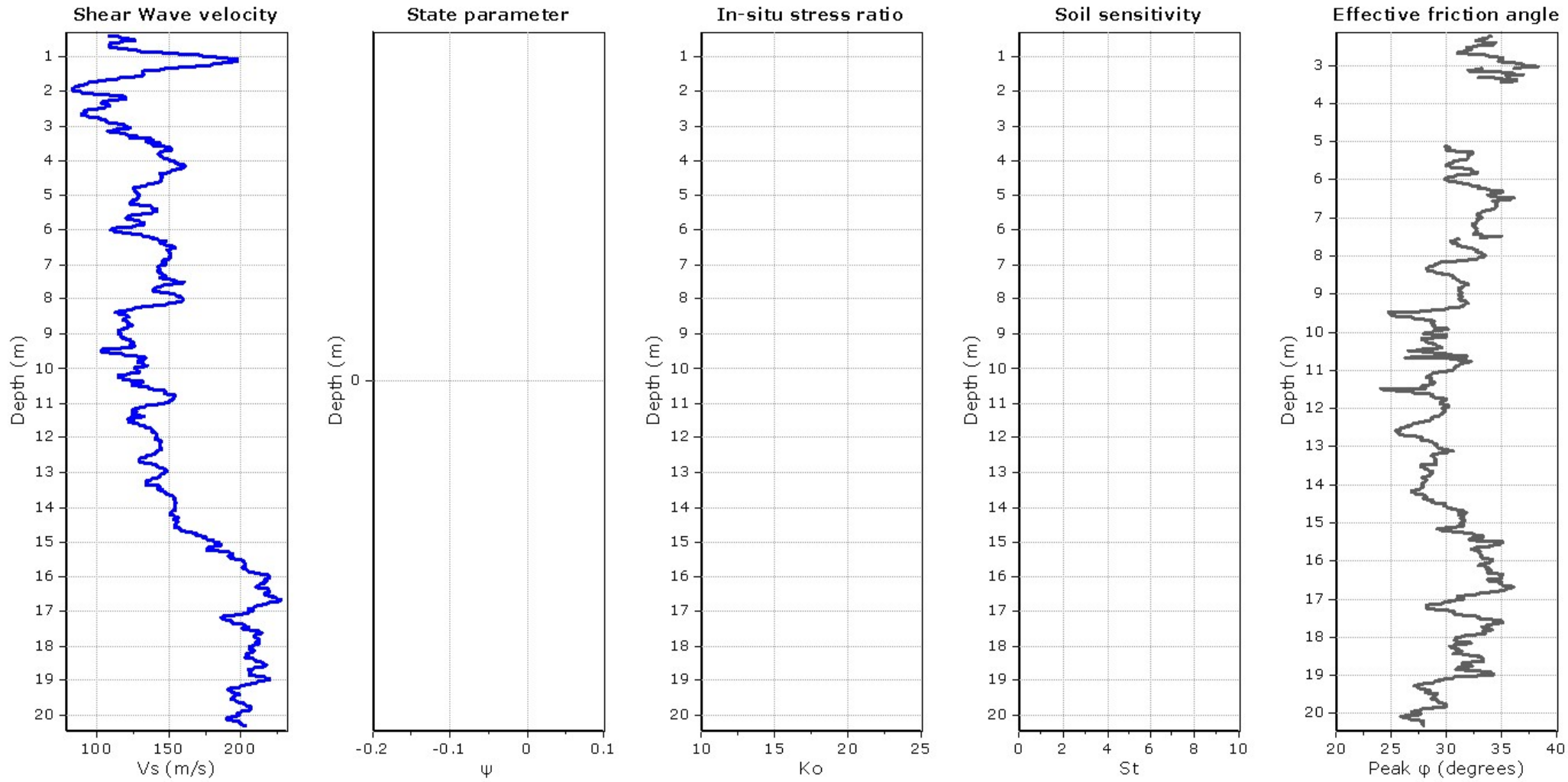
Permeability: Based on SBT_n
SPT N_{60}: Based on I_c and q_t
Young's modulus: Based on variable alpha using I_c (Robertson, 2009)
Relative density constant, C_{Dr}: 350.0
Phi: Based on Kulhawy & Mayne (1990)
User defined estimation data



Calculation parameters

Constrained modulus: Based on variable alpha using I_c and Q_{tn} (Robertson, 2009)
Go: Based on variable alpha using I_c (Robertson, 2009)
Undrained shear strength cone factor for clays, N_{kt}: 14

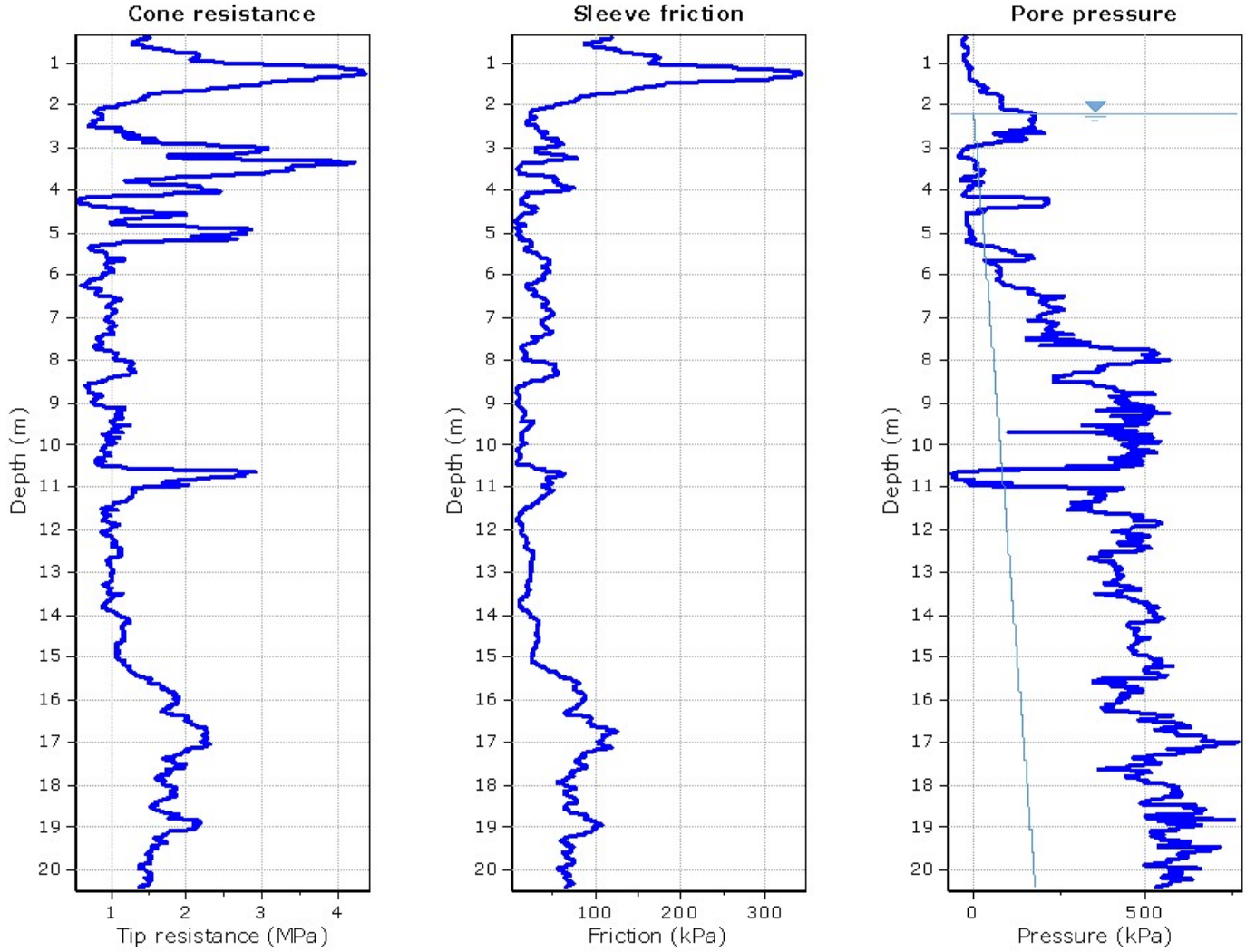
OCR factor for clays, N_{kt}: 0.33
User defined estimation data
Flat Dilatometer Test data



Calculation parameters

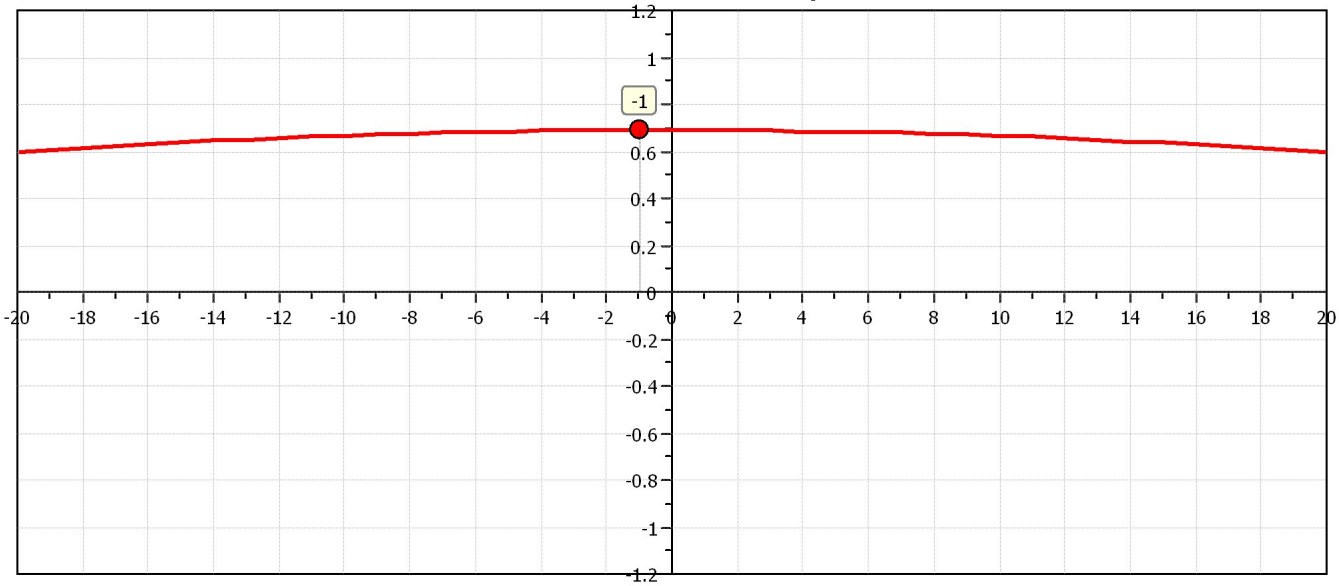
Soil Sensitivity factor, N_S: 350.00

User defined estimation data

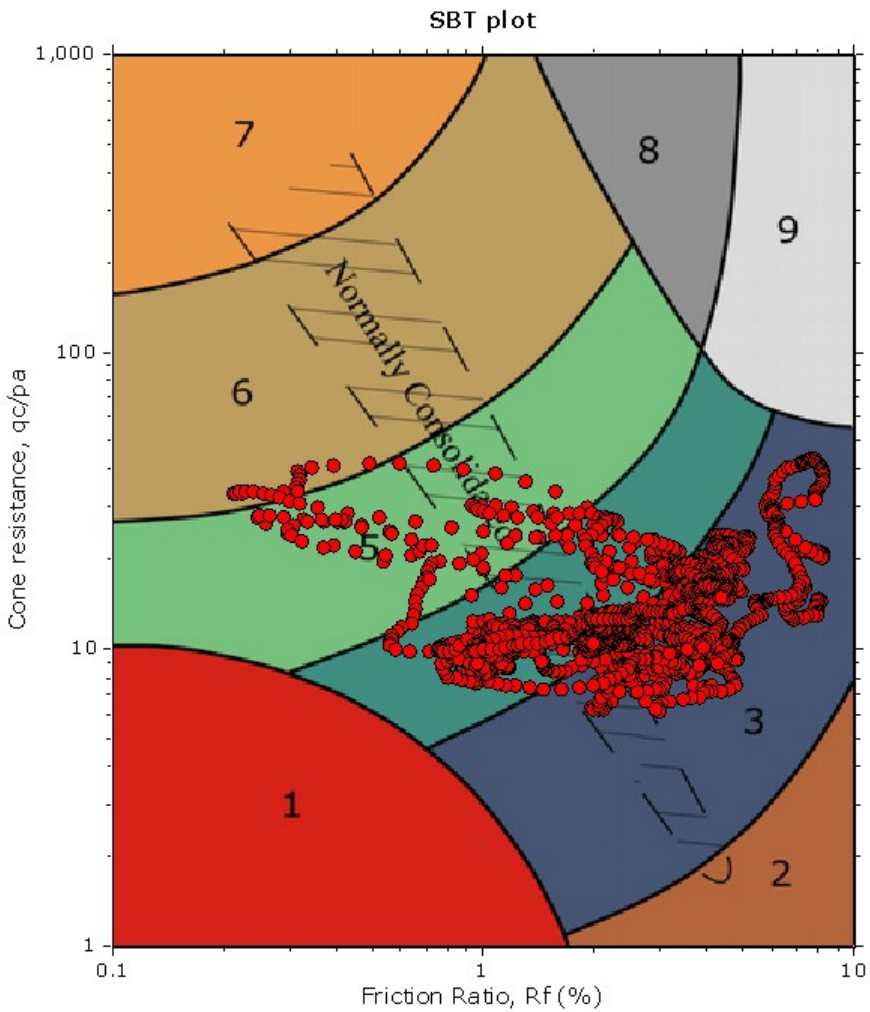


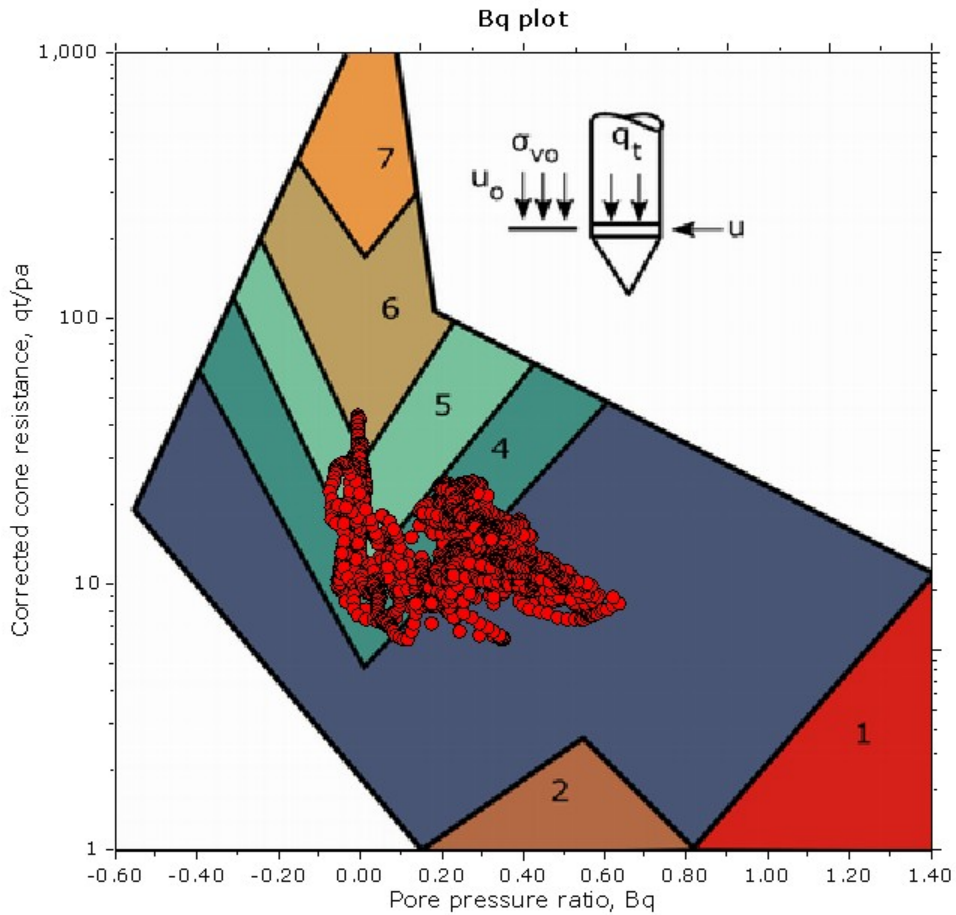
The plot below presents the cross correlation coeficient between the raw qc and fs values (as measured on the field). X axes presents the lag distance (one lag is the distance between two sucessive CPT measurements).

Cross correlation between qc & fs



SBT - Bq plots

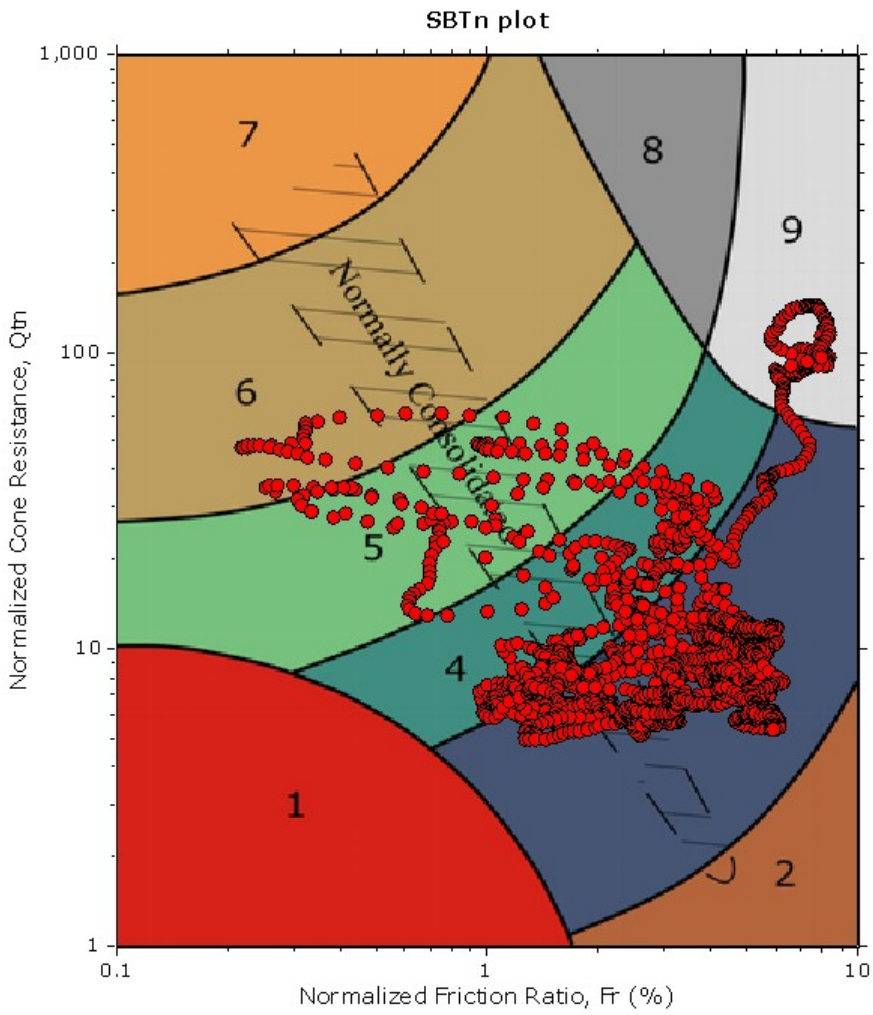


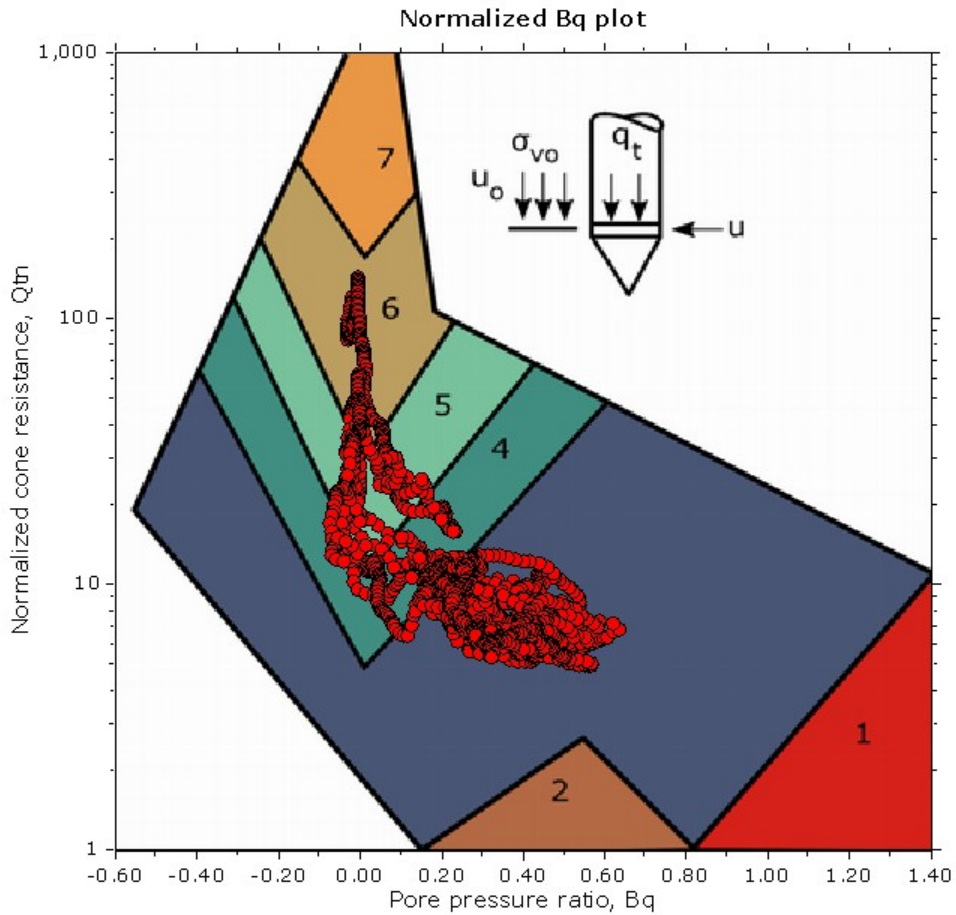


SBT legend

1. Sensitive fine grained
2. Organic material
3. Clay to silty clay
4. Clayey silt to silty clay
5. Silty sand to sandy silt
6. Clean sand to silty sand
7. Gravelly sand to sand
8. Very stiff sand to clayey sand
9. Very stiff fine grained

SBT - Bq plots (normalized)





SBTn legend

- 1. Sensitive fine grained
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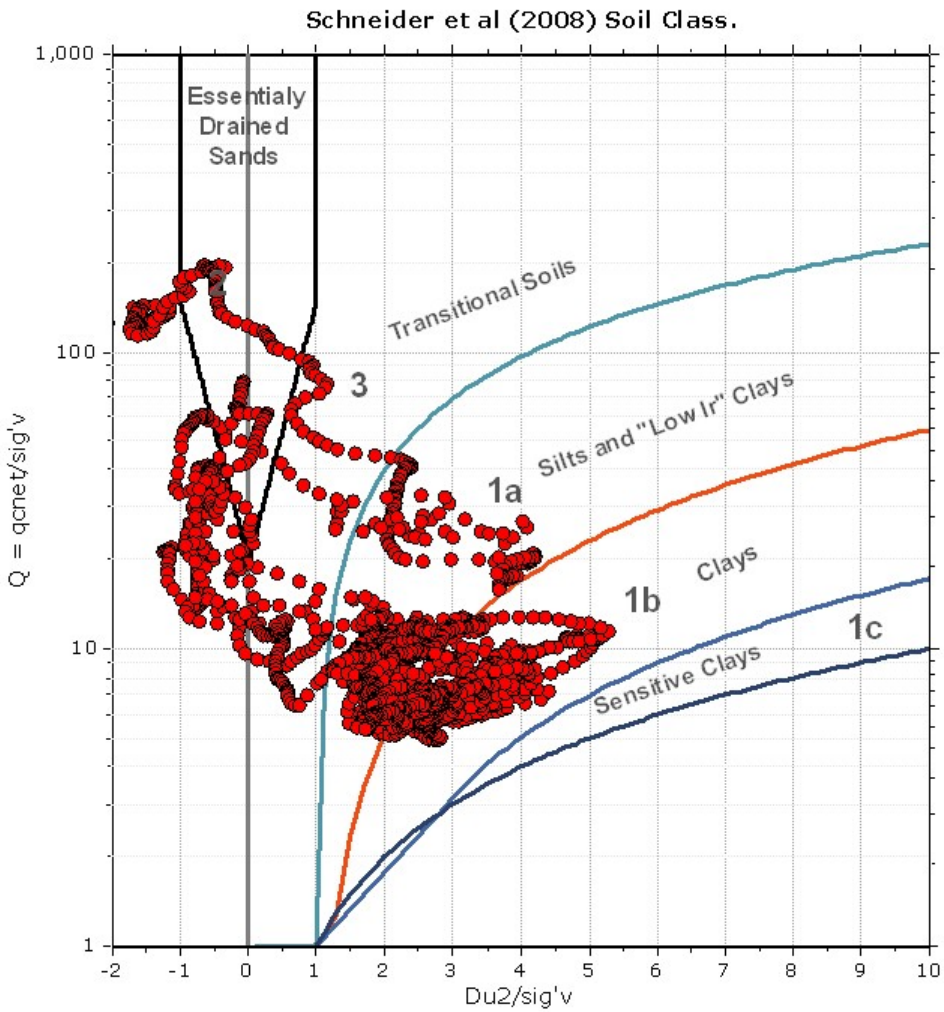
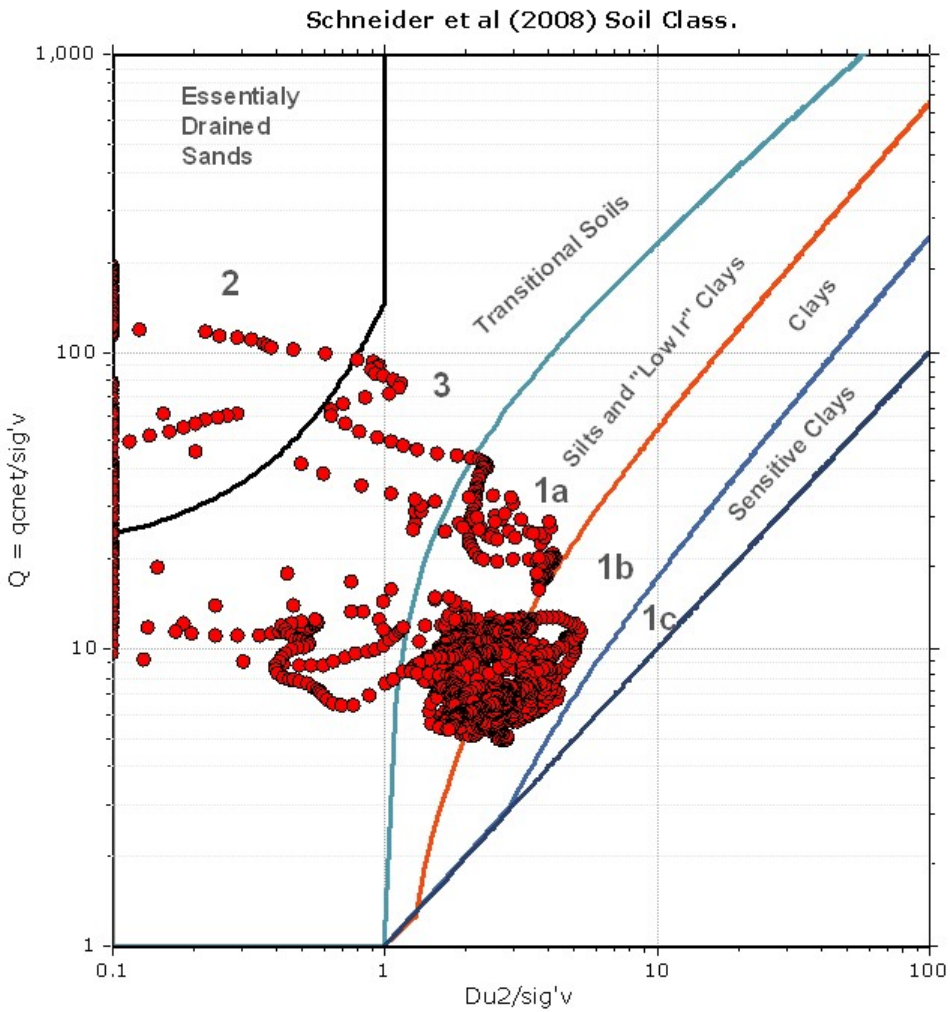
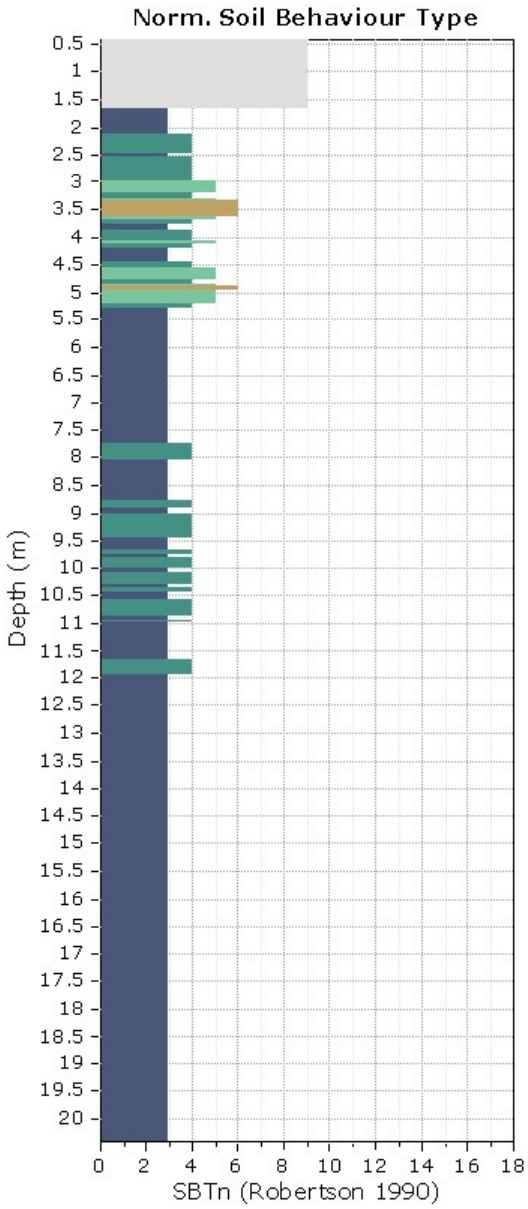
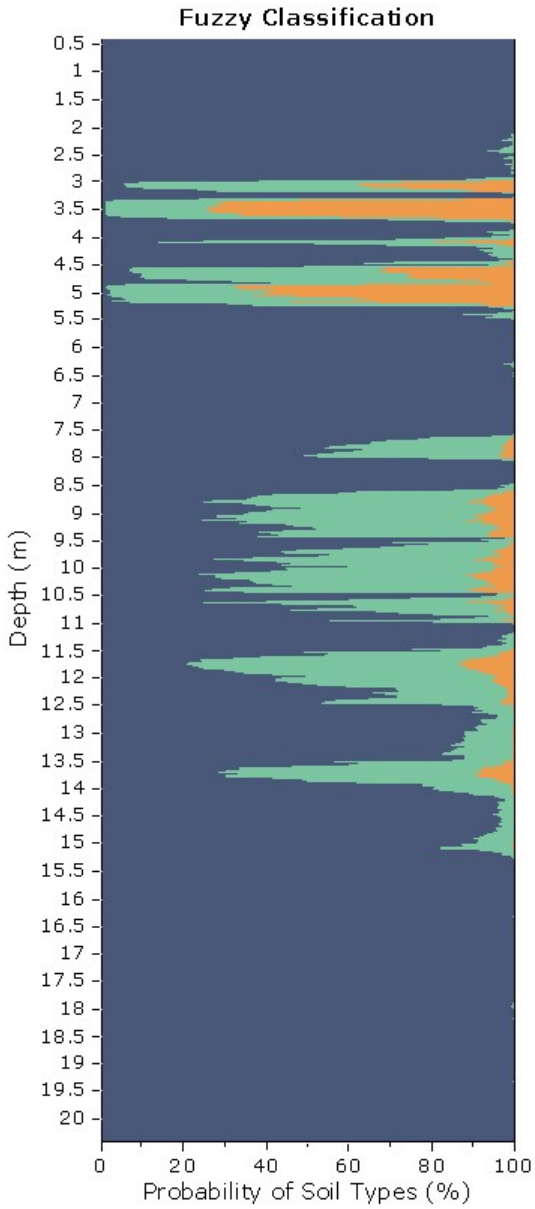
Bq plots (Schneider)






Norm. Soil Behaviour Type
Depth (m)
SBTn (Robertson 1990)


Fuzzy Classification
Depth (m)
Probability of Soil Types (%)

Geo Group Srl
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Via Cesare Costa 182
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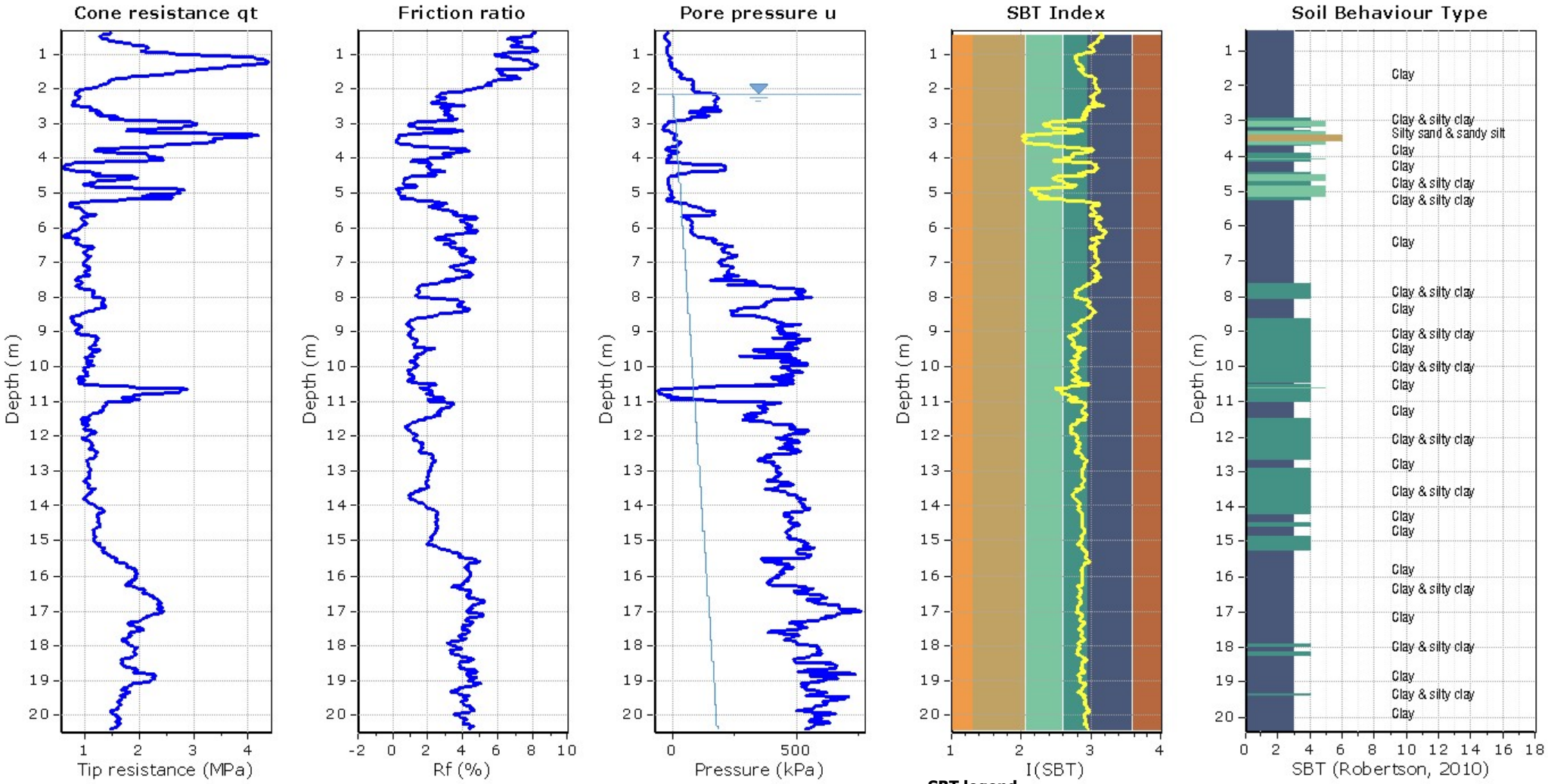
CPT: CPTU2
Total depth: 20.40 m, Date: 09/12/2021
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

Project:
Location:



SBT legend

1. Sensitive fine grained
2. Organic material
3. Clay to silty clay
4. Clayey silt to silty clay
5. Silty sand to sandy silt
6. Clean sand to silty sand
7. Gravely sand to sand
8. Very stiff sand to clayey sand
9. Very stiff fine grained

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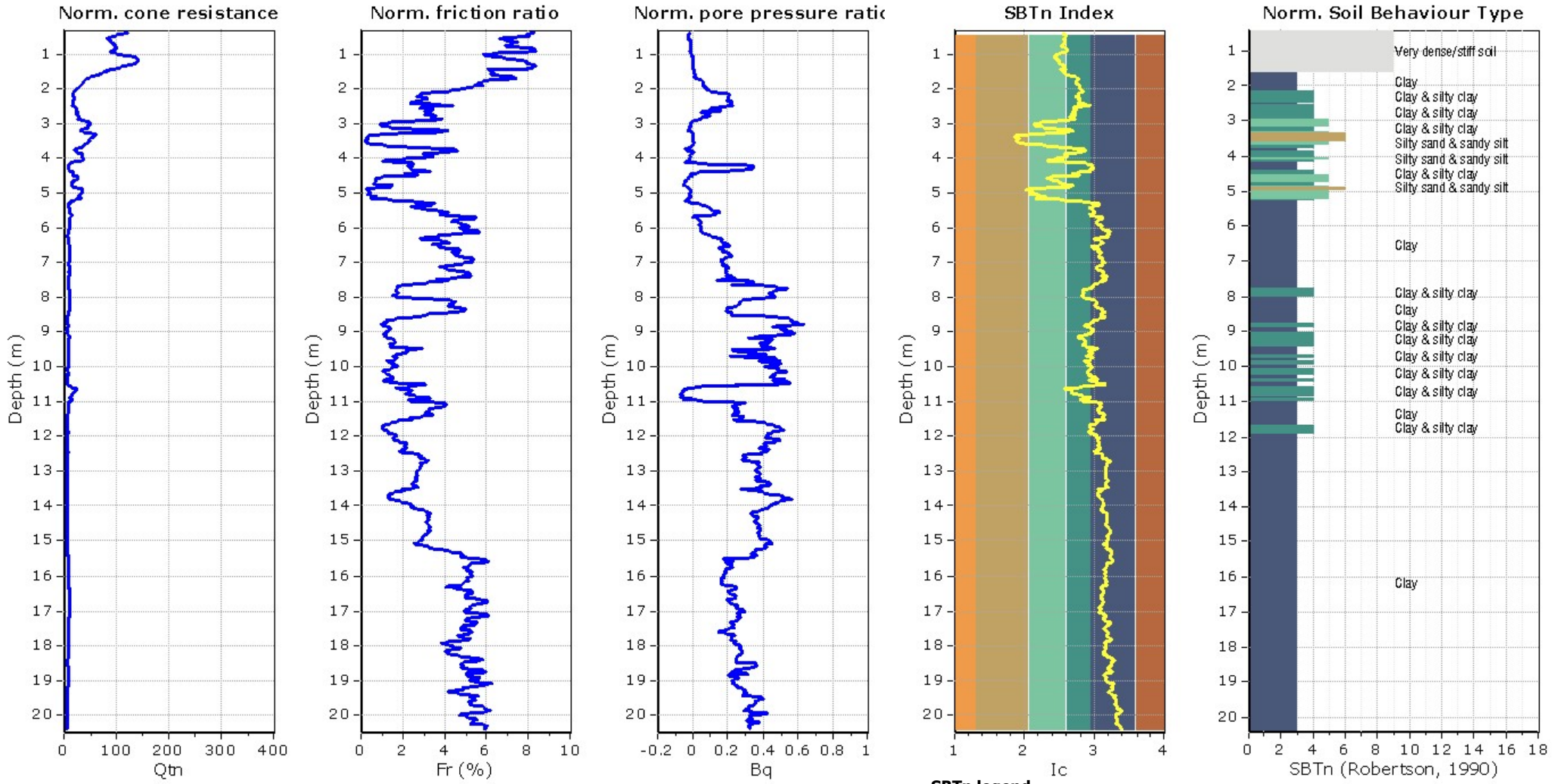
CPT: CPTU2
Total depth: 20.40 m, Date: 09/12/2021
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

Project:
Location:



SBTn legend

1. Sensitive fine grained
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5. Silty sand to sandy silt
6. Clean sand to silty sand
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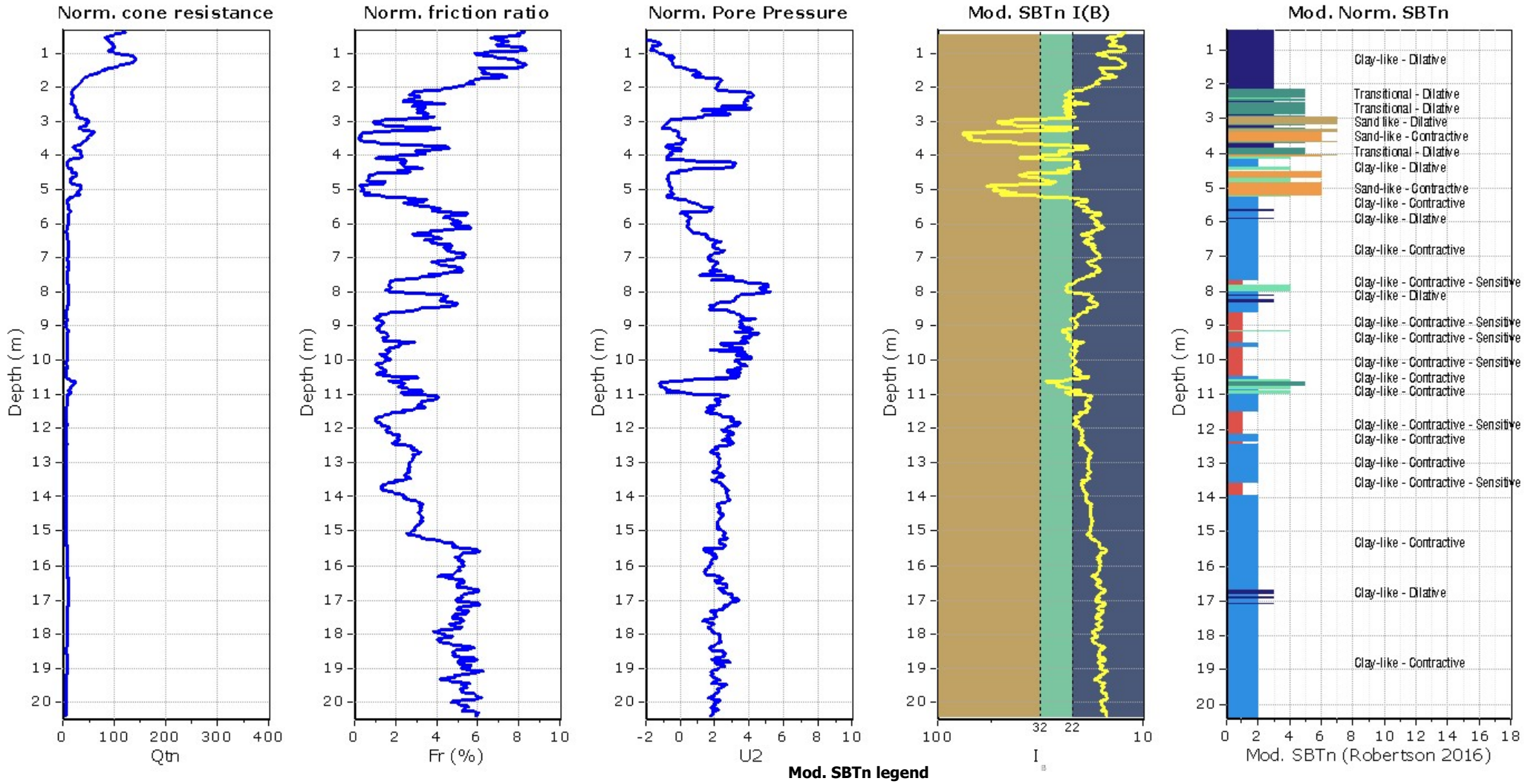
www.geogroupmodena.it

CPT: CPTU2
Total depth: 20.40 m, Date: 09/12/2021
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

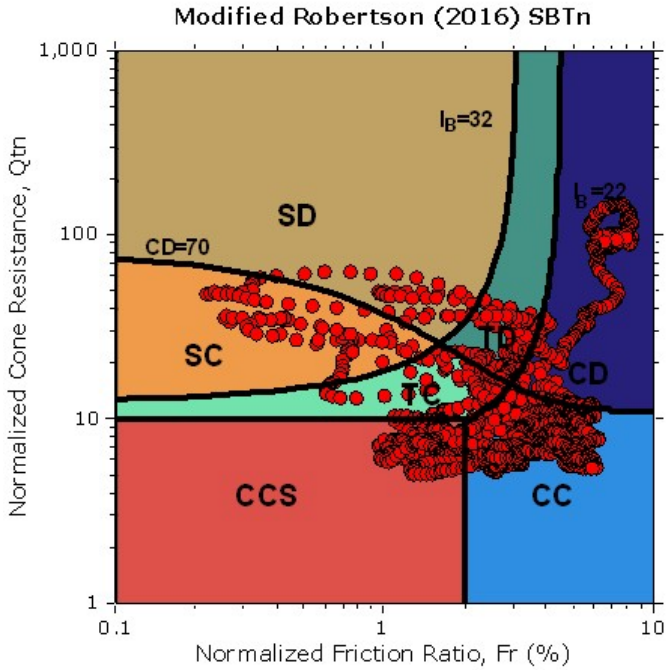
Project:
Location:

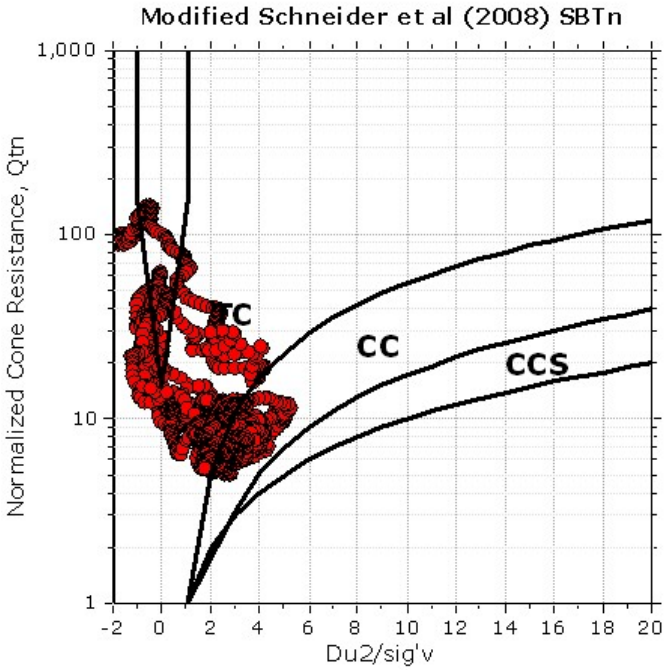


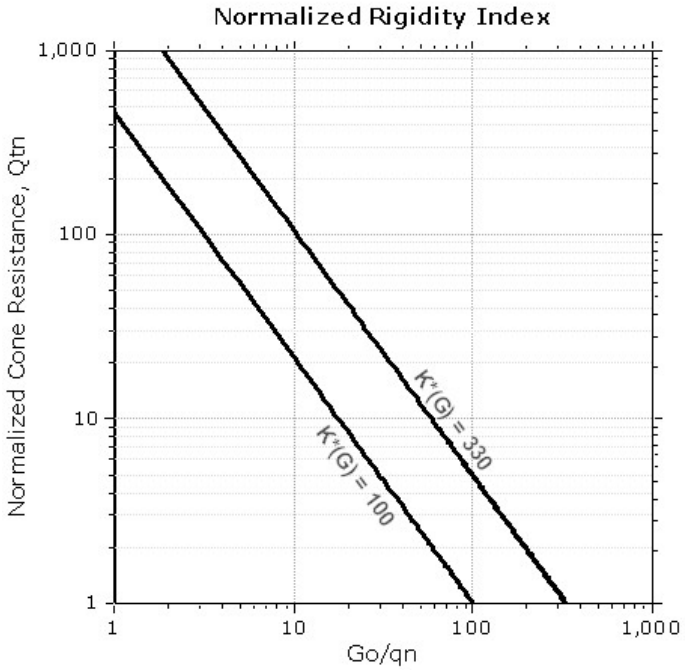
Mod. SBTn legend

1. CCS: ClayLike - Contractive, Sensitive
2. CC: Clay-like - Contractive
3. CD: Clay-Like: Dilative
4. TC: Transitional - Contractive
5. TD: Transitional - Dilative
6. SC: Sand-like - Contractive
7. SD: Sand-like - Dilative

Updated SBTn plots







CCS: Clay-like - Contractive - Sensitive
CC: Clay-like - Contractive
CD: Clay-like - Dilative
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TD: Transitional - Dilative
SC: Sand-like - Contractive
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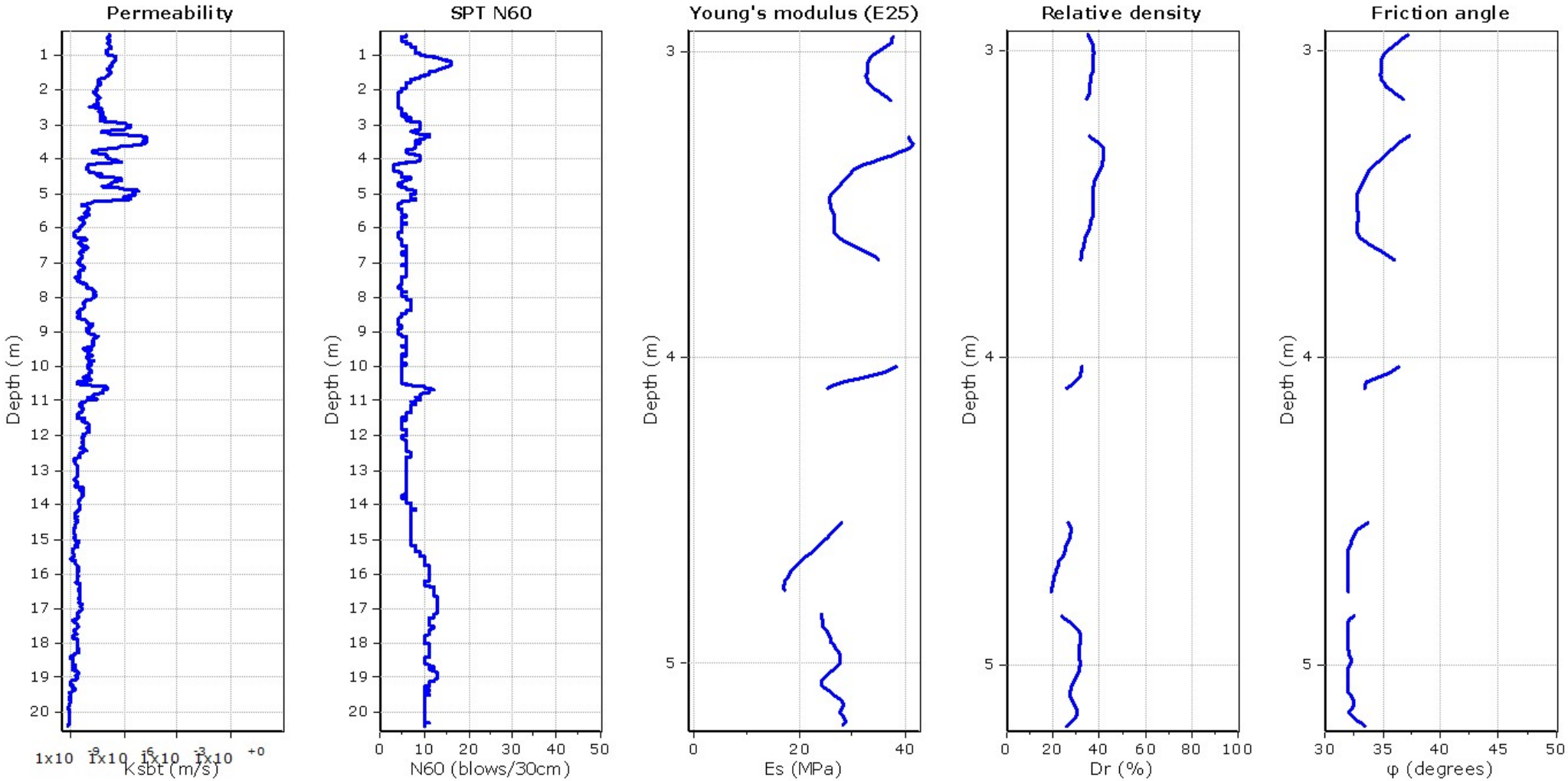
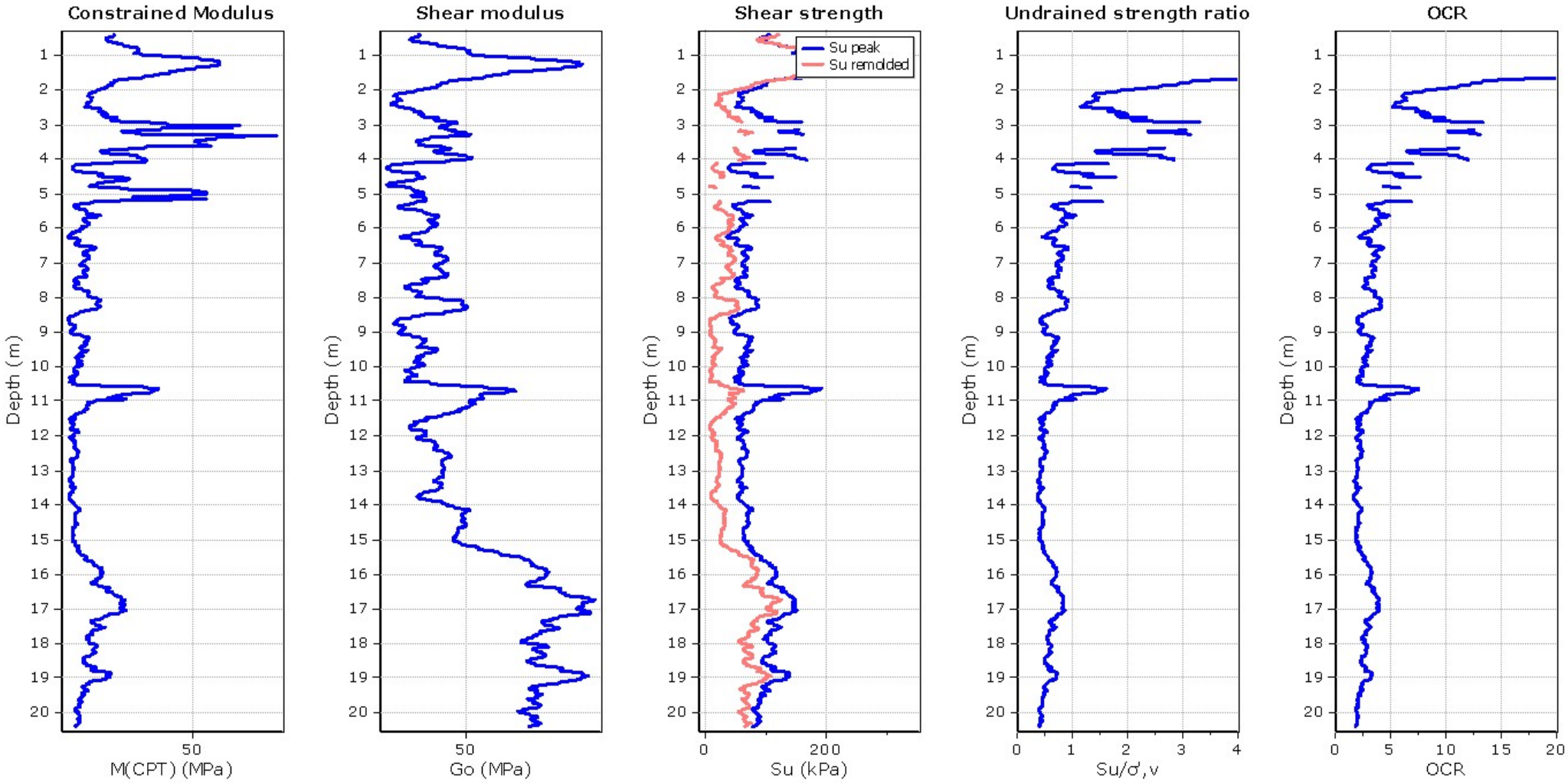
K(G) > 330: Soils with significant microstructure (e.g. age/cementation)



Calculation parameters

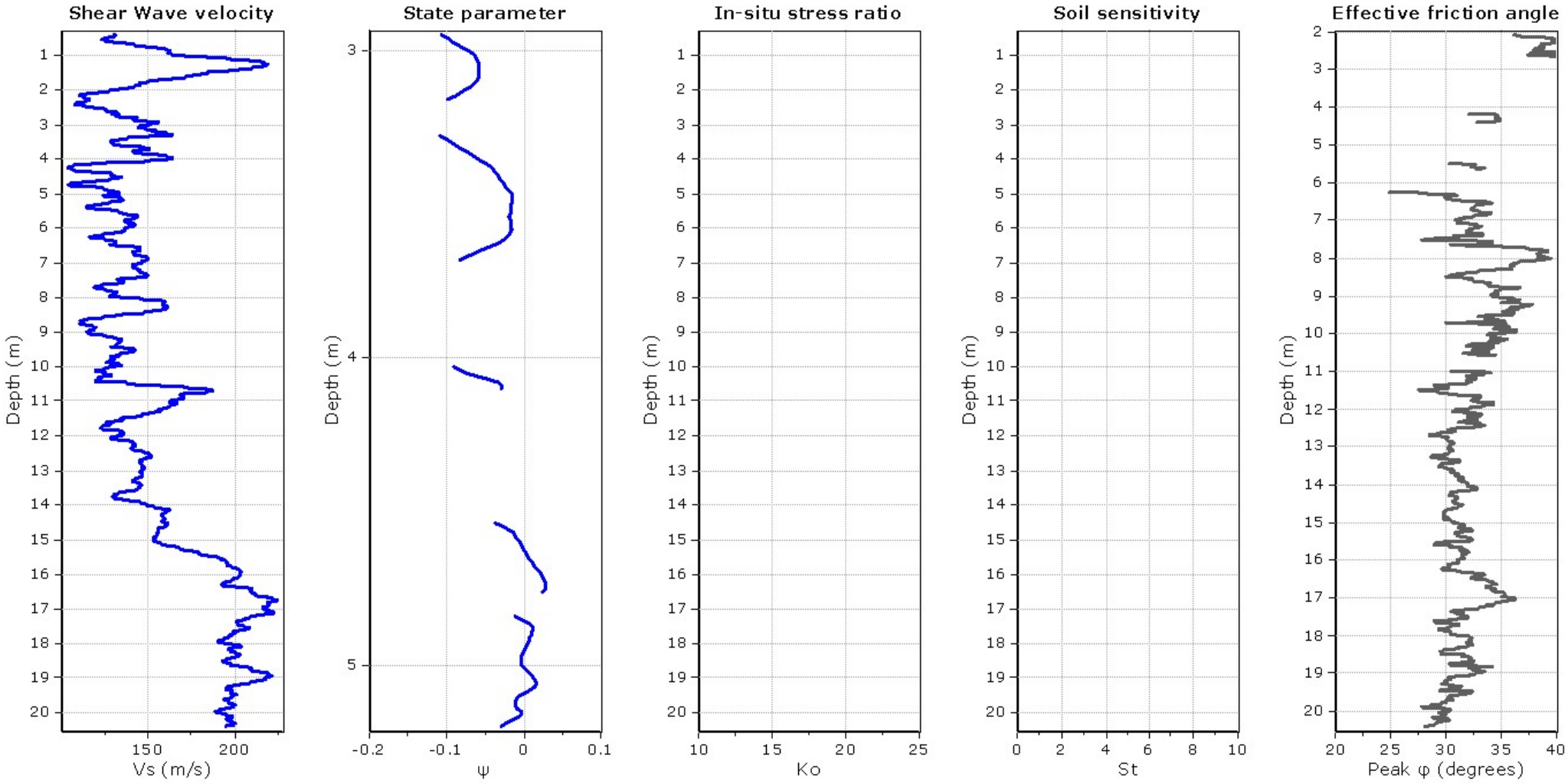
Permeability: Based on SBT_n
SPT N_{60}: Based on I_c and q_t
Young's modulus: Based on variable alpha using I_c (Robertson, 2009)
Relative density constant, C_{Dr}: 350.0
Phi: Based on Kulhawy & Mayne (1990)
User defined estimation data



Calculation parameters

Constrained modulus: Based on variable alpha using I_c and Q_{tn} (Robertson, 2009)
Go: Based on variable alpha using I_c (Robertson, 2009)
Undrained shear strength cone factor for clays, N_{kt}: 14

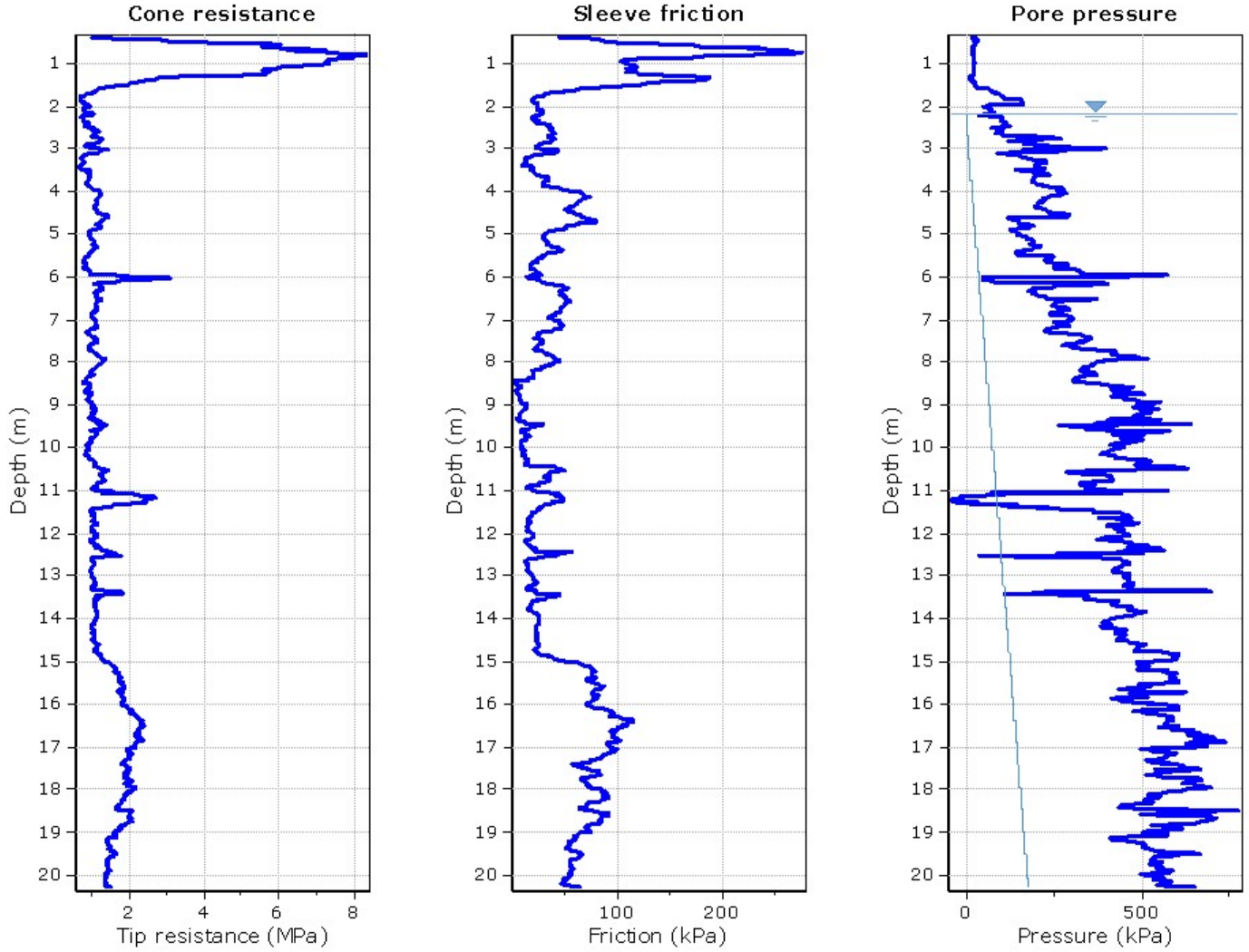
OCR factor for clays, N_{kt}: 0.33
User defined estimation data
Flat Dilatometer Test data



Calculation parameters

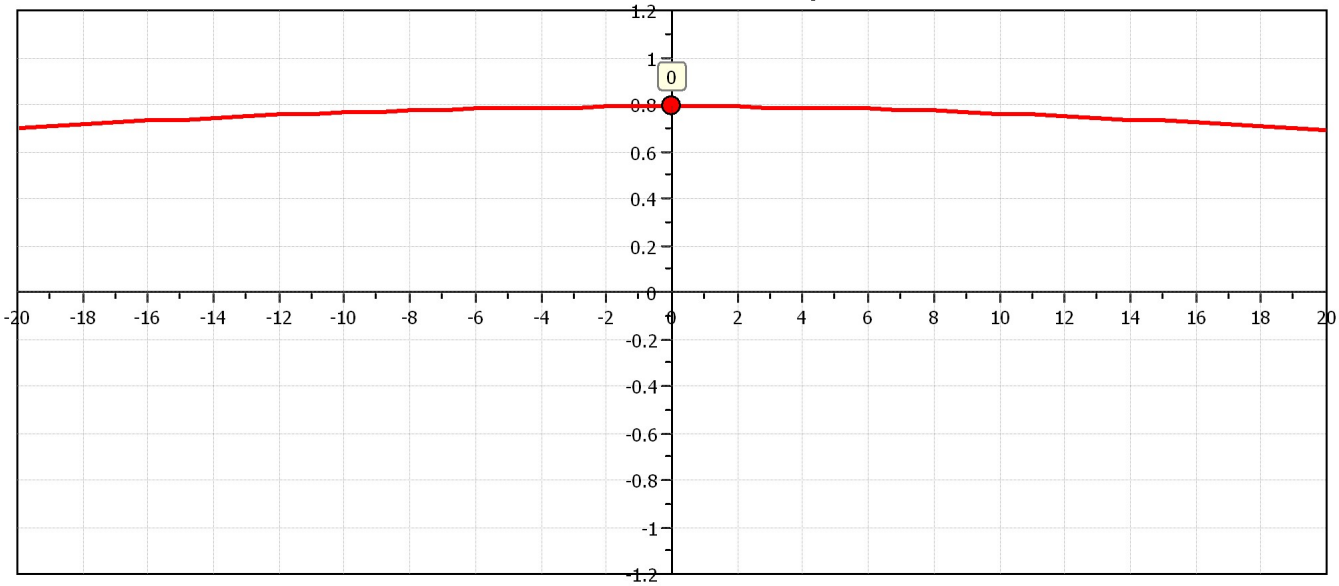
Soil Sensitivity factor, N_S: 350.00

User defined estimation data

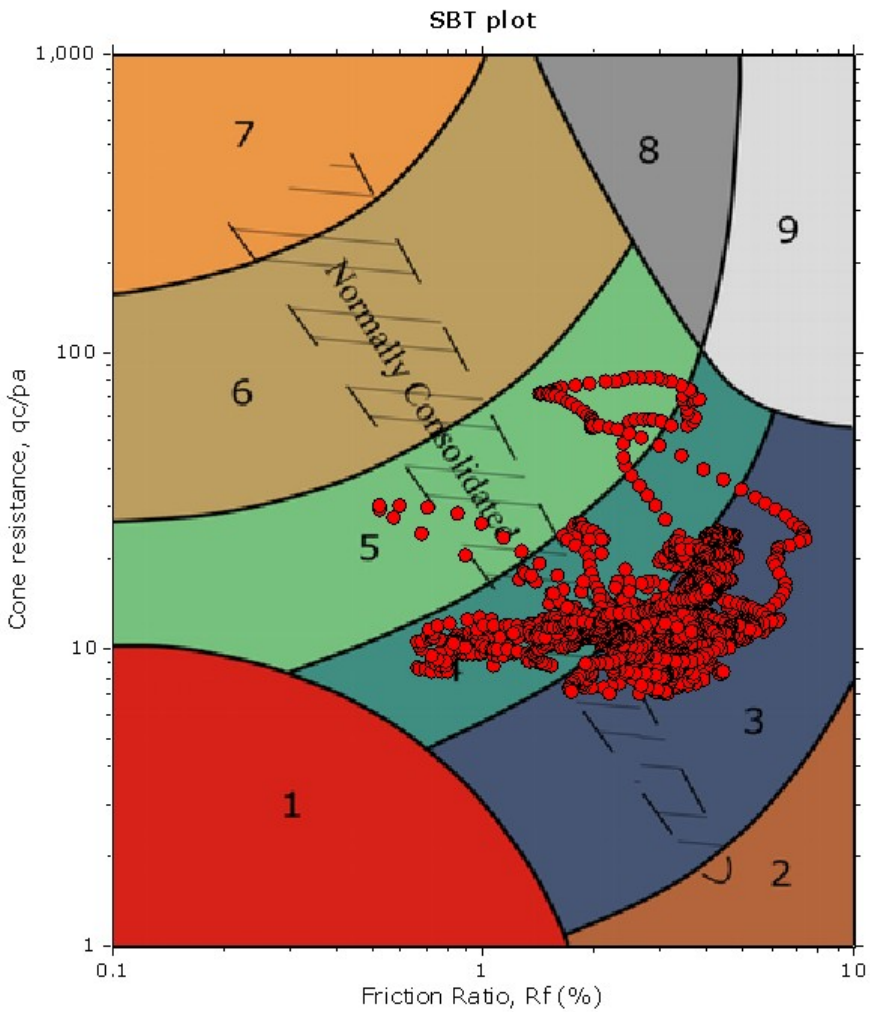


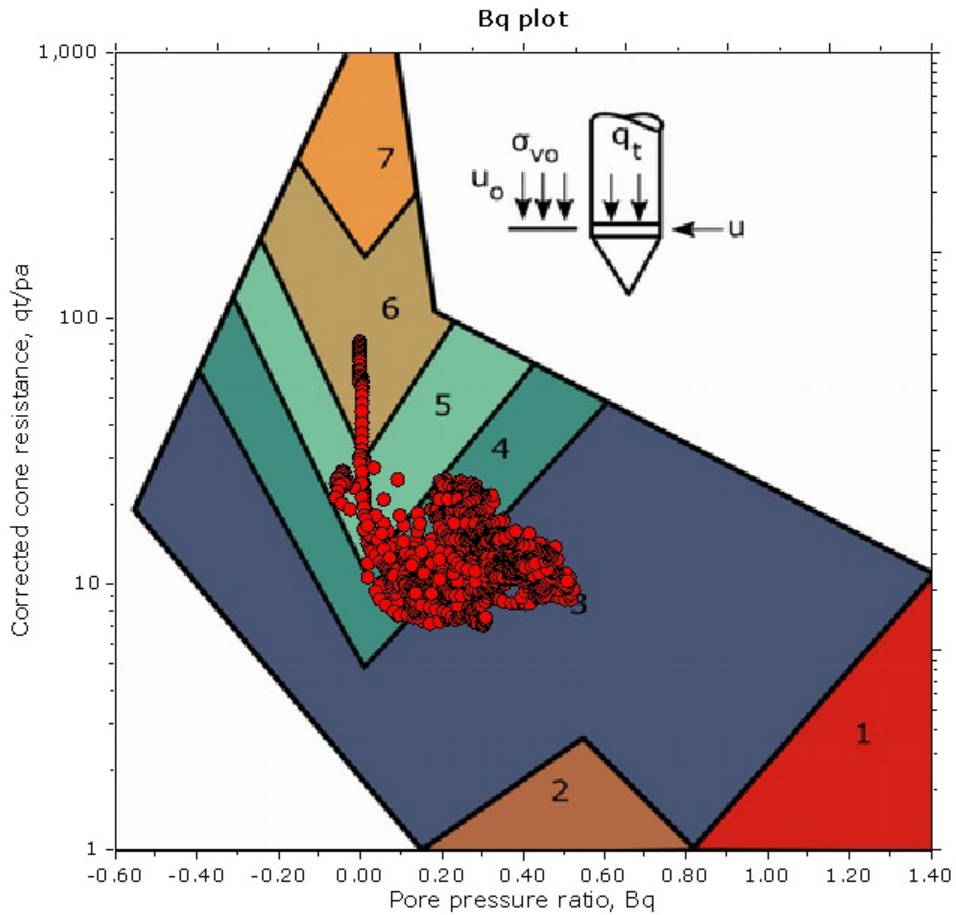
The plot below presents the cross correlation coeficient between the raw qc and fs values (as measured on the field). X axes presents the lag distance (one lag is the distance between two sucessive CPT measurements).

Cross correlation between qc & fs



SBT - Bq plots

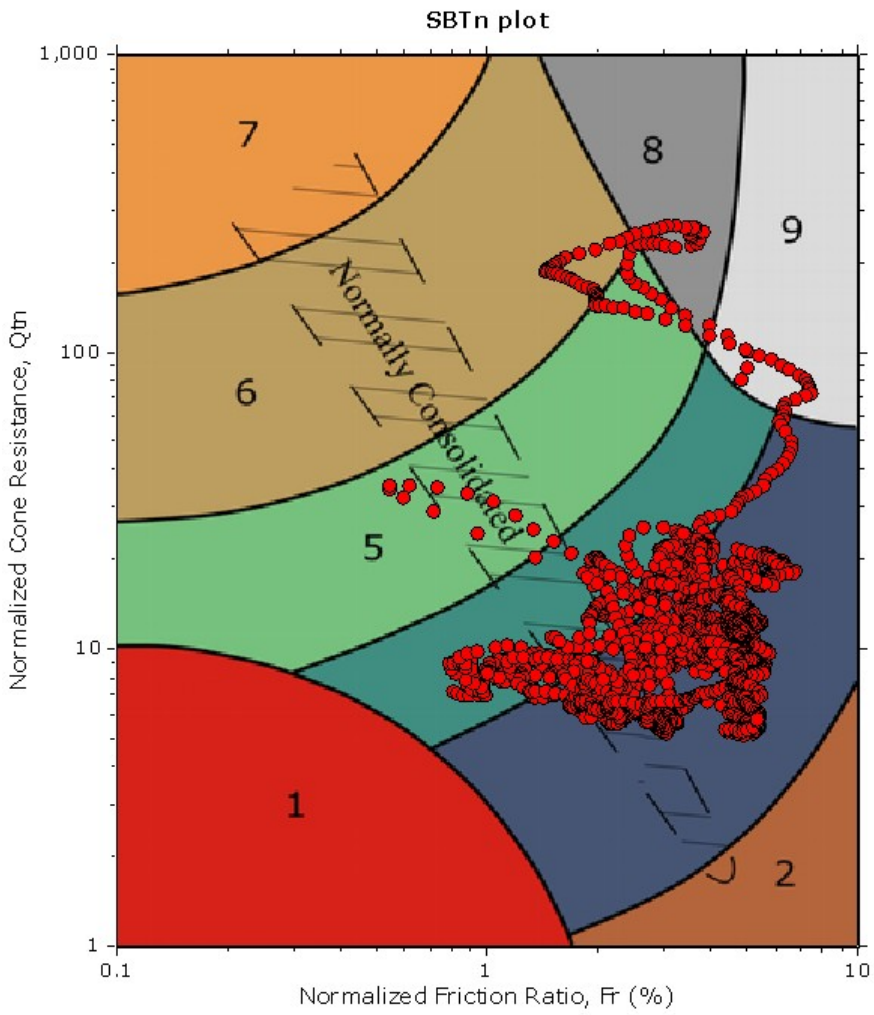


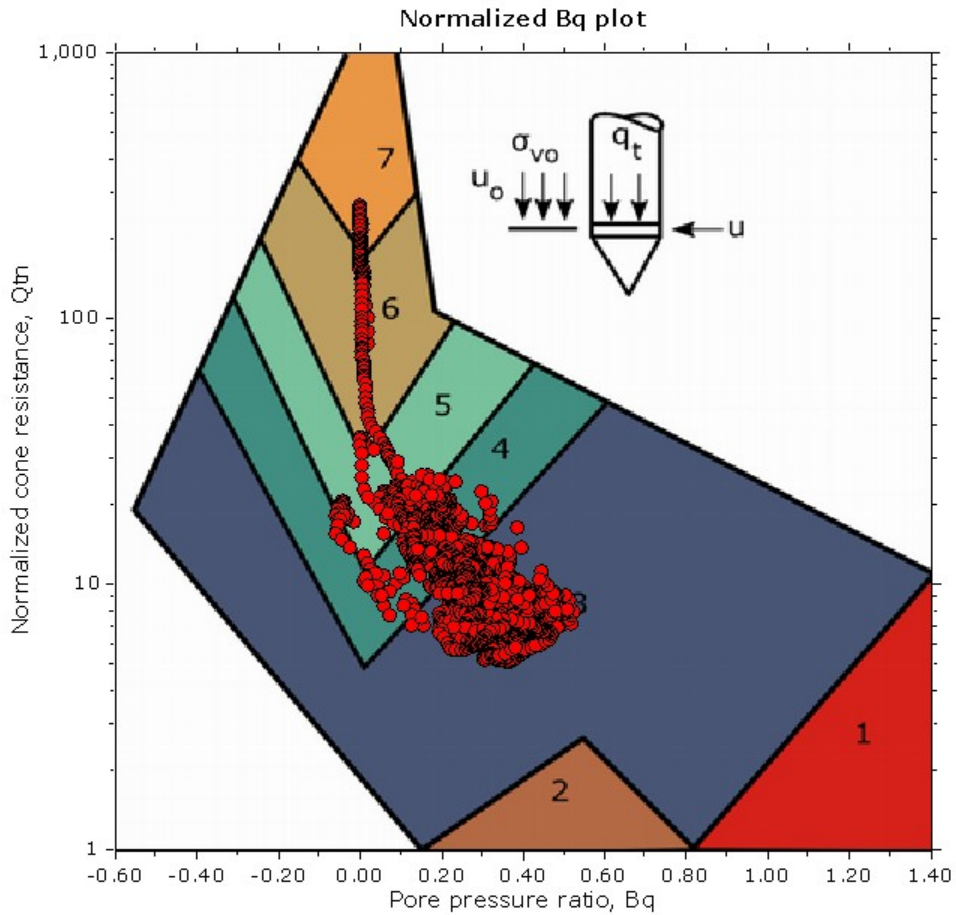


SBT legend

1. Sensitive fine grained
2. Organic material
3. Clay to silty clay
4. Clayey silt to silty clay
5. Silty sand to sandy silt
6. Clean sand to silty sand
7. Gravelly sand to sand
8. Very stiff sand to clayey sand
9. Very stiff fine grained

SBT - Bq plots (normalized)

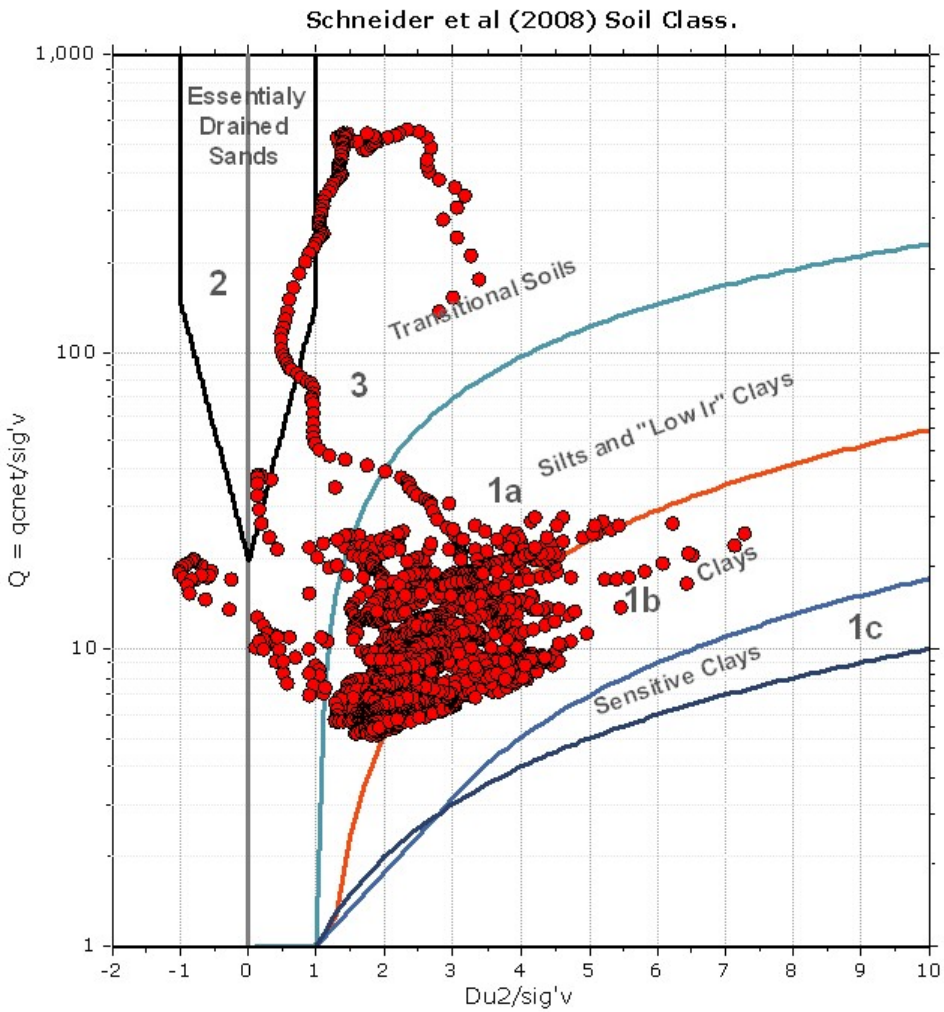


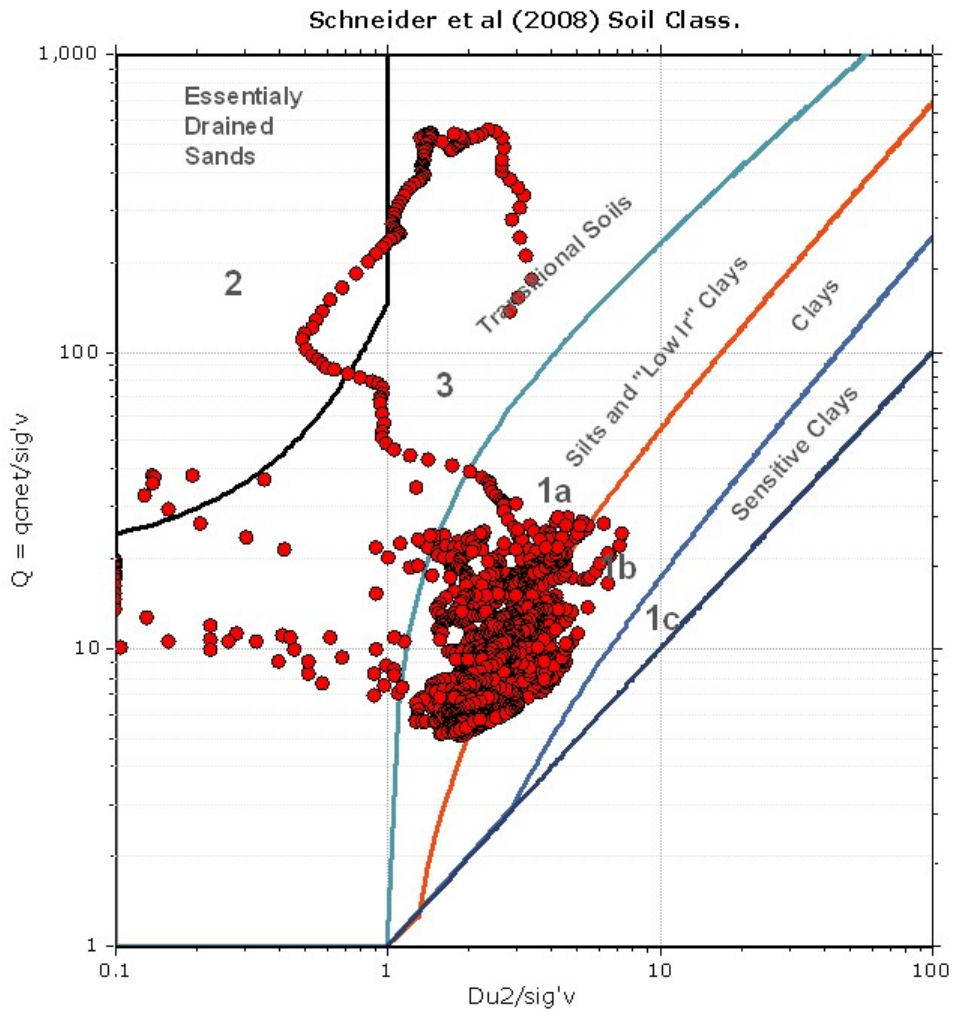


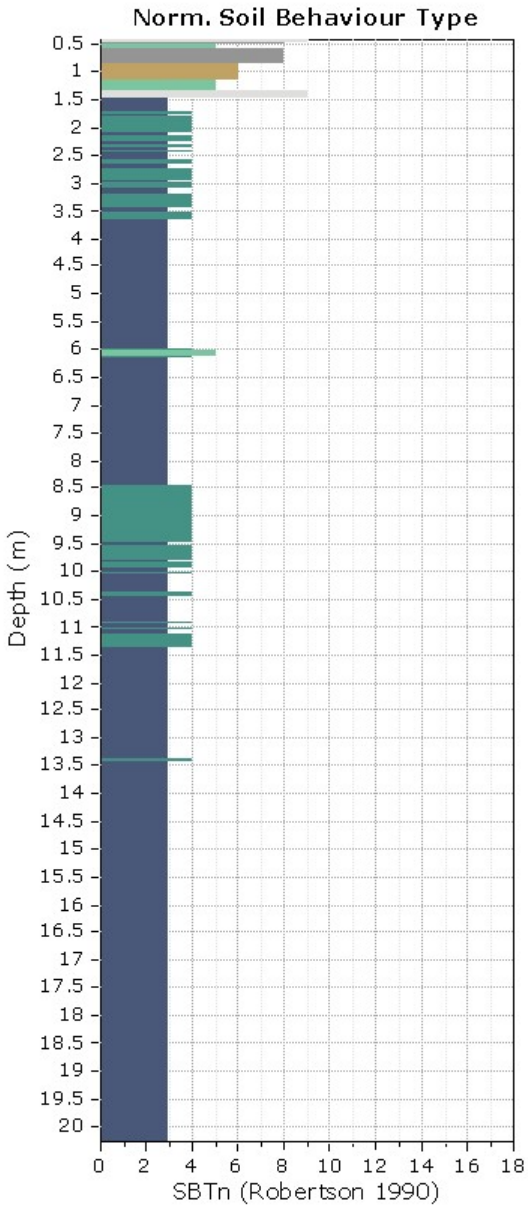
SBTn legend

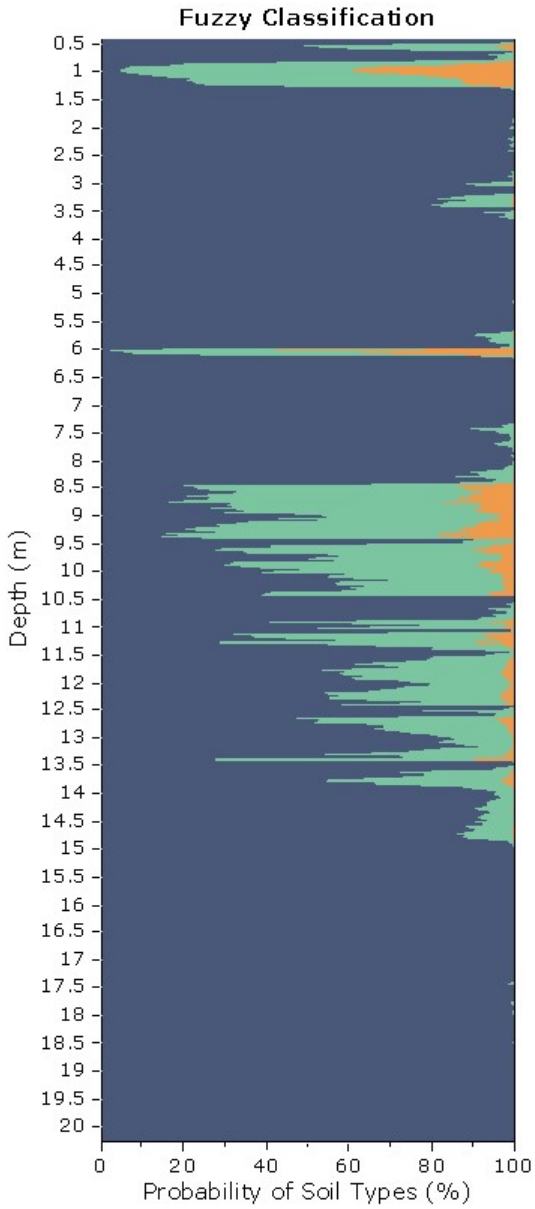
- 1. Sensitive fine grained
- 2. Organic material
- 3. Clay to silty clay
- 4. Clayey silt to silty clay
- 5. Silty sand to sandy silt
- 6. Clean sand to silty sand
- 7. Gravelly sand to sand
- 8. Very stiff sand to clayey sand
- 9. Very stiff fine grained

Bq plots (Schneider)






Norm. Soil Behaviour Type
Depth (m)
SBTn (Robertson 1990)


Fuzzy Classification
Depth (m)
Probability of Soil Types (%)

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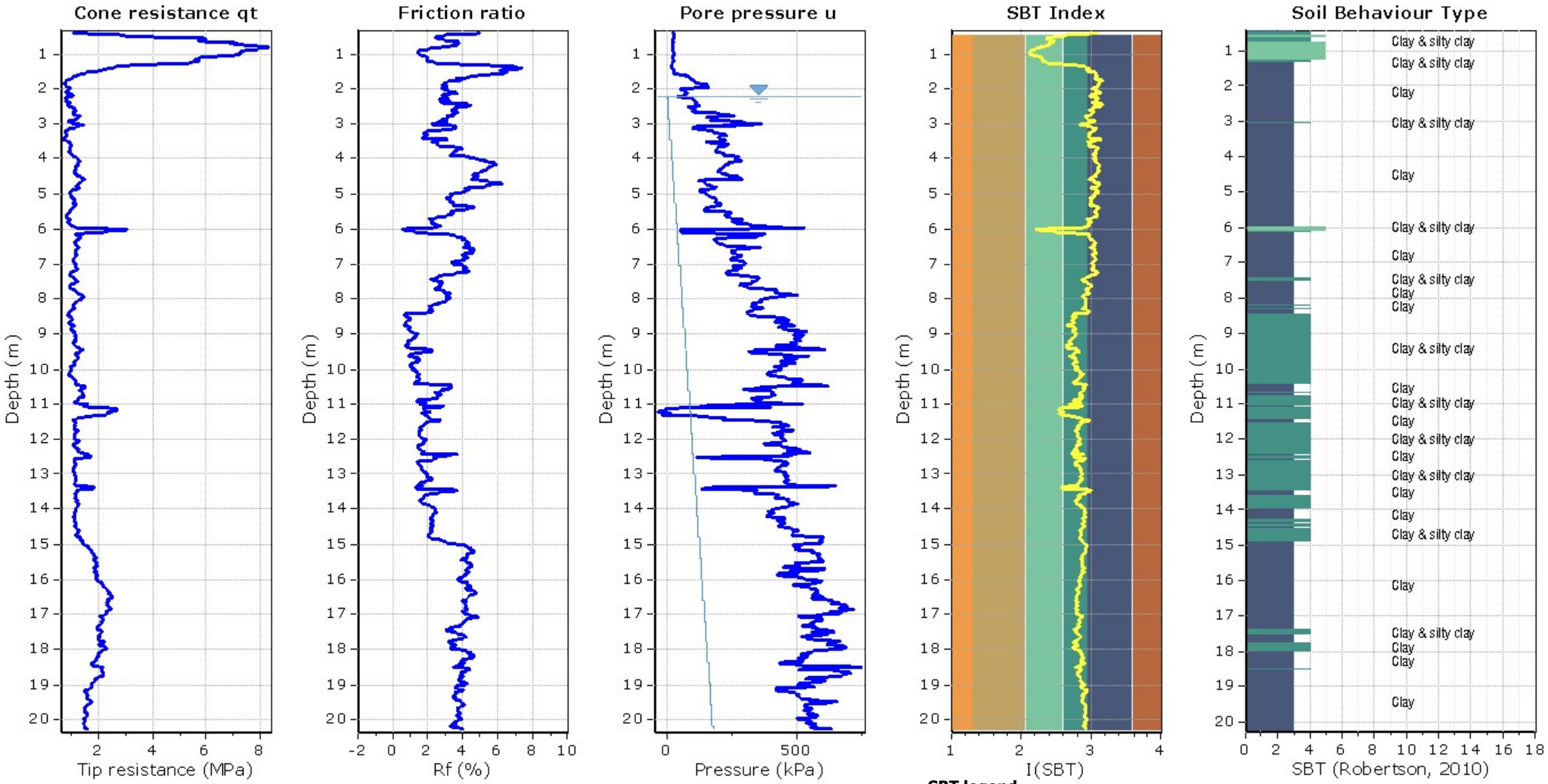
CPT: CPTU3
Total depth: 20.27 m, Date: 09/12/2021
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

Project:
Location:



SBT legend

1. Sensitive fine grained
2. Organic material
3. Clay to silty clay
4. Clayey silt to silty clay
5. Silty sand to sandy silt
6. Clean sand to silty sand
7. Gravely sand to sand
8. Very stiff sand to clayey sand
9. Very stiff fine grained

Geo Group Srl
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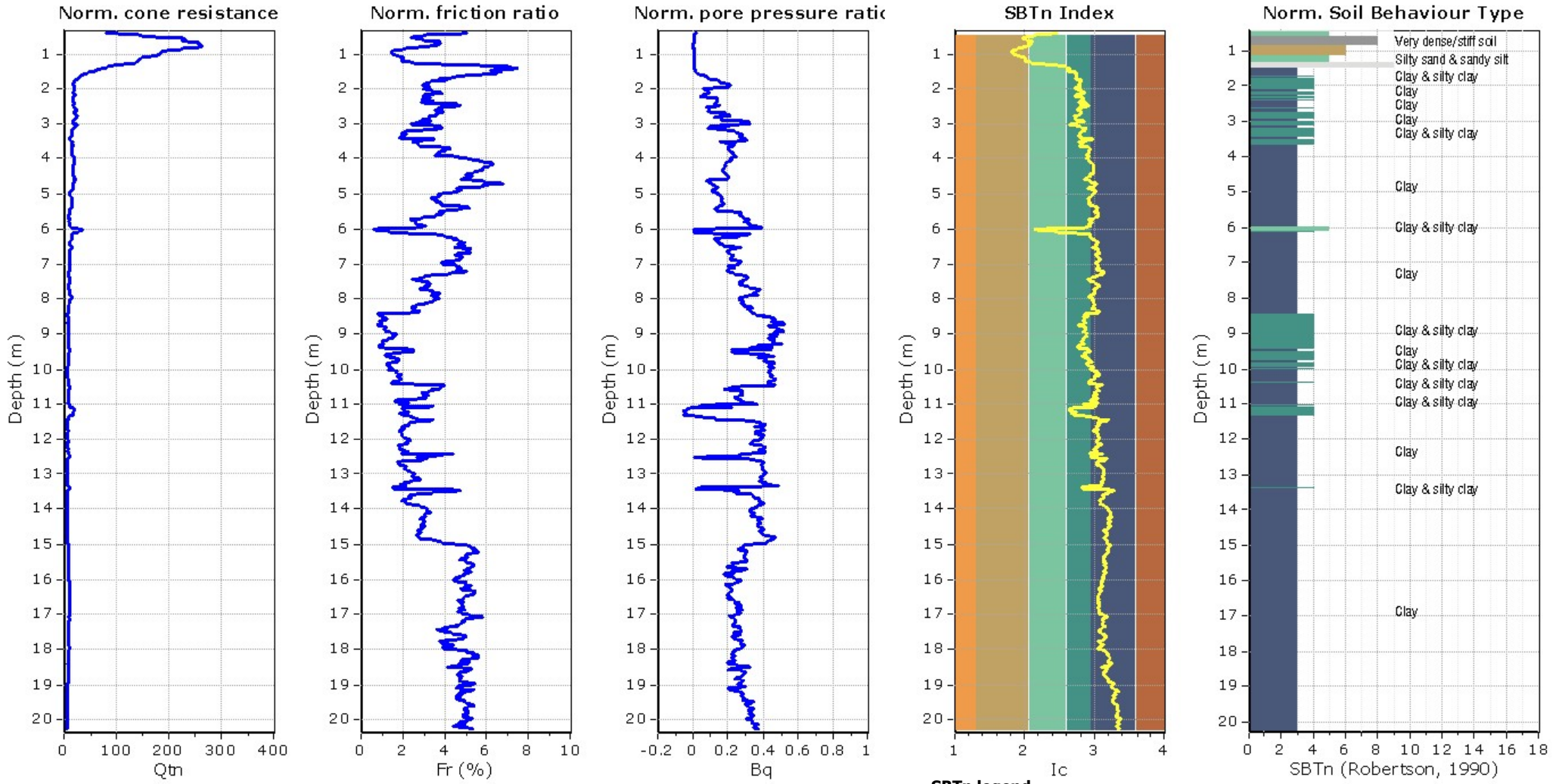
CPT: CPTU3
Total depth: 20.27 m, Date: 09/12/2021
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

Project:
Location:



SBTn legend

1. Sensitive fine grained
2. Organic material
3. Clay to silty clay
4. Clayey silt to silty clay
5. Silty sand to sandy silt
6. Clean sand to silty sand
7. Gravely sand to sand
8. Very stiff sand to clayey sand
9. Very stiff fine grained

Geo Group Srl
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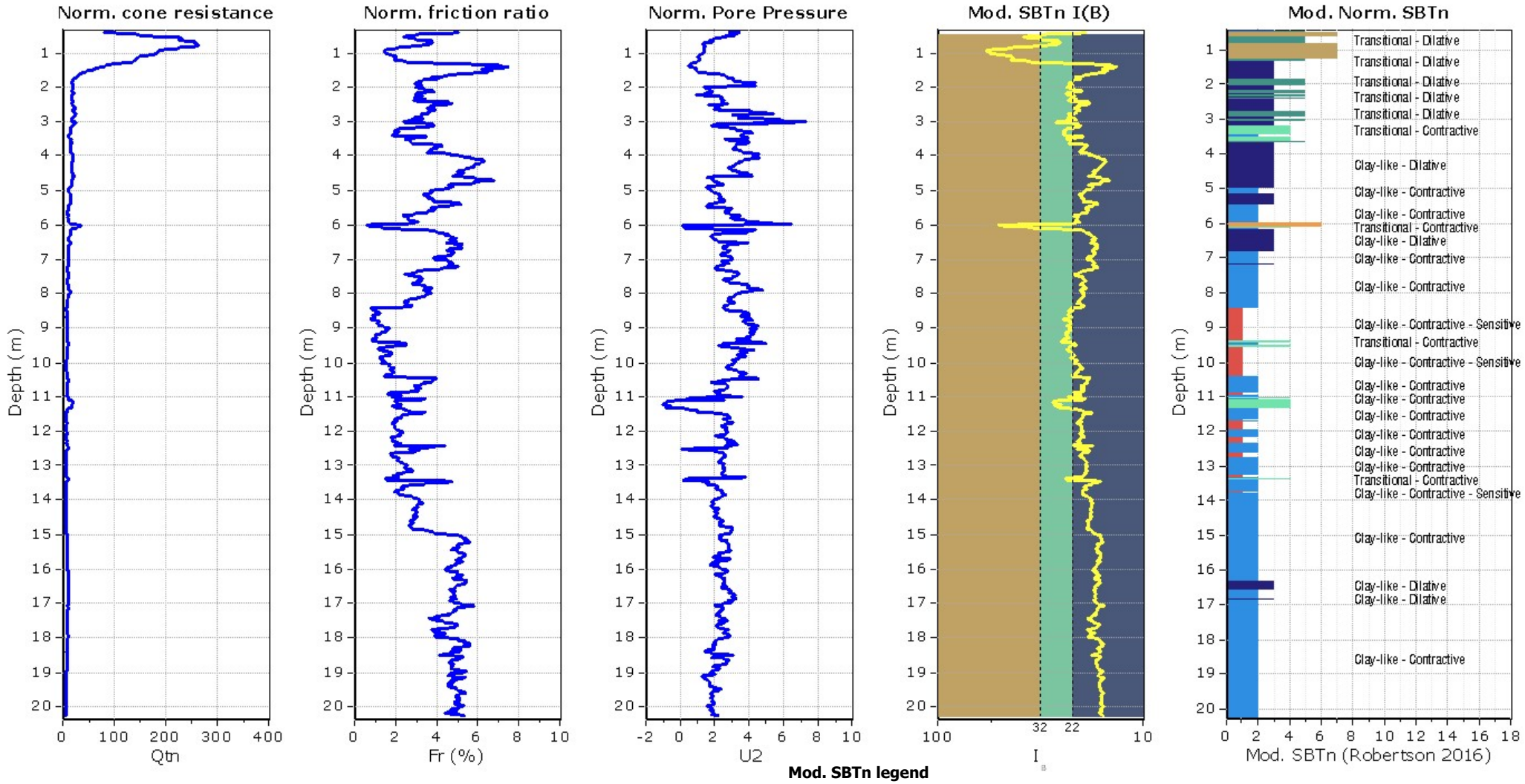
www.geogroupmodena.it

CPT: CPTU3
Total depth: 20.27 m, Date: 09/12/2021
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

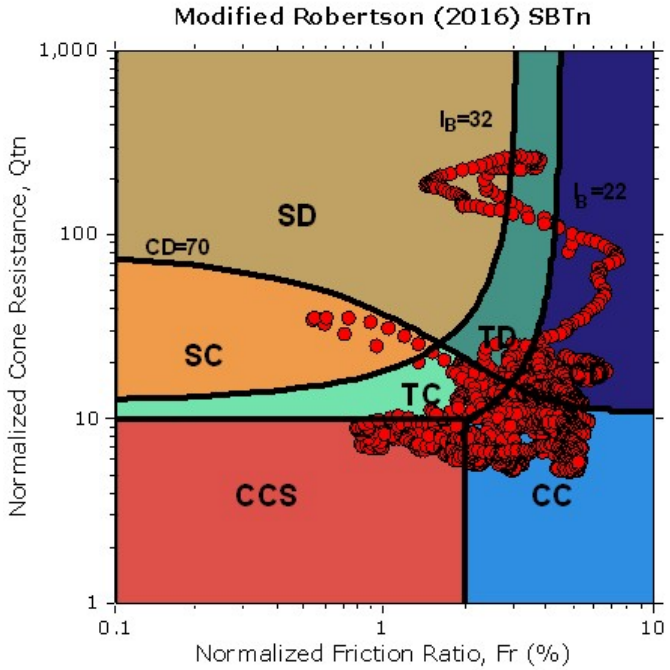
Project:
Location:

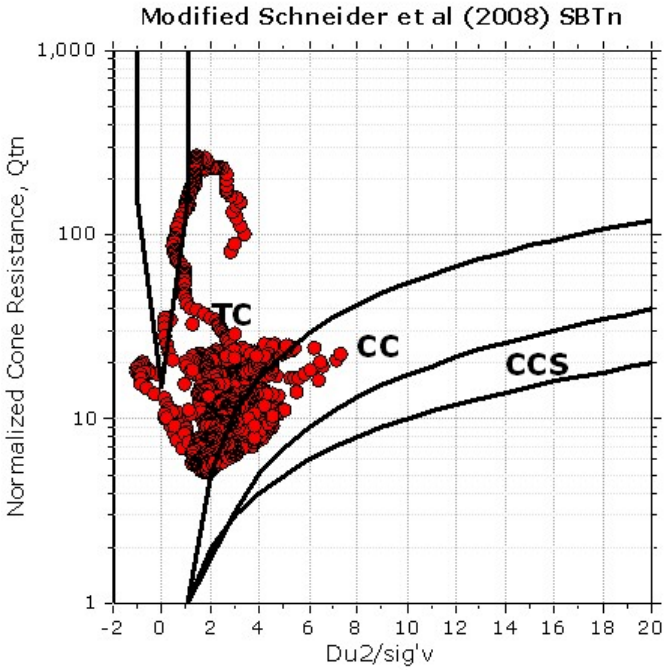


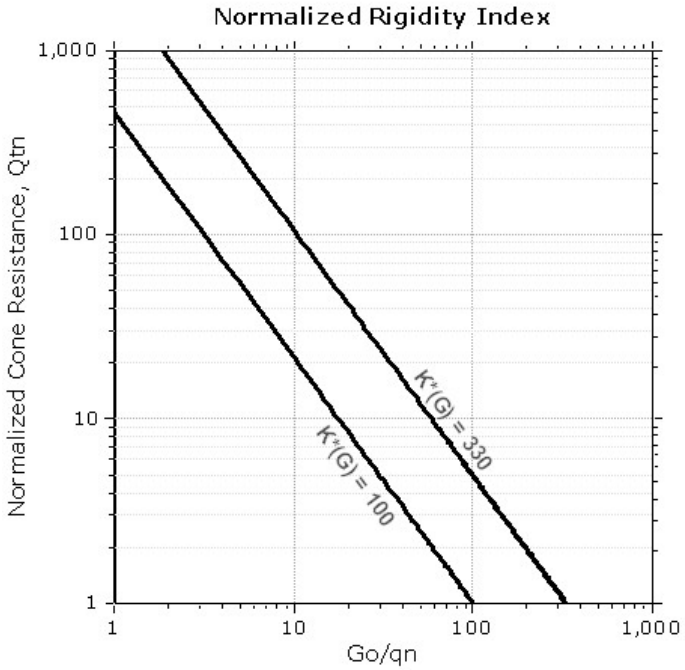
Mod. SBTn legend

1. CCS: ClayLike - Contractive, Sensitive
2. CC: Clay-like - Contractive
3. CD: Clay-Like: Dilative
4. TC: Transitional - Contractive
5. TD: Transitional - Dilative
6. SC: Sand-like - Contractive
7. SD: Sand-like - Dilative

Updated SBTn plots

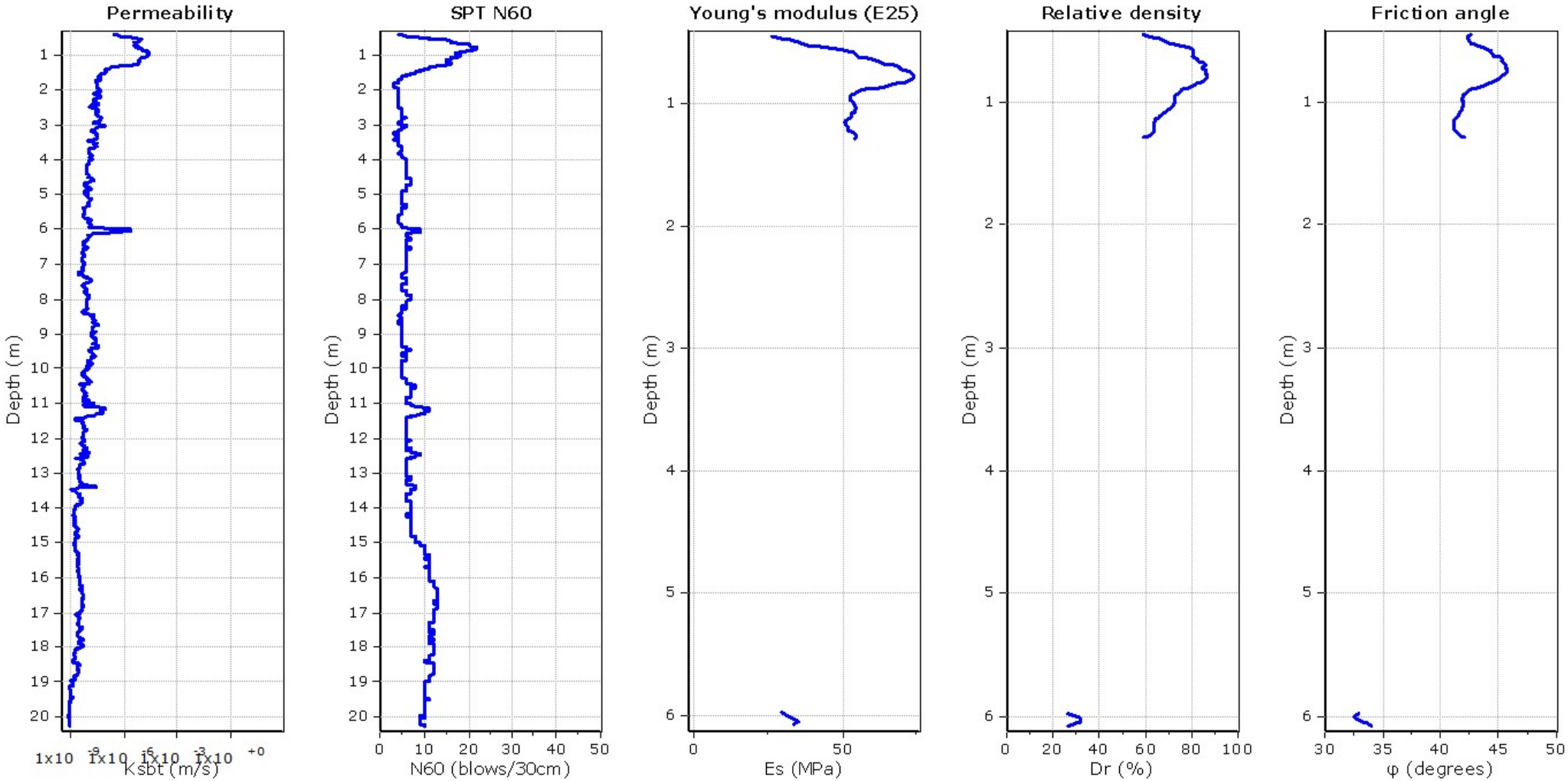






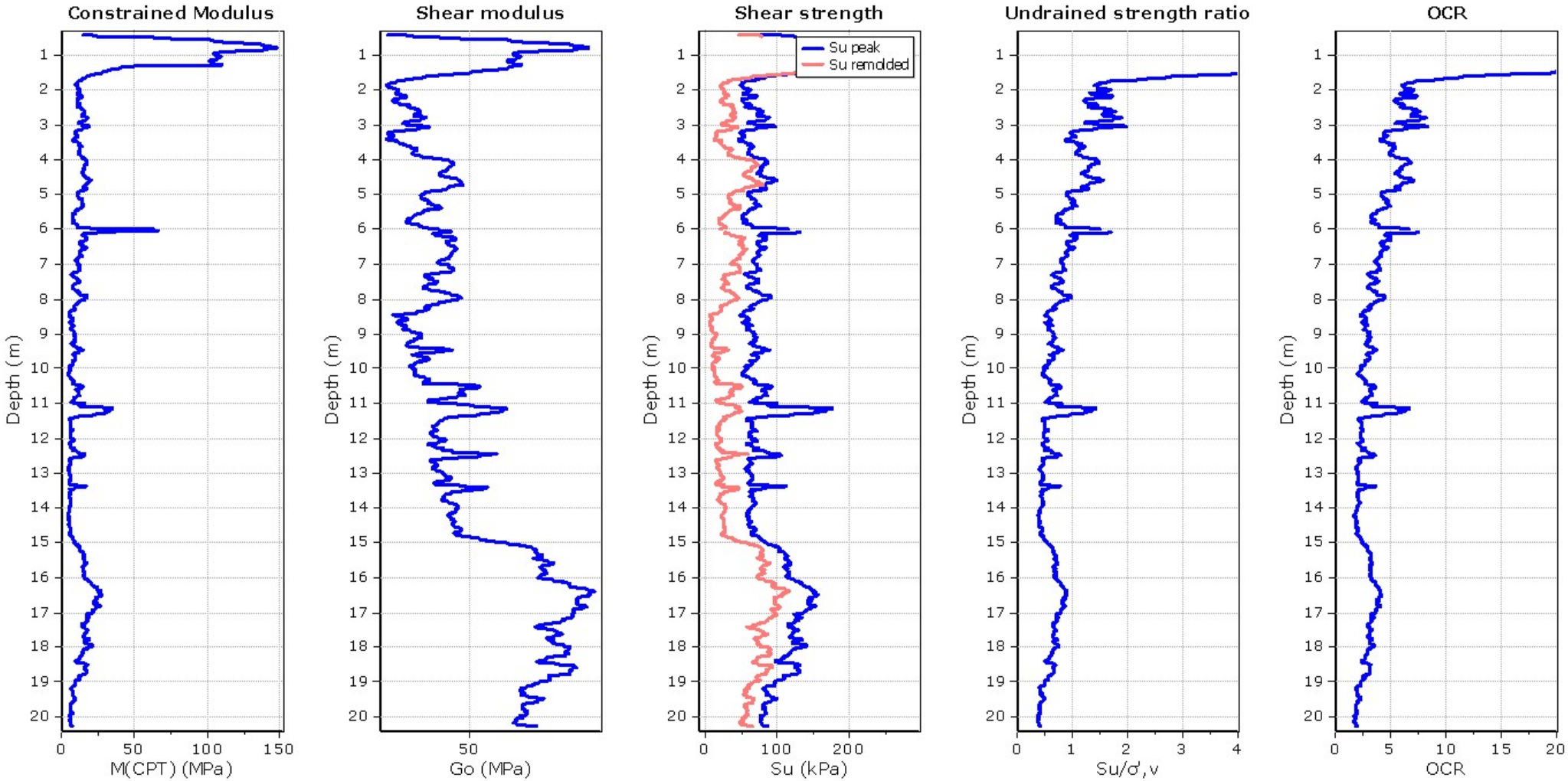
CCS: Clay-like - Contractive - Sensitive
CC: Clay-like - Contractive
CD: Clay-like - Dilative
TC: Transitional - Contractive
TD: Transitional - Dilative
SC: Sand-like - Contractive
SD: Sand-like - Dilative

K(G) > 330: Soils with significant microstructure (e.g. age/cementation)



Calculation parameters

Permeability: Based on SBT_n
SPT N_{60}: Based on I_c and q_t
Young's modulus: Based on variable alpha using I_c (Robertson, 2009)
Relative density constant, C_{Dr}: 350.0
Phi: Based on Kulhawy & Mayne (1990)
User defined estimation data



Calculation parameters

Constrained modulus: Based on variable alpha using I_c and Q_{tn} (Robertson, 2009)
Go: Based on variable alpha using I_c (Robertson, 2009)
Undrained shear strength cone factor for clays, N_{kt}: 14

OCR factor for clays, N_{kt}: 0.33
User defined estimation data
Flat Dilatometer Test data

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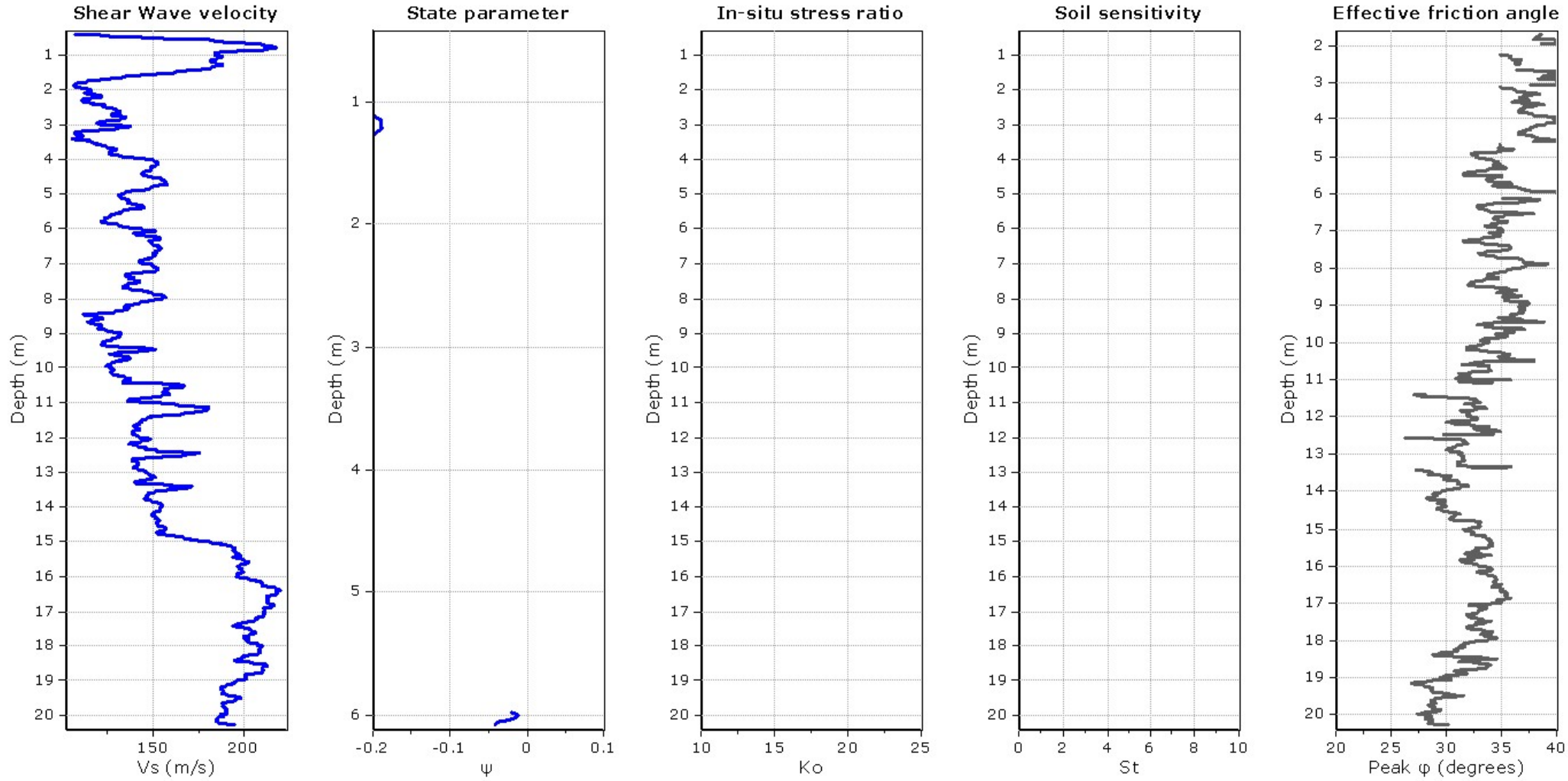
CPT: CPTU3
Total depth: 20.27 m, Date: 09/12/2021
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

Project:
Location:



Calculation parameters

Soil Sensitivity factor, N_S: 350.00

User defined estimation data

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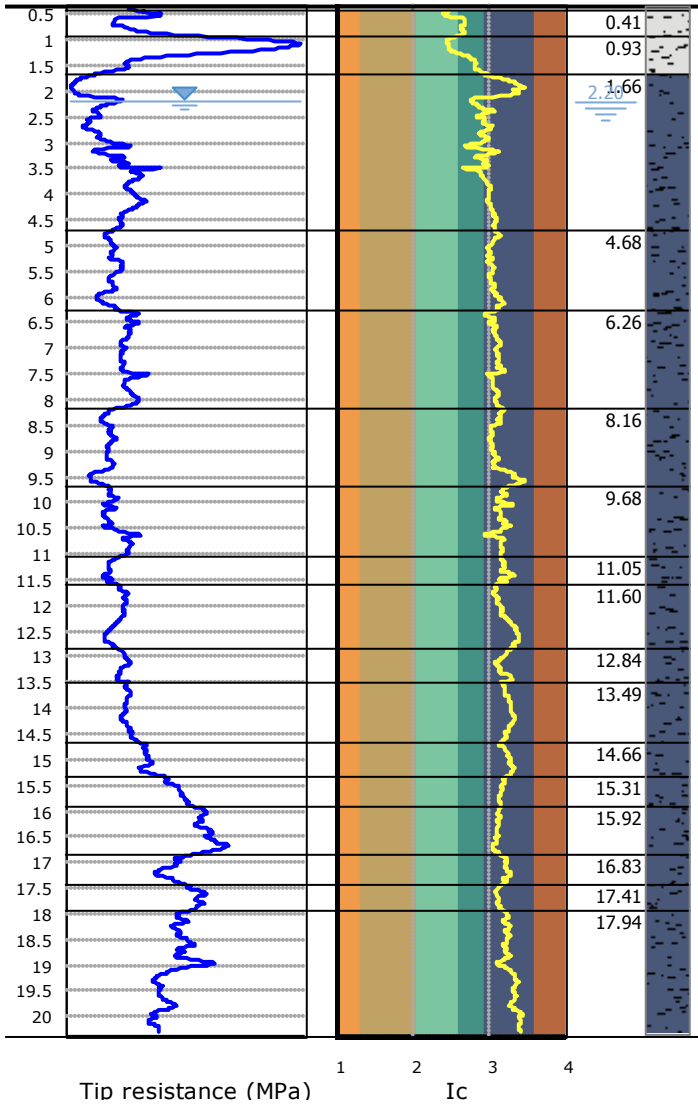
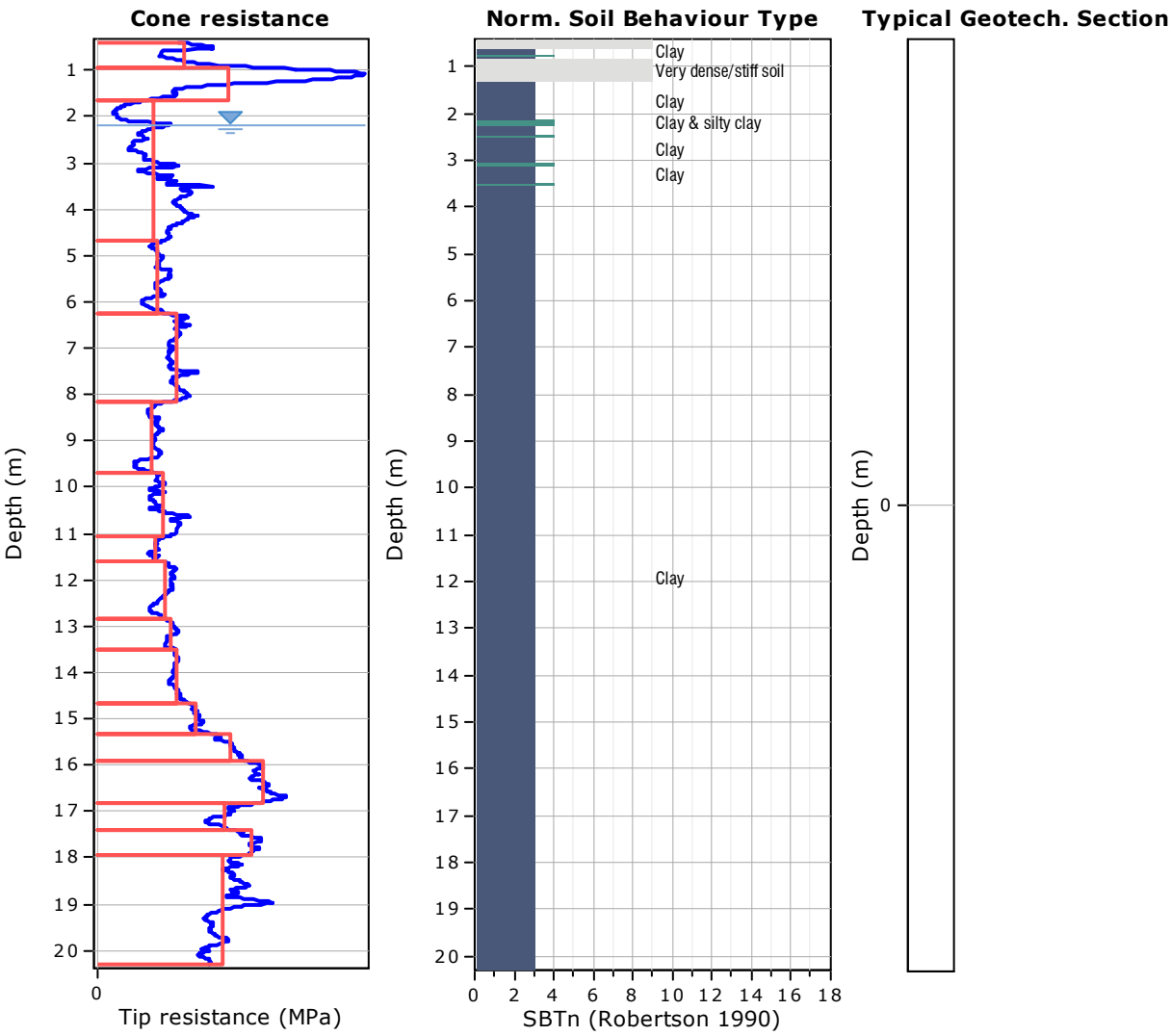
CPT: CPTU1
Total depth: 20.30 m, Date: 09/12/2021
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

Project:
Location:



Depth (m)	Description	qt (MPa)	Ksbt (m/s)	N60	Es (MPa)	Dr	Phi (°)	M (MPa)	Go (MPa)	Su (kPa)	Su ratio	OCR	Gamma (kN/m³)
0.41	Very dense/stiff soil	1.2	1.12E-7	4.9	-	-	-	16.7	28.9	85.2	4.9	22.8	19.0
0.93	Very dense/stiff soil	1.8	7.11E-8	7.5	-	-	-	24.9	46.8	127.2	4.4	20.1	19.0
1.66	Clay	0.8	6.77E-9	3.9	-	-	-	8.6	28.5	50.3	1.0	4.7	19.0
4.68	Clay	0.8	4.30E-9	4.4	-	-	-	7.4	31.9	52.2	0.7	3.4	19.0
6.26	Clay	1.1	3.69E-9	6.1	-	-	-	10.4	43.0	68.4	0.8	3.6	19.0
8.16	Clay	0.8	2.72E-9	4.2	-	-	-	3.3	28.0	41.7	0.4	1.9	19.0
9.68	Clay	0.9	2.18E-9	5.2	-	-	-	4.3	35.1	50.8	0.4	2.0	19.0
11.05	Clay	0.8	1.62E-9	5.0	-	-	-	2.9	31.4	42.9	0.3	1.6	19.0
11.60	Clay	0.9	1.55E-9	5.6	-	-	-	3.6	37.4	49.8	0.4	1.7	19.0
12.84	Clay	1.0	1.78E-9	6.0	-	-	-	4.1	39.2	54.6	0.4	1.8	19.0
13.49	Clay	1.1	1.18E-9	6.7	-	-	-	4.5	45.7	58.7	0.4	1.8	19.0
14.66	Clay	1.4	1.19E-9	8.4	-	-	-	7.5	60.6	78.0	0.5	2.3	19.0
15.31	Clay	1.9	2.03E-9	10.8	-	-	-	14.7	77.8	111.2	0.7	3.1	19.0
15.92	Clay	2.3	3.12E-9	12.8	-	-	-	23.1	92.2	142.4	0.8	3.8	19.0
16.83	Clay	1.8	1.40E-9	10.5	-	-	-	11.5	76.8	102.5	0.6	2.6	19.0
17.41	Clay	2.1	2.80E-9	11.8	-	-	-	17.6	84.9	128.5	0.7	3.2	19.0
17.94	Clay	1.8	1.03E-9	10.9	-	-	-	9.7	80.5	98.9	0.5	2.3	19.0



Tabular results

.:: Layer No: 1 ::.

Code: Layer_1 **Start depth:** 0.41 (m), **End depth:** 0.93 (m)

Description: Very dense/stiff soil

Basic results	Estimation results	
Total cone resistance: 1.21 ±0.34 MPa	Permeability: 1.12E-07 ±1.23E-07 m/s	Constrained Mod.: 16.70 ±4.71 MPa
Sleeve friction: 75.90 ±28.91 kPa	N_{60}: 4.90 ±1.17 blows	Go: 28.88 ±7.32 MPa
Ic: 2.60 ±0.10	Es: 0.00 ±0.00 MPa	Su: 85.22 ±24.02 kPa
SBT_n: 9	Dr (%): 0.00 ±0.00	Su ratio: 4.95 ±1.22
SBTn description: Very dense/stiff soil	φ (degrees): 0.00 ±0.00 °	O.C.R.: 22.85 ±5.66
	Unit weight: 19.00 ±0.00 kN/m³	

.:: Layer No: 2 ::.

Code: Layer_2 **Start depth:** 0.93 (m), **End depth:** 1.66 (m)

Description: Very dense/stiff soil

Basic results	**Estimation results**	
Total cone resistance: 1.81 ±1.11 MPa	Permeability: 7.11E-08 ±1.26E-07 m/s	Constrained Mod.: 24.92 ±15.62 MPa
Sleeve friction: 121.25 ±75.15 kPa	N_{60}: 7.48 ±3.63 blows	Go: 46.79 ±17.38 MPa
Ic: 2.66 ±0.17	Es: 0.00 ±0.00 MPa	Su: 127.16 ±79.70 kPa
SBT_n: 9	Dr (%): 0.00 ±0.00	Su ratio: 4.35 ±2.93
SBTn description: Very dense/stiff soil	φ (degrees): 0.00 ±0.00 °	O.C.R.: 20.10 ±13.52
	Unit weight: 19.00 ±0.00 kN/m³	

.:: Layer No: 3 ::.

Code: Layer_3 **Start depth:** 1.66 (m), **End depth:** 4.68 (m)

Description: Clay

Basic results	**Estimation results**	
Total cone resistance: 0.76 ±0.33 MPa	Permeability: 6.77E-09 ±1.10E-08 m/s	Constrained Mod.: 8.58 ±5.35 MPa
Sleeve friction: 33.82 ±25.52 kPa	N_{60}: 3.91 ±1.61 blows	Go: 28.46 ±11.39 MPa
Ic: 3.00 ±0.15	Es: 0.00 ±0.00 MPa	Su: 50.26 ±23.02 kPa
SBT_n: 3	Dr (%): 0.00 ±0.00	Su ratio: 1.01 ±0.34
SBTn description: Clay	φ (degrees): 0.00 ±0.00 °	O.C.R.: 4.66 ±1.55
	Unit weight: 19.00 ±0.00 kN/m³	

.:: Layer No: 4 ::.

Code: Layer_4 **Start depth:** 4.68 (m), **End depth:** 6.26 (m)

Description: Clay

Basic results	**Estimation results**	
Total cone resistance: 0.84 ±0.10 MPa	Permeability: 4.30E-09 ±1.62E-09 m/s	Constrained Mod.: 7.45 ±2.22 MPa
Sleeve friction: 29.30 ±8.64 kPa	N_{60}: 4.42 ±0.57 blows	Go: 31.91 ±3.80 MPa
Ic: 3.06 ±0.05	Es: 0.00 ±0.00 MPa	Su: 52.20 ±7.47 kPa
SBT_n: 3	Dr (%): 0.00 ±0.00	Su ratio: 0.73 ±0.12
SBTn description: Clay	φ (degrees): 0.00 ±0.00 °	O.C.R.: 3.36 ±0.56
	Unit weight: 19.00 ±0.00 kN/m³	

.:: Layer No: 5 ::.

Code: Layer_5 **Start depth:** 6.26 (m), **End depth:** 8.16 (m)

Description: Clay

Basic results	**Estimation results**	
Total cone resistance: 1.09 ±0.10 MPa	Permeability: 3.69E-09 ±1.70E-09 m/s	Constrained Mod.: 10.45 ±2.36 MPa
Sleeve friction: 45.91 ±7.34 kPa	N_{60}: 6.08 ±0.44 blows	Go: 42.97 ±3.17 MPa
Ic: 3.09 ±0.05	Es: 0.00 ±0.00 MPa	Su: 68.37 ±7.03 kPa
SBT_n: 3	Dr (%): 0.00 ±0.00	Su ratio: 0.78 ±0.09
SBTn description: Clay	φ (degrees): 0.00 ±0.00 °	O.C.R.: 3.60 ±0.44
	Unit weight: 19.00 ±0.00 kN/m³	

.:: Layer No: 6 ::.

Code: Layer_6 **Start depth:** 8.16 (m), **End depth:** 9.68 (m)

Description: Clay

Basic results	**Estimation results**	
Total cone resistance: 0.76 ±0.11 MPa	Permeability: 2.72E-09 ±1.94E-09 m/s	Constrained Mod.: 3.29 ±1.23 MPa
Sleeve friction: 12.98 ±5.23 kPa	N_{60}: 4.20 ±0.59 blows	Go: 28.03 ±3.29 MPa
Ic: 3.14 ±0.13	Es: 0.00 ±0.00 MPa	Su: 41.70 ±7.93 kPa
SBT_n: 3	Dr (%): 0.00 ±0.00	Su ratio: 0.40 ±0.08
SBTn description: Clay	φ (degrees): 0.00 ±0.00 °	O.C.R.: 1.86 ±0.39
	Unit weight: 19.00 ±0.00 kN/m³	

.:: Layer No: 7 ::.

Code: Layer_7 **Start depth:** 9.68 (m), **End depth:** 11.05 (m)

Description: Clay

Basic results	**Estimation results**	
Total cone resistance: 0.91 ±0.16 MPa	Permeability: 2.18E-09 ±1.64E-09 m/s	Constrained Mod.: 4.33 ±1.87 MPa
Sleeve friction: 19.87 ±8.63 kPa	N_{60}: 5.21 ±0.74 blows	Go: 35.14 ±6.06 MPa
Ic: 3.16 ±0.07	Es: 0.00 ±0.00 MPa	Su: 50.79 ±10.71 kPa
SBT_n: 3	Dr (%): 0.00 ±0.00	Su ratio: 0.43 ±0.08
SBTn description: Clay	φ (degrees): 0.00 ±0.00 °	O.C.R.: 2.01 ±0.38
	Unit weight: 19.00 ±0.00 kN/m³	

.:: Layer No: 8 ::.

Code: Layer_8 **Start depth:** 11.05 (m), **End depth:** 11.60 (m)

Description: Clay

Basic results	**Estimation results**	
Total cone resistance: 0.82 ±0.06 MPa	Permeability: 1.62E-09 ±5.10E-10 m/s	Constrained Mod.: 2.88 ±0.62 MPa
Sleeve friction: 13.80 ±2.79 kPa	N_{60}: 4.96 ±0.27 blows	Go: 31.44 ±2.00 MPa
Ic: 3.21 ±0.05	Es: 0.00 ±0.00 MPa	Su: 42.94 ±4.32 kPa
SBT_n: 3	Dr (%): 0.00 ±0.00	Su ratio: 0.34 ±0.04
SBTn description: Clay	φ (degrees): 0.00 ±0.00 °	O.C.R.: 1.58 ±0.17
	Unit weight: 19.00 ±0.00 kN/m³	

.:: Layer No: 9 ::.

Code: Layer_9 **Start depth:** 11.60 (m), **End depth:** 12.84 (m)

Description: Clay

Basic results	**Estimation results**	
Total cone resistance: 0.93 ±0.11 MPa	Permeability: 1.55E-09 ±1.29E-09 m/s	Constrained Mod.: 3.63 ±1.30 MPa
Sleeve friction: 20.33 ±3.50 kPa	N_{60}: 5.64 ±0.48 blows	Go: 37.43 ±2.59 MPa
Ic: 3.23 ±0.12	Es: 0.00 ±0.00 MPa	Su: 49.79 ±8.52 kPa
SBT_n: 3	Dr (%): 0.00 ±0.00	Su ratio: 0.37 ±0.07
SBTn description: Clay	φ (degrees): 0.00 ±0.00 °	O.C.R.: 1.72 ±0.33
	Unit weight: 19.00 ±0.00 kN/m³	

.:: Layer No: 10 ::.

Code: Layer_10 **Start depth:** 12.84 (m), **End depth:** 13.49 (m)

Description: Clay

Basic results	**Estimation results**	
Total cone resistance: 1.02 ±0.06 MPa	Permeability: 1.78E-09 ±8.95E-10 m/s	Constrained Mod.: 4.10 ±0.73 MPa
Sleeve friction: 19.92 ±4.43 kPa	N_{60}: 6.00 ±0.00 blows	Go: 39.24 ±2.46 MPa
Ic: 3.19 ±0.07	Es: 0.00 ±0.00 MPa	Su: 54.59 ±4.65 kPa
SBT_n: 3	Dr (%): 0.00 ±0.00	Su ratio: 0.38 ±0.03
SBTn description: Clay	φ (degrees): 0.00 ±0.00 °	O.C.R.: 1.77 ±0.16
	Unit weight: 19.00 ±0.00 kN/m³	

.:: Layer No: 11 ::.

Code: Layer_11 **Start depth:** 13.49 (m), **End depth:** 14.66 (m)

Description: Clay

Basic results	**Estimation results**	
Total cone resistance: 1.09 ±0.06 MPa	Permeability: 1.18E-09 ±3.73E-10 m/s	Constrained Mod.: 4.47 ±0.56 MPa
Sleeve friction: 29.03 ±2.83 kPa	N_{60}: 6.74 ±0.43 blows	Go: 45.68 ±1.75 MPa
Ic: 3.26 ±0.05	Es: 0.00 ±0.00 MPa	Su: 58.66 ±3.79 kPa
SBT_n: 3	Dr (%): 0.00 ±0.00	Su ratio: 0.39 ±0.02
SBTn description: Clay	φ (degrees): 0.00 ±0.00 °	O.C.R.: 1.80 ±0.11
	Unit weight: 19.00 ±0.00 kN/m³	

.:: Layer No: 12 ::.

Code: Layer_12 **Start depth:** 14.66 (m), **End depth:** 15.31 (m)

Description: Clay

Basic results	**Estimation results**	
Total cone resistance: 1.38 ±0.07 MPa	Permeability: 1.19E-09 ±4.88E-10 m/s	Constrained Mod.: 7.49 ±0.88 MPa
Sleeve friction: 53.45 ±12.42 kPa	N_{60}: 8.36 ±0.63 blows	Go: 60.59 ±5.43 MPa
Ic: 3.25 ±0.05	Es: 0.00 ±0.00 MPa	Su: 78.03 ±4.69 kPa
SBT_n: 3	Dr (%): 0.00 ±0.00	Su ratio: 0.49 ±0.03
SBTn description: Clay	φ (degrees): 0.00 ±0.00 °	O.C.R.: 2.26 ±0.13
	Unit weight: 19.00 ±0.00 kN/m³	

.:: Layer No: 13 ::.

Code: Layer_13 **Start depth:** 15.31 (m), **End depth:** 15.92 (m)

Description: Clay

Basic results	**Estimation results**	
Total cone resistance: 1.85 ±0.13 MPa	Permeability: 2.03E-09 ±4.07E-10 m/s	Constrained Mod.: 14.68 ±2.29 MPa
Sleeve friction: 85.27 ±8.45 kPa	N_{60}: 10.76 ±0.61 blows	Go: 77.83 ±4.25 MPa
Ic: 3.17 ±0.03	Es: 0.00 ±0.00 MPa	Su: 111.20 ±9.31 kPa
SBT_n: 3	Dr (%): 0.00 ±0.00	Su ratio: 0.67 ±0.05
SBTn description: Clay	φ (degrees): 0.00 ±0.00 °	O.C.R.: 3.11 ±0.23
	Unit weight: 19.00 ±0.00 kN/m³	

.:: Layer No: 14 ::.

Code: Layer_14 **Start depth:** 15.92 (m), **End depth:** 16.83 (m)

Description: Clay

Basic results	**Estimation results**	
Total cone resistance: 2.31 ±0.13 MPa	Permeability: 3.12E-09 ±5.82E-10 m/s	Constrained Mod.: 23.10 ±2.86 MPa
Sleeve friction: 112.65 ±7.77 kPa	N_{60}: 12.77 ±0.64 blows	Go: 92.23 ±3.45 MPa
Ic: 3.11 ±0.03	Es: 0.00 ±0.00 MPa	Su: 142.40 ±9.25 kPa
SBT_n: 3	Dr (%): 0.00 ±0.00	Su ratio: 0.83 ±0.05
SBTn description: Clay	φ (degrees): 0.00 ±0.00 °	O.C.R.: 3.82 ±0.22
	Unit weight: 19.00 ±0.00 kN/m³	

.:: Layer No: 15 ::.

Code: Layer_15 **Start depth:** 16.83 (m), **End depth:** 17.41 (m)

Description: Clay

Basic results	**Estimation results**	
Total cone resistance: 1.76 ±0.17 MPa	Permeability: 1.40E-09 ±4.07E-10 m/s	Constrained Mod.: 11.50 ±2.83 MPa
Sleeve friction: 77.99 ±13.70 kPa	N_{60}: 10.47 ±0.88 blows	Go: 76.83 ±6.13 MPa
Ic: 3.23 ±0.04	Es: 0.00 ±0.00 MPa	Su: 102.46 ±11.98 kPa
SBT_n: 3	Dr (%): 0.00 ±0.00	Su ratio: 0.57 ±0.07
SBTn description: Clay	φ (degrees): 0.00 ±0.00 °	O.C.R.: 2.65 ±0.33
	Unit weight: 19.00 ±0.00 kN/m³	

.:: Layer No: 16 ::.

Code: Layer_16 **Start depth:** 17.41 (m), **End depth:** 17.94 (m)

Description: Clay

Basic results	**Estimation results**	
Total cone resistance: 2.13 ±0.10 MPa	Permeability: 2.80E-09 ±5.11E-10 m/s	Constrained Mod.: 17.58 ±1.89 MPa
Sleeve friction: 86.94 ±6.10 kPa	N_{60}: 11.82 ±0.50 blows	Go: 84.88 ±2.97 MPa
Ic: 3.13 ±0.03	Es: 0.00 ±0.00 MPa	Su: 128.46 ±7.08 kPa
SBT_n: 3	Dr (%): 0.00 ±0.00	Su ratio: 0.70 ±0.04
SBTn description: Clay	φ (degrees): 0.00 ±0.00 °	O.C.R.: 3.23 ±0.17
	Unit weight: 19.00 ±0.00 kN/m³	

.:: Layer No: 17 ::.

Code: Layer_17 **Start depth:** 17.94 (m), **End depth:** 20.30 (m)

Description: Clay

Basic results	**Estimation results**	
Total cone resistance: 1.75 ±0.23 MPa	Permeability: 1.03E-09 ±5.29E-10 m/s	Constrained Mod.: 9.73 ±3.76 MPa
Sleeve friction: 80.97 ±11.43 kPa	N_{60}: 10.86 ±0.85 blows	Go: 80.49 ±5.88 MPa
Ic: 3.29 ±0.08	Es: 0.00 ±0.00 MPa	Su: 98.91 ±16.86 kPa
SBT_n: 3	Dr (%): 0.00 ±0.00	Su ratio: 0.50 ±0.10
SBTn description: Clay	φ (degrees): 0.00 ±0.00 °	O.C.R.: 2.32 ±0.45
	Unit weight: 19.00 ±0.00 kN/m³	

Summary table of mean values

From depth To depth (m)	Thickness (m)	Permeability (m/s)	SPT_{N60} (blows/30cm)	E_s (MPa)	D_r (%)	Friction angle	Constrained modulus, M (MPa)	Shear modulus, G_O (MPa)	Undrained strength, S_U (kPa)	Undrained strength ratio	OCR	Unit weight (kN/m³)
0.41 0.93	0.52	1.12E-07 (±1.23E-07)	4.9 (±1.2)	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)	16.7 (±4.7)	28.9 (±7.3)	85.2 (±24.0)	4.9 (±1.2)	22.8 (±5.7)	19.0 (±0.0)
0.93 1.66	0.73	7.11E-08 (±1.26E-07)	7.5 (±3.6)	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)	24.9 (±15.6)	46.8 (±17.4)	127.2 (±79.7)	4.4 (±2.9)	20.1 (±13.5)	19.0 (±0.0)
1.66 4.68	3.02	6.77E-09 (±1.10E-08)	3.9 (±1.6)	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)	8.6 (±5.3)	28.5 (±11.4)	50.3 (±23.0)	1.0 (±0.3)	4.7 (±1.6)	19.0 (±0.0)
4.68 6.26	1.58	4.30E-09 (±1.62E-09)	4.4 (±0.6)	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)	7.4 (±2.2)	31.9 (±3.8)	52.2 (±7.5)	0.7 (±0.1)	3.4 (±0.6)	19.0 (±0.0)
6.26 8.16	1.90	3.69E-09 (±1.70E-09)	6.1 (±0.4)	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)	10.4 (±2.4)	43.0 (±3.2)	68.4 (±7.0)	0.8 (±0.1)	3.6 (±0.4)	19.0 (±0.0)
8.16 9.68	1.52	2.72E-09 (±1.94E-09)	4.2 (±0.6)	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)	3.3 (±1.2)	28.0 (±3.3)	41.7 (±7.9)	0.4 (±0.1)	1.9 (±0.4)	19.0 (±0.0)
9.68 11.05	1.37	2.18E-09 (±1.64E-09)	5.2 (±0.7)	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)	4.3 (±1.9)	35.1 (±6.1)	50.8 (±10.7)	0.4 (±0.1)	2.0 (±0.4)	19.0 (±0.0)
11.05 11.60	0.55	1.62E-09 (±5.10E-10)	5.0 (±0.3)	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)	2.9 (±0.6)	31.4 (±2.0)	42.9 (±4.3)	0.3 (±0.0)	1.6 (±0.2)	19.0 (±0.0)
11.60 12.84	1.24	1.55E-09 (±1.29E-09)	5.6 (±0.5)	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)	3.6 (±1.3)	37.4 (±2.6)	49.8 (±8.5)	0.4 (±0.1)	1.7 (±0.3)	19.0 (±0.0)
12.84 13.49	0.65	1.78E-09 (±8.95E-10)	6.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)	4.1 (±0.7)	39.2 (±2.5)	54.6 (±4.6)	0.4 (±0.0)	1.8 (±0.2)	19.0 (±0.0)
13.49 14.66	1.17	1.18E-09 (±3.73E-10)	6.7 (±0.4)	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)	4.5 (±0.6)	45.7 (±1.7)	58.7 (±3.8)	0.4 (±0.0)	1.8 (±0.1)	19.0 (±0.0)
14.66 15.31	0.65	1.19E-09 (±4.88E-10)	8.4 (±0.6)	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)	7.5 (±0.9)	60.6 (±5.4)	78.0 (±4.7)	0.5 (±0.0)	2.3 (±0.1)	19.0 (±0.0)

Summary table of mean values

From depth To depth (m)	Thickness (m)	Permeability (m/s)	SPT_{N60} (blows/30cm)	E_s (MPa)	D_r (%)	Friction angle	Constrained modulus, M (MPa)	Shear modulus, G_O (MPa)	Undrained strength, S_U (kPa)	Undrained strength ratio	OCR	Unit weight (kN/m³)
15.31	0.61	2.03E-09	10.8	0.0	0.0	0.0	14.7	77.8	111.2	0.7	3.1	19.0
15.92		(±4.07E-10)	(±0.6)	(±0.0)	(±0.0)	(±0.0)	(±2.3)	(±4.2)	(±9.3)	(±0.1)	(±0.2)	(±0.0)
15.92	0.91	3.12E-09	12.8	0.0	0.0	0.0	23.1	92.2	142.4	0.8	3.8	19.0
16.83		(±5.82E-10)	(±0.6)	(±0.0)	(±0.0)	(±0.0)	(±2.9)	(±3.5)	(±9.3)	(±0.0)	(±0.2)	(±0.0)
16.83	0.58	1.40E-09	10.5	0.0	0.0	0.0	11.5	76.8	102.5	0.6	2.6	19.0
17.41		(±4.07E-10)	(±0.9)	(±0.0)	(±0.0)	(±0.0)	(±2.8)	(±6.1)	(±12.0)	(±0.1)	(±0.3)	(±0.0)
17.41	0.53	2.80E-09	11.8	0.0	0.0	0.0	17.6	84.9	128.5	0.7	3.2	19.0
17.94		(±5.11E-10)	(±0.5)	(±0.0)	(±0.0)	(±0.0)	(±1.9)	(±3.0)	(±7.1)	(±0.0)	(±0.2)	(±0.0)
17.94	2.36	1.03E-09	10.9	0.0	0.0	0.0	9.7	80.5	98.9	0.5	2.3	19.0
20.30		(±5.29E-10)	(±0.9)	(±0.0)	(±0.0)	(±0.0)	(±3.8)	(±5.9)	(±16.9)	(±0.1)	(±0.4)	(±0.0)

Depth values presented in this table are measured from free ground surface

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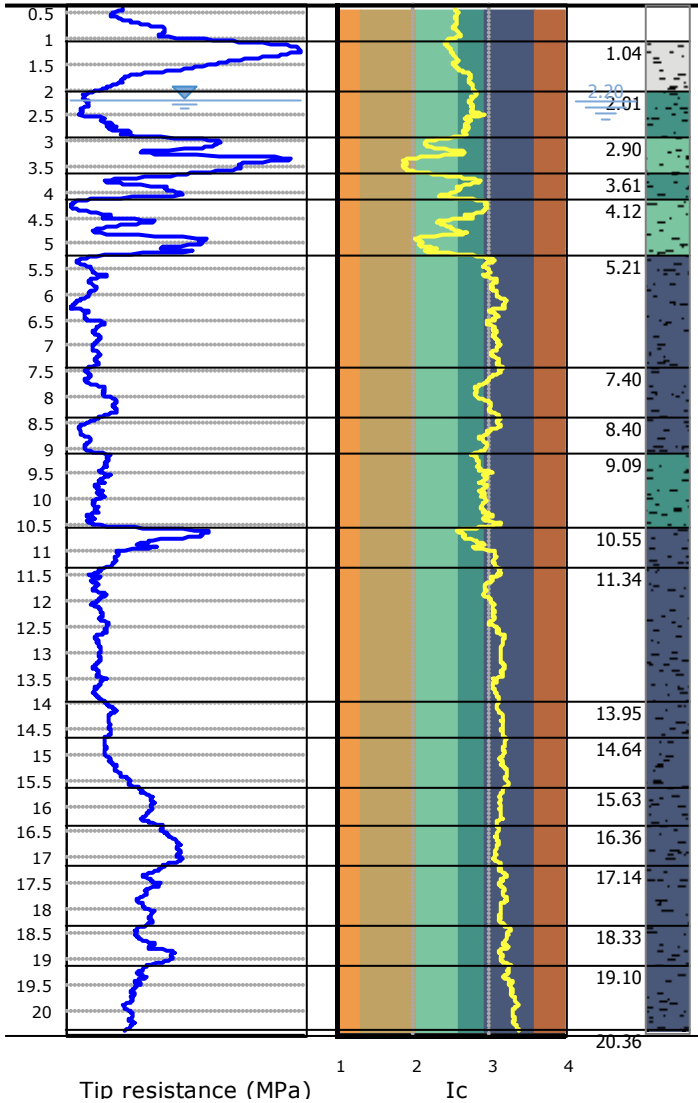
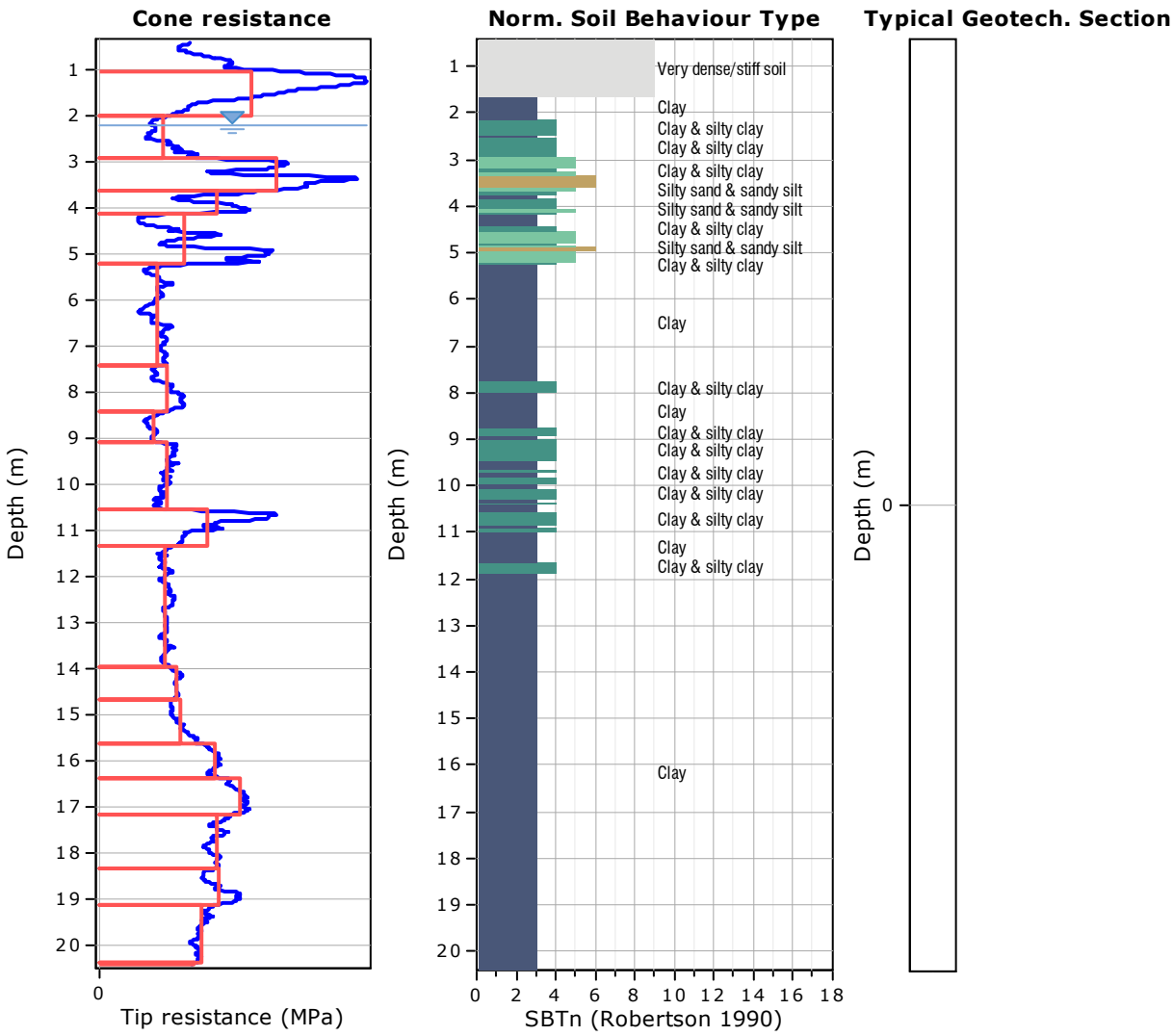
CPT: CPTU2
Total depth: 20.40 m, Date: 09/12/2021
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

Project:
Location:

Depth (m) Elevation: 0.00 (m)



Depth (m)	Description	qt (MPa)	Ksbt (m/s)	N60	Es (MPa)	Dr	Phi (°)	M (MPa)	Go (MPa)	Su (kPa)	Su ratio	OCR	Gamma (kN/m³)
1.04	Very dense/stiff soil	2.5	1.01E-7	9.9	-	-	-	34.3	60.4	174.8	5.1	23.5	19.0
2.01	Clay & silty clay	1.0	3.62E-8	4.6	-	-	-	13.7	29.1	69.9	1.5	6.9	19.0
2.90	Silty sand & sandy silt	2.9	1.85E-6	8.8	31.6	37.3	34.5	45.4	41.0	-	-	-	19.0
3.61	Clay & silty clay	1.9	1.37E-7	7.5	-	-	-	26.0	42.6	118.8	2.0	9.1	19.0
4.12	Silty sand & sandy silt	1.4	1.83E-7	5.2	24.2	26.9	32.2	18.1	28.5	-	-	-	19.0
5.21	Clay	1.0	4.35E-9	5.2	-	-	-	8.7	36.3	59.5	0.7	3.5	19.0
7.40	Clay	1.1	7.12E-9	5.6	-	-	-	9.7	38.1	68.2	0.7	3.3	19.0
8.40	Clay	0.9	6.45E-9	4.4	-	-	-	4.8	28.4	50.1	0.5	2.3	19.0
9.09	Clay & silty clay	1.1	1.09E-8	5.4	-	-	-	7.2	33.1	64.1	0.6	2.6	19.0
10.55	Clay	1.8	1.37E-8	8.4	-	-	-	17.5	54.3	109.5	0.9	4.2	19.0
11.34	Clay	1.1	3.49E-9	5.9	-	-	-	5.1	38.0	59.9	0.4	2.0	19.0
13.95	Clay	1.3	2.25E-9	7.1	-	-	-	6.4	48.4	70.4	0.5	2.1	19.0
14.64	Clay	1.3	1.55E-9	7.8	-	-	-	6.5	53.7	73.0	0.5	2.1	19.0
15.63	Clay	1.9	2.31E-9	10.6	-	-	-	14.5	76.4	111.8	0.7	3.1	19.0
16.36	Clay	2.3	3.22E-9	12.6	-	-	-	21.9	90.3	140.2	0.8	3.7	19.0
17.14	Clay	1.9	2.01E-9	11.0	-	-	-	13.2	78.3	111.7	0.6	2.8	19.0
18.33	Clay	1.9	1.54E-9	11.5	-	-	-	12.9	83.0	112.8	0.6	2.7	19.0
19.10	Clay	1.7	9.26E-10	10.2	-	-	-	8.0	75.5	91.2	0.4	2.1	19.0
20.36	Clay	1.5	7.08E-10	10.0	-	-	-	6.3	74.3	81.6	0.4	1.8	19.0



Tabular results

.:: Layer No: 1 ::.

Code: Layer_1 **Start depth:** 1.04 (m), **End depth:** 2.01 (m)

Description: Very dense/stiff soil

Basic results	**Estimation results**	
Total cone resistance: 2.48 ±1.18 MPa	Permeability: 1.01E-07 ±1.10E-07 m/s	Constrained Mod.: 34.27 ±16.60 MPa
Sleeve friction: 162.56 ±103.70 kPa	N_{60}: 9.89 ±3.99 blows	Go: 60.36 ±20.07 MPa
Ic: 2.61 ±0.12	Es: 0.00 ±0.00 MPa	Su: 174.83 ±84.71 kPa
SBT_n: 9	Dr (%): 0.00 ±0.00	Su ratio: 5.10 ±3.08
SBTn description: Very dense/stiff soil	φ (degrees): 0.00 ±0.00 °	O.C.R.: 23.55 ±14.21
	Unit weight: 19.00 ±0.00 kN/m³	

.:: Layer No: 2 ::.

Code: Layer_2 **Start depth:** 2.01 (m), **End depth:** 2.90 (m)

Description: Clay & silty clay

Basic results	**Estimation results**	
Total cone resistance: 1.03 ±0.25 MPa	Permeability: 3.62E-08 ±1.61E-08 m/s	Constrained Mod.: 13.70 ±3.49 MPa
Sleeve friction: 31.75 ±10.88 kPa	N_{60}: 4.62 ±0.90 blows	Go: 29.06 ±5.40 MPa
Ic: 2.76 ±0.06	Es: 0.00 ±0.00 MPa	Su: 69.88 ±17.80 kPa
SBT_n: 4	Dr (%): 0.00 ±0.00	Su ratio: 1.50 ±0.29
SBTn description: Clay & silty clay	φ (degrees): 0.00 ±0.00 °	O.C.R.: 6.92 ±1.33
	Unit weight: 19.00 ±0.00 kN/m³	

.:: Layer No: 3 ::.

Code: Layer_3 **Start depth:** 2.90 (m), **End depth:** 3.61 (m)

Description: Silty sand & sandy silt

Basic results	**Estimation results**	
Total cone resistance: 2.88 ±0.69 MPa	Permeability: 1.85E-06 ±7.92E-06 m/s	Constrained Mod.: 45.43 ±16.25 MPa
Sleeve friction: 26.56 ±23.71 kPa	N_{60}: 8.79 ±1.00 blows	Go: 41.03 ±6.16 MPa
Ic: 2.18 ±0.28	Es: 31.59 ±4.92 MPa	Su: 0.00 ±0.00 kPa
SBT_n: 5	Dr (%): 37.35 ±2.04	Su ratio: 0.00 ±0.00
SBTn description: Silty sand & sandy silt	φ (degrees): 34.50 ±1.43 °	O.C.R.: 0.00 ±0.00
	Unit weight: 19.00 ±0.00 kN/m³	

.:: Layer No: 4 ::.

Code: Layer_4 **Start depth:** 3.61 (m), **End depth:** 4.12 (m)

Description: Clay & silty clay

Basic results	**Estimation results**	
Total cone resistance: 1.90 ±0.47 MPa	Permeability: 1.37E-07 ±7.22E-07 m/s	Constrained Mod.: 25.97 ±8.53 MPa
Sleeve friction: 44.35 ±17.31 kPa	N_{60}: 7.48 ±1.21 blows	Go: 42.62 ±6.08 MPa
Ic: 2.56 ±0.19	Es: 0.00 ±0.00 MPa	Su: 118.79 ±30.39 kPa
SBT_n: 4	Dr (%): 0.00 ±0.00	Su ratio: 1.96 ±0.44
SBTn description: Clay & silty clay	φ (degrees): 0.00 ±0.00 °	O.C.R.: 9.06 ±2.04
	Unit weight: 19.00 ±0.00 kN/m³	

.:: Layer No: 5 ::.

Code: Layer_5 **Start depth:** 4.12 (m), **End depth:** 5.21 (m)

Description: Silty sand & sandy silt

Basic results	**Estimation results**	
Total cone resistance: 1.39 ±0.74 MPa	Permeability: 1.83E-07 ±1.82E-06 m/s	Constrained Mod.: 18.12 ±17.23 MPa
Sleeve friction: 13.20 ±6.74 kPa	N_{60}: 5.22 ±1.70 blows	Go: 28.53 ±4.86 MPa
Ic: 2.51 ±0.31	Es: 24.16 ±3.44 MPa	Su: 0.00 ±0.00 kPa
SBT_n: 5	Dr (%): 26.93 ±3.81	Su ratio: 0.00 ±0.00
SBTn description: Silty sand & sandy silt	φ (degrees): 32.23 ±0.39 °	O.C.R.: 0.00 ±0.00
	Unit weight: 19.00 ±0.00 kN/m³	

.:: Layer No: 6 ::.

Code: Layer_6 **Start depth:** 5.21 (m), **End depth:** 7.40 (m)

Description: Clay

Basic results	**Estimation results**	
Total cone resistance: 0.95 ±0.14 MPa	Permeability: 4.35E-09 ±1.16E-08 m/s	Constrained Mod.: 8.70 ±2.73 MPa
Sleeve friction: 34.60 ±9.27 kPa	N_{60}: 5.19 ±0.72 blows	Go: 36.29 ±4.89 MPa
Ic: 3.06 ±0.09	Es: 0.00 ±0.00 MPa	Su: 59.50 ±9.97 kPa
SBT_n: 3	Dr (%): 0.00 ±0.00	Su ratio: 0.75 ±0.13
SBTn description: Clay	φ (degrees): 0.00 ±0.00 °	O.C.R.: 3.46 ±0.61
	Unit weight: 19.00 ±0.00 kN/m³	

.:: Layer No: 7 ::.

Code: Layer_7 **Start depth:** 7.40 (m), **End depth:** 8.40 (m)

Description: Clay

Basic results	**Estimation results**	
Total cone resistance: 1.11 ±0.19 MPa	Permeability: 7.12E-09 ±7.64E-09 m/s	Constrained Mod.: 9.68 ±3.60 MPa
Sleeve friction: 28.19 ±16.22 kPa	N_{60}: 5.57 ±1.03 blows	Go: 38.05 ±7.85 MPa
Ic: 2.99 ±0.11	Es: 0.00 ±0.00 MPa	Su: 68.20 ±13.22 kPa
SBT_n: 3	Dr (%): 0.00 ±0.00	Su ratio: 0.72 ±0.12
SBTn description: Clay	φ (degrees): 0.00 ±0.00 °	O.C.R.: 3.35 ±0.57
	Unit weight: 19.00 ±0.00 kN/m³	

.:: Layer No: 8 ::.

Code: Layer_8 **Start depth:** 8.40 (m), **End depth:** 9.09 (m)

Description: Clay

Basic results	**Estimation results**	
Total cone resistance: 0.87 ±0.09 MPa	Permeability: 6.45E-09 ±4.56E-09 m/s	Constrained Mod.: 4.82 ±1.27 MPa
Sleeve friction: 11.62 ±10.29 kPa	N_{60}: 4.43 ±0.65 blows	Go: 28.44 ±5.40 MPa
Ic: 3.01 ±0.09	Es: 0.00 ±0.00 MPa	Su: 50.08 ±6.14 kPa
SBT_n: 3	Dr (%): 0.00 ±0.00	Su ratio: 0.49 ±0.06
SBTn description: Clay	φ (degrees): 0.00 ±0.00 °	O.C.R.: 2.27 ±0.29
	Unit weight: 19.00 ±0.00 kN/m³	

.:: Layer No: 9 ::.

Code: Layer_9 **Start depth:** 9.09 (m), **End depth:** 10.55 (m)

Description: Clay & silty clay

Basic results	**Estimation results**	
Total cone resistance: 1.09 ±0.11 MPa	Permeability: 1.09E-08 ±6.03E-09 m/s	Constrained Mod.: 7.20 ±2.03 MPa
Sleeve friction: 14.03 ±5.18 kPa	N_{60}: 5.41 ±0.52 blows	Go: 33.08 ±3.46 MPa
Ic: 2.93 ±0.07	Es: 0.00 ±0.00 MPa	Su: 64.08 ±8.02 kPa
SBT_n: 4	Dr (%): 0.00 ±0.00	Su ratio: 0.57 ±0.09
SBTn description: Clay & silty clay	φ (degrees): 0.00 ±0.00 °	O.C.R.: 2.65 ±0.40
	Unit weight: 19.00 ±0.00 kN/m³	

.:: Layer No: 10 ::.

Code: Layer_10 **Start depth:** 10.55 (m), **End depth:** 11.34 (m)

Description: Clay

Basic results	**Estimation results**	
Total cone resistance: 1.75 ±0.54 MPa	Permeability: 1.37E-08 ±3.64E-08 m/s	Constrained Mod.: 17.48 ±10.20 MPa
Sleeve friction: 43.26 ±7.81 kPa	N_{60}: 8.43 ±1.50 blows	Go: 54.28 ±6.11 MPa
Ic: 2.89 ±0.18	Es: 0.00 ±0.00 MPa	Su: 109.53 ±39.06 kPa
SBT_n: 3	Dr (%): 0.00 ±0.00	Su ratio: 0.90 ±0.34
SBTn description: Clay	φ (degrees): 0.00 ±0.00 °	O.C.R.: 4.16 ±1.59
	Unit weight: 19.00 ±0.00 kN/m³	

.:: Layer No: 11 ::.

Code: Layer_11 **Start depth:** 11.34 (m), **End depth:** 13.95 (m)

Description: Clay

Basic results	**Estimation results**	
Total cone resistance: 1.08 ±0.06 MPa	Permeability: 3.49E-09 ±2.47E-09 m/s	Constrained Mod.: 5.11 ±0.91 MPa
Sleeve friction: 17.28 ±5.86 kPa	N_{60}: 5.86 ±0.49 blows	Go: 38.02 ±4.00 MPa
Ic: 3.09 ±0.08	Es: 0.00 ±0.00 MPa	Su: 59.91 ±4.69 kPa
SBT_n: 3	Dr (%): 0.00 ±0.00	Su ratio: 0.44 ±0.04
SBTn description: Clay	φ (degrees): 0.00 ±0.00 °	O.C.R.: 2.01 ±0.20
	Unit weight: 19.00 ±0.00 kN/m³	

.:: Layer No: 12 ::.

Code: Layer_12 **Start depth:** 13.95 (m), **End depth:** 14.64 (m)

Description: Clay

Basic results	**Estimation results**	
Total cone resistance: 1.26 ±0.04 MPa	Permeability: 2.25E-09 ±5.06E-10 m/s	Constrained Mod.: 6.35 ±0.58 MPa
Sleeve friction: 29.76 ±3.64 kPa	N_{60}: 7.05 ±0.29 blows	Go: 48.38 ±2.30 MPa
Ic: 3.16 ±0.03	Es: 0.00 ±0.00 MPa	Su: 70.41 ±3.11 kPa
SBT_n: 3	Dr (%): 0.00 ±0.00	Su ratio: 0.46 ±0.02
SBTn description: Clay	φ (degrees): 0.00 ±0.00 °	O.C.R.: 2.13 ±0.10
	Unit weight: 19.00 ±0.00 kN/m³	

.:: Layer No: 13 ::.

Code: Layer_13 **Start depth:** 14.64 (m), **End depth:** 15.63 (m)

Description: Clay

Basic results	**Estimation results**	
Total cone resistance: 1.31 ±0.16 MPa	Permeability: 1.55E-09 ±3.55E-10 m/s	Constrained Mod.: 6.51 ±1.94 MPa
Sleeve friction: 37.58 ±18.37 kPa	N_{60}: 7.81 ±1.10 blows	Go: 53.70 ±9.40 MPa
Ic: 3.21 ±0.03	Es: 0.00 ±0.00 MPa	Su: 73.05 ±10.79 kPa
SBT_n: 3	Dr (%): 0.00 ±0.00	Su ratio: 0.45 ±0.06
SBTn description: Clay	φ (degrees): 0.00 ±0.00 °	O.C.R.: 2.10 ±0.27
	Unit weight: 19.00 ±0.00 kN/m³	

.:: Layer No: 14 ::.

Code: Layer_14 **Start depth:** 15.63 (m), **End depth:** 16.36 (m)

Description: Clay

Basic results	**Estimation results**	
Total cone resistance: 1.87 ±0.08 MPa	Permeability: 2.31E-09 ±3.62E-10 m/s	Constrained Mod.: 14.53 ±1.35 MPa
Sleeve friction: 78.31 ±6.63 kPa	N_{60}: 10.62 ±0.48 blows	Go: 76.43 ±2.68 MPa
Ic: 3.15 ±0.02	Es: 0.00 ±0.00 MPa	Su: 111.77 ±5.33 kPa
SBT_n: 3	Dr (%): 0.00 ±0.00	Su ratio: 0.66 ±0.03
SBTn description: Clay	φ (degrees): 0.00 ±0.00 °	O.C.R.: 3.06 ±0.14
	Unit weight: 19.00 ±0.00 kN/m³	

.:: Layer No: 15 ::.

Code: Layer_15 **Start depth:** 16.36 (m), **End depth:** 17.14 (m)

Description: Clay

Basic results	**Estimation results**	
Total cone resistance: 2.28 ±0.12 MPa	Permeability: 3.22E-09 ±4.68E-10 m/s	Constrained Mod.: 21.94 ±2.37 MPa
Sleeve friction: 104.46 ±10.94 kPa	N_{60}: 12.61 ±0.54 blows	Go: 90.29 ±4.59 MPa
Ic: 3.11 ±0.02	Es: 0.00 ±0.00 MPa	Su: 140.17 ±8.28 kPa
SBT_n: 3	Dr (%): 0.00 ±0.00	Su ratio: 0.80 ±0.04
SBTn description: Clay	φ (degrees): 0.00 ±0.00 °	O.C.R.: 3.69 ±0.19
	Unit weight: 19.00 ±0.00 kN/m³	

.:: Layer No: 16 ::.

Code: Layer_16 **Start depth:** 17.14 (m), **End depth:** 18.33 (m)

Description: Clay

Basic results	**Estimation results**	
Total cone resistance: 1.90 ±0.11 MPa	Permeability: 2.01E-09 ±3.97E-10 m/s	Constrained Mod.: 13.24 ±2.15 MPa
Sleeve friction: 74.82 ±11.39 kPa	N_{60}: 10.99 ±0.64 blows	Go: 78.33 ±4.48 MPa
Ic: 3.17 ±0.03	Es: 0.00 ±0.00 MPa	Su: 111.67 ±8.30 kPa
SBT_n: 3	Dr (%): 0.00 ±0.00	Su ratio: 0.61 ±0.05
SBTn description: Clay	φ (degrees): 0.00 ±0.00 °	O.C.R.: 2.80 ±0.24
	Unit weight: 19.00 ±0.00 kN/m³	

.:: Layer No: 17 ::.

Code: Layer_17 **Start depth:** 18.33 (m), **End depth:** 19.10 (m)

Description: Clay

Basic results	**Estimation results**	
Total cone resistance: 1.94 ±0.23 MPa	Permeability: 1.54E-09 ±5.24E-10 m/s	Constrained Mod.: 12.89 ±3.67 MPa
Sleeve friction: 83.18 ±14.10 kPa	N_{60}: 11.47 ±1.17 blows	Go: 83.03 ±7.52 MPa
Ic: 3.21 ±0.05	Es: 0.00 ±0.00 MPa	Su: 112.82 ±16.02 kPa
SBT_n: 3	Dr (%): 0.00 ±0.00	Su ratio: 0.58 ±0.08
SBTn description: Clay	φ (degrees): 0.00 ±0.00 °	O.C.R.: 2.69 ±0.36
	Unit weight: 19.00 ±0.00 kN/m³	

.:: Layer No: 18 ::.

Code: Layer_18 **Start depth:** 19.10 (m), **End depth:** 20.36 (m)

Description: Clay

Basic results	**Estimation results**	
Total cone resistance: 1.65 ±0.09 MPa	Permeability: 9.26E-10 ±2.31E-10 m/s	Constrained Mod.: 8.03 ±1.41 MPa
Sleeve friction: 67.79 ±7.23 kPa	N_{60}: 10.23 ±0.47 blows	Go: 75.45 ±3.09 MPa
Ic: 3.30 ±0.05	Es: 0.00 ±0.00 MPa	Su: 91.16 ±7.10 kPa
SBT_n: 3	Dr (%): 0.00 ±0.00	Su ratio: 0.45 ±0.04
SBTn description: Clay	φ (degrees): 0.00 ±0.00 °	O.C.R.: 2.08 ±0.19
	Unit weight: 19.00 ±0.00 kN/m³	

.:: Layer No: 19 ::.

Code: Layer_19 **Start depth:** 20.36 (m), **End depth:** 20.40 (m)

Description: Clay

Basic results	**Estimation results**	
Total cone resistance: 1.53 ±0.02 MPa	Permeability: 7.08E-10 ±1.60E-11 m/s	Constrained Mod.: 6.25 ±0.25 MPa
Sleeve friction: 67.05 ±1.38 kPa	N_{60}: 10.00 ±0.00 blows	Go: 74.27 ±0.80 MPa
Ic: 3.38 ±0.01	Es: 0.00 ±0.00 MPa	Su: 81.61 ±1.62 kPa
SBT_n: 3	Dr (%): 0.00 ±0.00	Su ratio: 0.39 ±0.01
SBTn description: Clay	φ (degrees): 0.00 ±0.00 °	O.C.R.: 1.81 ±0.04
	Unit weight: 19.00 ±0.00 kN/m³	

Summary table of mean values

From depth To depth (m)	Thickness (m)	Permeability (m/s)	SPT_{N60} (blows/30cm)	E_s (MPa)	D_r (%)	Friction angle	Constrained modulus, M (MPa)	Shear modulus, G_O (MPa)	Undrained strength, S_U (kPa)	Undrained strength ratio	OCR	Unit weight (kN/m³)
1.04 2.01	0.97	1.01E-07 (±1.10E-07)	9.9 (±4.0)	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)	34.3 (±16.6)	60.4 (±20.1)	174.8 (±84.7)	5.1 (±3.1)	23.5 (±14.2)	19.0 (±0.0)
2.01 2.90	0.89	3.62E-08 (±1.61E-08)	4.6 (±0.9)	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)	13.7 (±3.5)	29.1 (±5.4)	69.9 (±17.8)	1.5 (±0.3)	6.9 (±1.3)	19.0 (±0.0)
2.90 3.61	0.71	1.85E-06 (±7.92E-06)	8.8 (±1.0)	31.6 (±4.9)	37.3 (±2.0)	34.5 (±1.4)	45.4 (±16.2)	41.0 (±6.2)	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)	19.0 (±0.0)
3.61 4.12	0.51	1.37E-07 (±7.22E-07)	7.5 (±1.2)	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)	26.0 (±8.5)	42.6 (±6.1)	118.8 (±30.4)	2.0 (±0.4)	9.1 (±2.0)	19.0 (±0.0)
4.12 5.21	1.09	1.83E-07 (±1.82E-06)	5.2 (±1.7)	24.2 (±3.4)	26.9 (±3.8)	32.2 (±0.4)	18.1 (±17.2)	28.5 (±4.9)	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)	19.0 (±0.0)
5.21 7.40	2.19	4.35E-09 (±1.16E-08)	5.2 (±0.7)	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)	8.7 (±2.7)	36.3 (±4.9)	59.5 (±10.0)	0.7 (±0.1)	3.5 (±0.6)	19.0 (±0.0)
7.40 8.40	1.00	7.12E-09 (±7.64E-09)	5.6 (±1.0)	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)	9.7 (±3.6)	38.1 (±7.9)	68.2 (±13.2)	0.7 (±0.1)	3.3 (±0.6)	19.0 (±0.0)
8.40 9.09	0.69	6.45E-09 (±4.56E-09)	4.4 (±0.7)	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)	4.8 (±1.3)	28.4 (±5.4)	50.1 (±6.1)	0.5 (±0.1)	2.3 (±0.3)	19.0 (±0.0)
9.09 10.55	1.46	1.09E-08 (±6.03E-09)	5.4 (±0.5)	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)	7.2 (±2.0)	33.1 (±3.5)	64.1 (±8.0)	0.6 (±0.1)	2.6 (±0.4)	19.0 (±0.0)
10.55 11.34	0.79	1.37E-08 (±3.64E-08)	8.4 (±1.5)	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)	17.5 (±10.2)	54.3 (±6.1)	109.5 (±39.1)	0.9 (±0.3)	4.2 (±1.6)	19.0 (±0.0)
11.34 13.95	2.61	3.49E-09 (±2.47E-09)	5.9 (±0.5)	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)	5.1 (±0.9)	38.0 (±4.0)	59.9 (±4.7)	0.4 (±0.0)	2.0 (±0.2)	19.0 (±0.0)
13.95 14.64	0.69	2.25E-09 (±5.06E-10)	7.1 (±0.3)	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)	6.4 (±0.6)	48.4 (±2.3)	70.4 (±3.1)	0.5 (±0.0)	2.1 (±0.1)	19.0 (±0.0)

Summary table of mean values

From depth To depth (m)	Thickness (m)	Permeability (m/s)	SPT_{N60} (blows/30cm)	E_s (MPa)	D_r (%)	Friction angle	Constrained modulus, M (MPa)	Shear modulus, G_O (MPa)	Undrained strength, S_U (kPa)	Undrained strength ratio	OCR	Unit weight (kN/m³)
14.64	0.99	1.55E-09	7.8	0.0	0.0	0.0	6.5	53.7	73.0	0.5	2.1	19.0
15.63		(±3.55E-10)	(±1.1)	(±0.0)	(±0.0)	(±0.0)	(±1.9)	(±9.4)	(±10.8)	(±0.1)	(±0.3)	(±0.0)
15.63	0.73	2.31E-09	10.6	0.0	0.0	0.0	14.5	76.4	111.8	0.7	3.1	19.0
16.36		(±3.62E-10)	(±0.5)	(±0.0)	(±0.0)	(±0.0)	(±1.4)	(±2.7)	(±5.3)	(±0.0)	(±0.1)	(±0.0)
16.36	0.78	3.22E-09	12.6	0.0	0.0	0.0	21.9	90.3	140.2	0.8	3.7	19.0
17.14		(±4.68E-10)	(±0.5)	(±0.0)	(±0.0)	(±0.0)	(±2.4)	(±4.6)	(±8.3)	(±0.0)	(±0.2)	(±0.0)
17.14	1.19	2.01E-09	11.0	0.0	0.0	0.0	13.2	78.3	111.7	0.6	2.8	19.0
18.33		(±3.97E-10)	(±0.6)	(±0.0)	(±0.0)	(±0.0)	(±2.2)	(±4.5)	(±8.3)	(±0.1)	(±0.2)	(±0.0)
18.33	0.77	1.54E-09	11.5	0.0	0.0	0.0	12.9	83.0	112.8	0.6	2.7	19.0
19.10		(±5.24E-10)	(±1.2)	(±0.0)	(±0.0)	(±0.0)	(±3.7)	(±7.5)	(±16.0)	(±0.1)	(±0.4)	(±0.0)
19.10	1.26	9.26E-10	10.2	0.0	0.0	0.0	8.0	75.5	91.2	0.4	2.1	19.0
20.36		(±2.31E-10)	(±0.5)	(±0.0)	(±0.0)	(±0.0)	(±1.4)	(±3.1)	(±7.1)	(±0.0)	(±0.2)	(±0.0)
20.36	0.04	7.08E-10	10.0	0.0	0.0	0.0	6.3	74.3	81.6	0.4	1.8	19.0
20.40		(±1.60E-11)	(±0.0)	(±0.0)	(±0.0)	(±0.0)	(±0.3)	(±0.8)	(±1.6)	(±0.0)	(±0.0)	(±0.0)

Depth values presented in this table are measured from free ground surface

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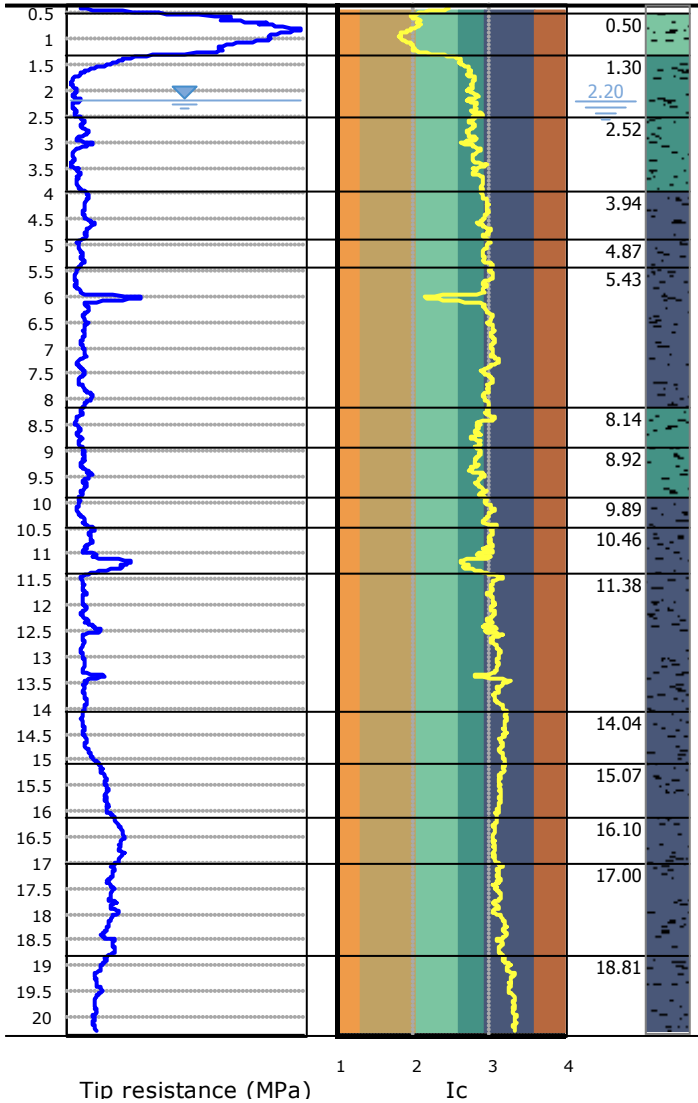
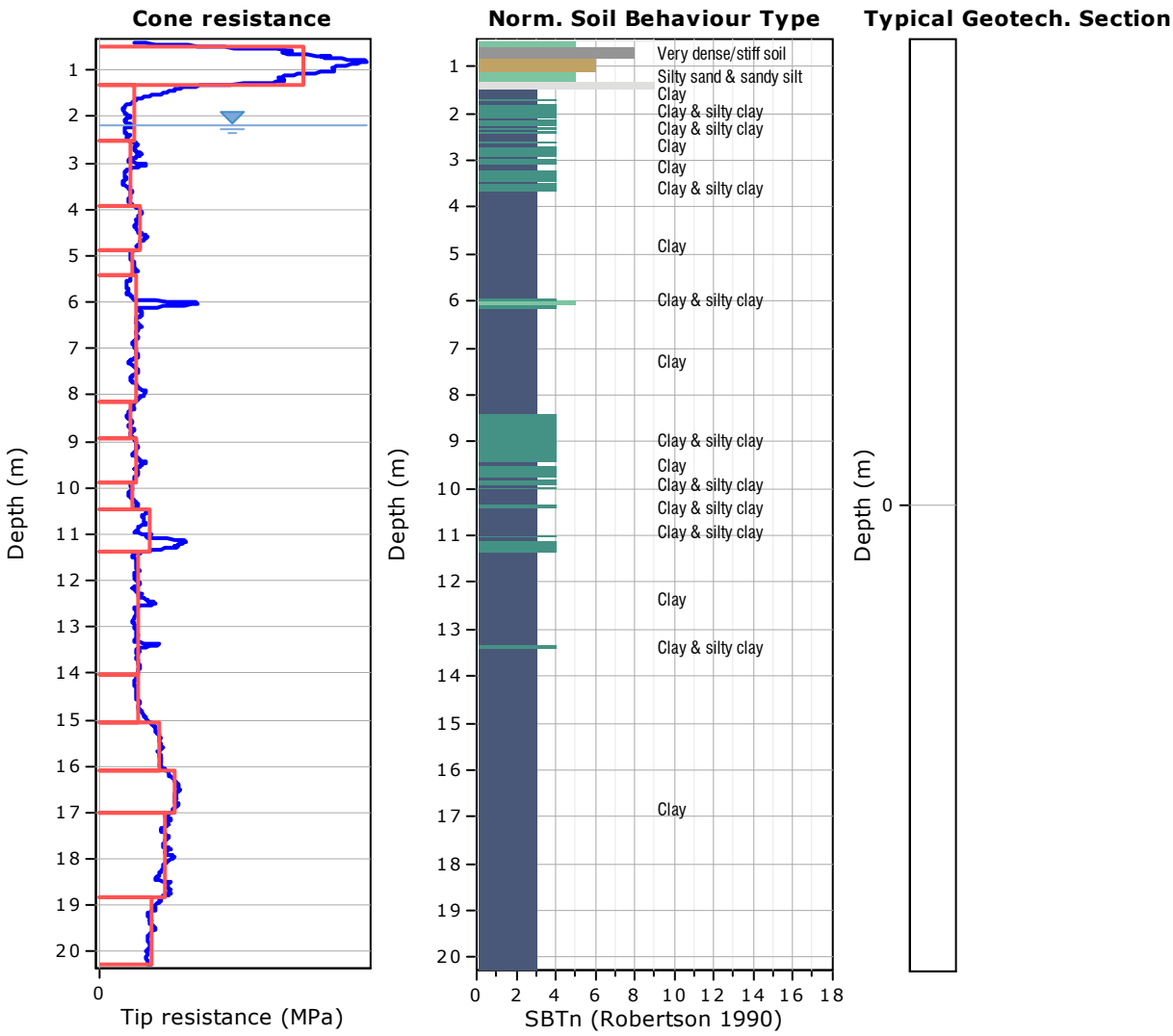
CPT: CPTU3
Total depth: 20.27 m, Date: 09/12/2021
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

Project:
Location:

Depth (m) Elevation: 0.00 (m)



	Description	qt (MPa)	Ksbt (m/s)	N60	Es (MPa)	Dr	Phi (°)	M (MPa)	Go (MPa)	Su (kPa)	Su ratio	OCR	Gamma (kN/m³)
0.50	Silty sand & sandy silt	6.4	8.12E-6	17.0	56.4	74.2	43.0	111.1	70.6	-	-	-	19.0
1.30	Clay & silty clay	1.1	3.93E-8	4.8	-	-	-	14.7	30.8	75.2	1.9	8.9	19.0
2.52	Clay & silty clay	1.0	2.35E-8	4.5	-	-	-	12.5	29.1	64.7	1.2	5.6	19.0
3.94	Clay	1.2	9.66E-9	6.2	-	-	-	16.0	43.2	81.9	1.3	6.1	19.0
4.87	Clay	1.0	8.61E-9	5.2	-	-	-	12.6	36.2	67.1	1.0	4.5	19.0
5.43	Clay	1.1	8.36E-9	5.7	-	-	-	11.7	39.1	69.3	0.8	3.8	19.0
8.14	Clay & silty clay	1.0	1.28E-8	4.8	-	-	-	6.7	29.3	58.4	0.6	2.7	19.0
8.92	Clay & silty clay	1.2	1.79E-8	5.3	-	-	-	8.8	32.9	69.7	0.6	3.0	19.0
9.89	Clay	1.0	7.17E-9	5.4	-	-	-	6.0	33.1	59.4	0.5	2.4	19.0
10.46	Clay	1.6	1.16E-8	7.7	-	-	-	14.2	49.4	96.6	0.8	3.7	19.0
11.38	Clay	1.2	3.88E-9	6.4	-	-	-	6.4	41.8	67.1	0.5	2.2	19.0
14.04	Clay	1.2	1.74E-9	7.2	-	-	-	5.6	48.0	66.7	0.4	2.0	19.0
15.07	Clay	1.9	2.39E-9	10.6	-	-	-	14.7	75.6	111.3	0.7	3.1	19.0
16.10	Clay	2.3	4.05E-9	12.6	-	-	-	23.4	88.9	143.9	0.8	3.8	19.0
17.00	Clay	2.0	2.51E-9	11.6	-	-	-	15.6	82.0	121.7	0.7	3.0	19.0
18.81	Clay	1.6	9.53E-10	10.0	-	-	-	7.3	71.3	86.7	0.4	2.0	19.0



Tabular results

.:: Layer No: 1 ::.

Code: Layer_1 **Start depth:** 0.50 (m), **End depth:** 1.30 (m)

Description: Silty sand & sandy silt

Basic results	**Estimation results**	
Total cone resistance: 6.35 ±1.14 MPa	Permeability: 8.12E-06 ±7.37E-06 m/s	Constrained Mod.: 111.06 ±19.80 MPa
Sleeve friction: 147.52 ±57.76 kPa	N_{60}: 16.96 ±2.72 blows	Go: 70.64 ±11.17 MPa
Ic: 1.99 ±0.10	Es: 56.39 ±8.96 MPa	Su: 0.00 ±0.00 kPa
SBT_n: 5	Dr (%): 74.18 ±8.37	Su ratio: 0.00 ±0.00
SBTn description: Silty sand & sandy silt	φ (degrees): 43.04 ±1.66 °	O.C.R.: 0.00 ±0.00
	Unit weight: 19.00 ±0.00 kN/m³	

.:: Layer No: 2 ::.

Code: Layer_2 **Start depth:** 1.30 (m), **End depth:** 2.52 (m)

Description: Clay & silty clay

Basic results	**Estimation results**	
Total cone resistance: 1.09 ±0.73 MPa	Permeability: 3.93E-08 ±1.04E-07 m/s	Constrained Mod.: 14.73 ±10.29 MPa
Sleeve friction: 42.69 ±54.46 kPa	N_{60}: 4.80 ±2.53 blows	Go: 30.79 ±13.54 MPa
Ic: 2.75 ±0.11	Es: 0.00 ±0.00 MPa	Su: 75.16 ±52.50 kPa
SBT_n: 4	Dr (%): 0.00 ±0.00	Su ratio: 1.93 ±1.72
SBTn description: Clay & silty clay	φ (degrees): 0.00 ±0.00 °	O.C.R.: 8.94 ±7.94
	Unit weight: 19.00 ±0.00 kN/m³	

.:: Layer No: 3 ::.

Code: Layer_3 **Start depth:** 2.52 (m), **End depth:** 3.94 (m)

Description: Clay & silty clay

Basic results	**Estimation results**	
Total cone resistance: 0.97 ±0.17 MPa	Permeability: 2.35E-08 ±1.46E-08 m/s	Constrained Mod.: 12.48 ±2.62 MPa
Sleeve friction: 28.44 ±9.66 kPa	N_{60}: 4.49 ±0.72 blows	Go: 29.08 ±4.15 MPa
Ic: 2.82 ±0.07	Es: 0.00 ±0.00 MPa	Su: 64.68 ±12.28 kPa
SBT_n: 4	Dr (%): 0.00 ±0.00	Su ratio: 1.22 ±0.27
SBTn description: Clay & silty clay	φ (degrees): 0.00 ±0.00 °	O.C.R.: 5.64 ±1.27
	Unit weight: 19.00 ±0.00 kN/m³	

.:: Layer No: 4 ::.

Code: Layer_4 **Start depth:** 3.94 (m), **End depth:** 4.87 (m)

Description: Clay

Basic results	**Estimation results**	
Total cone resistance: 1.23 ±0.09 MPa	Permeability: 9.66E-09 ±2.96E-09 m/s	Constrained Mod.: 16.05 ±1.27 MPa
Sleeve friction: 62.96 ±7.59 kPa	N_{60}: 6.17 ±0.41 blows	Go: 43.23 ±2.54 MPa
Ic: 2.95 ±0.04	Es: 0.00 ±0.00 MPa	Su: 81.87 ±6.48 kPa
SBT_n: 3	Dr (%): 0.00 ±0.00	Su ratio: 1.32 ±0.10
SBTn description: Clay	φ (degrees): 0.00 ±0.00 °	O.C.R.: 6.09 ±0.47
	Unit weight: 19.00 ±0.00 kN/m³	

.:: Layer No: 5 ::.

Code: Layer_5 **Start depth:** 4.87 (m), **End depth:** 5.43 (m)

Description: Clay

Basic results	**Estimation results**	
Total cone resistance: 1.04 ±0.07 MPa	Permeability: 8.61E-09 ±2.56E-09 m/s	Constrained Mod.: 12.61 ±1.42 MPa
Sleeve friction: 38.06 ±6.18 kPa	N_{60}: 5.20 ±0.41 blows	Go: 36.17 ±2.38 MPa
Ic: 2.97 ±0.04	Es: 0.00 ±0.00 MPa	Su: 67.09 ±4.78 kPa
SBT_n: 3	Dr (%): 0.00 ±0.00	Su ratio: 0.97 ±0.06
SBTn description: Clay	φ (degrees): 0.00 ±0.00 °	O.C.R.: 4.50 ±0.29
	Unit weight: 19.00 ±0.00 kN/m³	

.:: Layer No: 6 ::.

Code: Layer_6 **Start depth:** 5.43 (m), **End depth:** 8.14 (m)

Description: Clay

Basic results	**Estimation results**	
Total cone resistance: 1.14 ±0.36 MPa	Permeability: 8.36E-09 ±3.13E-07 m/s	Constrained Mod.: 11.69 ±7.48 MPa
Sleeve friction: 34.94 ±11.17 kPa	N_{60}: 5.72 ±0.98 blows	Go: 39.05 ±5.13 MPa
Ic: 2.97 ±0.16	Es: 0.00 ±0.00 MPa	Su: 69.31 ±11.62 kPa
SBT_n: 3	Dr (%): 0.00 ±0.00	Su ratio: 0.83 ±0.14
SBTn description: Clay	φ (degrees): 0.00 ±0.00 °	O.C.R.: 3.81 ±0.63
	Unit weight: 19.00 ±0.00 kN/m³	

.:: Layer No: 7 ::.

Code: Layer_7 **Start depth:** 8.14 (m), **End depth:** 8.92 (m)

Description: Clay & silty clay

Basic results	**Estimation results**	
Total cone resistance: 0.98 ±0.07 MPa	Permeability: 1.28E-08 ±8.26E-09 m/s	Constrained Mod.: 6.69 ±1.26 MPa
Sleeve friction: 11.65 ±7.35 kPa	N_{60}: 4.81 ±0.52 blows	Go: 29.31 ±4.29 MPa
Ic: 2.91 ±0.08	Es: 0.00 ±0.00 MPa	Su: 58.39 ±5.20 kPa
SBT_n: 4	Dr (%): 0.00 ±0.00	Su ratio: 0.58 ±0.06
SBTn description: Clay & silty clay	φ (degrees): 0.00 ±0.00 °	O.C.R.: 2.70 ±0.26
	Unit weight: 19.00 ±0.00 kN/m³	

.:: Layer No: 8 ::.

Code: Layer_8 **Start depth:** 8.92 (m), **End depth:** 9.89 (m)

Description: Clay & silty clay

Basic results	**Estimation results**	
Total cone resistance: 1.16 ±0.09 MPa	Permeability: 1.79E-08 ±6.93E-09 m/s	Constrained Mod.: 8.82 ±1.61 MPa
Sleeve friction: 13.54 ±5.56 kPa	N_{60}: 5.35 ±0.58 blows	Go: 32.93 ±3.74 MPa
Ic: 2.86 ±0.05	Es: 0.00 ±0.00 MPa	Su: 69.70 ±6.08 kPa
SBT_n: 4	Dr (%): 0.00 ±0.00	Su ratio: 0.65 ±0.06
SBTn description: Clay & silty clay	φ (degrees): 0.00 ±0.00 °	O.C.R.: 2.98 ±0.26
	Unit weight: 19.00 ±0.00 kN/m³	

.:: Layer No: 9 ::.

Code: Layer_9 **Start depth:** 9.89 (m), **End depth:** 10.46 (m)

Description: Clay

Basic results	**Estimation results**	
Total cone resistance: 1.03 ±0.10 MPa	Permeability: 7.17E-09 ±2.81E-09 m/s	Constrained Mod.: 6.01 ±1.40 MPa
Sleeve friction: 14.32 ±6.69 kPa	N_{60}: 5.35 ±0.59 blows	Go: 33.09 ±4.16 MPa
Ic: 2.99 ±0.05	Es: 0.00 ±0.00 MPa	Su: 59.38 ±7.00 kPa
SBT_n: 3	Dr (%): 0.00 ±0.00	Su ratio: 0.52 ±0.06
SBTn description: Clay	φ (degrees): 0.00 ±0.00 °	O.C.R.: 2.38 ±0.26
	Unit weight: 19.00 ±0.00 kN/m³	

.:: Layer No: 10 ::.

Code: Layer_10 **Start depth:** 10.46 (m), **End depth:** 11.38 (m)

Description: Clay

Basic results	**Estimation results**	
Total cone resistance: 1.57 ±0.48 MPa	Permeability: 1.16E-08 ±2.54E-08 m/s	Constrained Mod.: 14.20 ±9.09 MPa
Sleeve friction: 35.00 ±10.08 kPa	N_{60}: 7.65 ±1.57 blows	Go: 49.38 ±7.48 MPa
Ic: 2.92 ±0.14	Es: 0.00 ±0.00 MPa	Su: 96.62 ±34.34 kPa
SBT_n: 3	Dr (%): 0.00 ±0.00	Su ratio: 0.79 ±0.28
SBTn description: Clay	φ (degrees): 0.00 ±0.00 °	O.C.R.: 3.67 ±1.27
	Unit weight: 19.00 ±0.00 kN/m³	

.:: Layer No: 11 ::.

Code: Layer_11 **Start depth:** 11.38 (m), **End depth:** 14.04 (m)

Description: Clay

Basic results	**Estimation results**	
Total cone resistance: 1.18 ±0.15 MPa	Permeability: 3.88E-09 ±3.30E-09 m/s	Constrained Mod.: 6.38 ±2.49 MPa
Sleeve friction: 21.88 ±7.76 kPa	N_{60}: 6.41 ±0.71 blows	Go: 41.78 ±4.94 MPa
Ic: 3.08 ±0.07	Es: 0.00 ±0.00 MPa	Su: 67.08 ±10.87 kPa
SBT_n: 3	Dr (%): 0.00 ±0.00	Su ratio: 0.49 ±0.08
SBTn description: Clay	φ (degrees): 0.00 ±0.00 °	O.C.R.: 2.24 ±0.37
	Unit weight: 19.00 ±0.00 kN/m³	

.:: Layer No: 12 ::.

Code: Layer_12 **Start depth:** 14.04 (m), **End depth:** 15.07 (m)

Description: Clay

Basic results	**Estimation results**	
Total cone resistance: 1.21 ±0.13 MPa	Permeability: 1.74E-09 ±3.51E-10 m/s	Constrained Mod.: 5.61 ±1.59 MPa
Sleeve friction: 29.45 ±11.06 kPa	N_{60}: 7.20 ±0.73 blows	Go: 47.99 ±6.45 MPa
Ic: 3.19 ±0.03	Es: 0.00 ±0.00 MPa	Su: 66.66 ±9.24 kPa
SBT_n: 3	Dr (%): 0.00 ±0.00	Su ratio: 0.43 ±0.05
SBTn description: Clay	φ (degrees): 0.00 ±0.00 °	O.C.R.: 1.98 ±0.24
	Unit weight: 19.00 ±0.00 kN/m³	

.:: Layer No: 13 ::.

Code: Layer_13 **Start depth:** 15.07 (m), **End depth:** 16.10 (m)

Description: Clay

Basic results	**Estimation results**	
Total cone resistance: 1.85 ±0.10 MPa	Permeability: 2.39E-09 ±4.52E-10 m/s	Constrained Mod.: 14.73 ±1.55 MPa
Sleeve friction: 78.43 ±4.55 kPa	N_{60}: 10.60 ±0.55 blows	Go: 75.62 ±2.48 MPa
Ic: 3.15 ±0.03	Es: 0.00 ±0.00 MPa	Su: 111.27 ±6.67 kPa
SBT_n: 3	Dr (%): 0.00 ±0.00	Su ratio: 0.68 ±0.03
SBTn description: Clay	φ (degrees): 0.00 ±0.00 °	O.C.R.: 3.12 ±0.15
	Unit weight: 19.00 ±0.00 kN/m³	

.:: Layer No: 14 ::.

Code: Layer_14 **Start depth:** 16.10 (m), **End depth:** 17.00 (m)

Description: Clay

Basic results	**Estimation results**	
Total cone resistance: 2.33 ±0.10 MPa	Permeability: 4.05E-09 ±4.78E-10 m/s	Constrained Mod.: 23.38 ±2.11 MPa
Sleeve friction: 99.54 ±7.07 kPa	N_{60}: 12.63 ±0.48 blows	Go: 88.93 ±2.93 MPa
Ic: 3.07 ±0.02	Es: 0.00 ±0.00 MPa	Su: 143.92 ±6.76 kPa
SBT_n: 3	Dr (%): 0.00 ±0.00	Su ratio: 0.83 ±0.04
SBTn description: Clay	φ (degrees): 0.00 ±0.00 °	O.C.R.: 3.83 ±0.17
	Unit weight: 19.00 ±0.00 kN/m³	

.:: Layer No: 15 ::.

Code: Layer_15 **Start depth:** 17.00 (m), **End depth:** 18.81 (m)

Description: Clay

Basic results	**Estimation results**	
Total cone resistance: 2.04 ±0.12 MPa	Permeability: 2.51E-09 ±8.76E-10 m/s	Constrained Mod.: 15.59 ±2.33 MPa
Sleeve friction: 80.01 ±9.55 kPa	N_{60}: 11.57 ±0.55 blows	Go: 81.96 ±3.94 MPa
Ic: 3.14 ±0.05	Es: 0.00 ±0.00 MPa	Su: 121.66 ±8.80 kPa
SBT_n: 3	Dr (%): 0.00 ±0.00	Su ratio: 0.65 ±0.05
SBTn description: Clay	φ (degrees): 0.00 ±0.00 °	O.C.R.: 3.02 ±0.25
	Unit weight: 19.00 ±0.00 kN/m³	

.:: Layer No: 16 ::.

Code: Layer_16 **Start depth:** 18.81 (m), **End depth:** 20.26 (m)

Description: Clay

Basic results	**Estimation results**	
Total cone resistance: 1.59 ±0.13 MPa	Permeability: 9.53E-10 ±2.66E-10 m/s	Constrained Mod.: 7.34 ±1.88 MPa
Sleeve friction: 59.67 ±6.75 kPa	N_{60}: 10.03 ±0.53 blows	Go: 71.31 ±3.72 MPa
Ic: 3.30 ±0.05	Es: 0.00 ±0.00 MPa	Su: 86.75 ±9.62 kPa
SBT_n: 3	Dr (%): 0.00 ±0.00	Su ratio: 0.43 ±0.06
SBTn description: Clay	φ (degrees): 0.00 ±0.00 °	O.C.R.: 1.99 ±0.26
	Unit weight: 19.00 ±0.00 kN/m³	

Summary table of mean values

From depth To depth (m)	Thickness (m)	Permeability (m/s)	SPT_{N60} (blows/30cm)	E_s (MPa)	D_r (%)	Friction angle	Constrained modulus, M (MPa)	Shear modulus, G_O (MPa)	Undrained strength, S_U (kPa)	Undrained strength ratio	OCR	Unit weight (kN/m³)
0.50	0.80	8.12E-06	17.0	56.4	74.2	43.0	111.1	70.6	0.0	0.0	0.0	19.0
1.30		(±7.37E-06)	(±2.7)	(±9.0)	(±8.4)	(±1.7)	(±19.8)	(±11.2)	(±0.0)	(±0.0)	(±0.0)	(±0.0)
1.30	1.22	3.93E-08	4.8	0.0	0.0	0.0	14.7	30.8	75.2	1.9	8.9	19.0
2.52		(±1.04E-07)	(±2.5)	(±0.0)	(±0.0)	(±0.0)	(±10.3)	(±13.5)	(±52.5)	(±1.7)	(±7.9)	(±0.0)
2.52	1.42	2.35E-08	4.5	0.0	0.0	0.0	12.5	29.1	64.7	1.2	5.6	19.0
3.94		(±1.46E-08)	(±0.7)	(±0.0)	(±0.0)	(±0.0)	(±2.6)	(±4.1)	(±12.3)	(±0.3)	(±1.3)	(±0.0)
3.94	0.93	9.66E-09	6.2	0.0	0.0	0.0	16.0	43.2	81.9	1.3	6.1	19.0
4.87		(±2.96E-09)	(±0.4)	(±0.0)	(±0.0)	(±0.0)	(±1.3)	(±2.5)	(±6.5)	(±0.1)	(±0.5)	(±0.0)
4.87	0.56	8.61E-09	5.2	0.0	0.0	0.0	12.6	36.2	67.1	1.0	4.5	19.0
5.43		(±2.56E-09)	(±0.4)	(±0.0)	(±0.0)	(±0.0)	(±1.4)	(±2.4)	(±4.8)	(±0.1)	(±0.3)	(±0.0)
5.43	2.71	8.36E-09	5.7	0.0	0.0	0.0	11.7	39.1	69.3	0.8	3.8	19.0
8.14		(±3.13E-07)	(±1.0)	(±0.0)	(±0.0)	(±0.0)	(±7.5)	(±5.1)	(±11.6)	(±0.1)	(±0.6)	(±0.0)
8.14	0.78	1.28E-08	4.8	0.0	0.0	0.0	6.7	29.3	58.4	0.6	2.7	19.0
8.92		(±8.26E-09)	(±0.5)	(±0.0)	(±0.0)	(±0.0)	(±1.3)	(±4.3)	(±5.2)	(±0.1)	(±0.3)	(±0.0)
8.92	0.97	1.79E-08	5.3	0.0	0.0	0.0	8.8	32.9	69.7	0.6	3.0	19.0
9.89		(±6.93E-09)	(±0.6)	(±0.0)	(±0.0)	(±0.0)	(±1.6)	(±3.7)	(±6.1)	(±0.1)	(±0.3)	(±0.0)
9.89	0.57	7.17E-09	5.4	0.0	0.0	0.0	6.0	33.1	59.4	0.5	2.4	19.0
10.46		(±2.81E-09)	(±0.6)	(±0.0)	(±0.0)	(±0.0)	(±1.4)	(±4.2)	(±7.0)	(±0.1)	(±0.3)	(±0.0)
10.46	0.92	1.16E-08	7.7	0.0	0.0	0.0	14.2	49.4	96.6	0.8	3.7	19.0
11.38		(±2.54E-08)	(±1.6)	(±0.0)	(±0.0)	(±0.0)	(±9.1)	(±7.5)	(±34.3)	(±0.3)	(±1.3)	(±0.0)
11.38	2.66	3.88E-09	6.4	0.0	0.0	0.0	6.4	41.8	67.1	0.5	2.2	19.0
14.04		(±3.30E-09)	(±0.7)	(±0.0)	(±0.0)	(±0.0)	(±2.5)	(±4.9)	(±10.9)	(±0.1)	(±0.4)	(±0.0)
14.04	1.03	1.74E-09	7.2	0.0	0.0	0.0	5.6	48.0	66.7	0.4	2.0	19.0
15.07		(±3.51E-10)	(±0.7)	(±0.0)	(±0.0)	(±0.0)	(±1.6)	(±6.4)	(±9.2)	(±0.1)	(±0.2)	(±0.0)

Summary table of mean values

From depth To depth (m)	Thickness (m)	Permeability (m/s)	SPT_{N60} (blows/30cm)	E_s (MPa)	D_r (%)	Friction angle	Constrained modulus, M (MPa)	Shear modulus, G_O (MPa)	Undrained strength, S_U (kPa)	Undrained strength ratio	OCR	Unit weight (kN/m³)
15.07	1.03	2.39E-09	10.6	0.0	0.0	0.0	14.7	75.6	111.3	0.7	3.1	19.0
16.10		(±4.52E-10)	(±0.5)	(±0.0)	(±0.0)	(±0.0)	(±1.6)	(±2.5)	(±6.7)	(±0.0)	(±0.1)	(±0.0)
16.10	0.90	4.05E-09	12.6	0.0	0.0	0.0	23.4	88.9	143.9	0.8	3.8	19.0
17.00		(±4.78E-10)	(±0.5)	(±0.0)	(±0.0)	(±0.0)	(±2.1)	(±2.9)	(±6.8)	(±0.0)	(±0.2)	(±0.0)
17.00	1.81	2.51E-09	11.6	0.0	0.0	0.0	15.6	82.0	121.7	0.7	3.0	19.0
18.81		(±8.76E-10)	(±0.5)	(±0.0)	(±0.0)	(±0.0)	(±2.3)	(±3.9)	(±8.8)	(±0.1)	(±0.2)	(±0.0)
18.81	1.45	9.53E-10	10.0	0.0	0.0	0.0	7.3	71.3	86.7	0.4	2.0	19.0
20.26		(±2.66E-10)	(±0.5)	(±0.0)	(±0.0)	(±0.0)	(±1.9)	(±3.7)	(±9.6)	(±0.1)	(±0.3)	(±0.0)

Depth values presented in this table are measured from free ground surface

UFFICI: via Per Modena, 12 - 41051 Castelnuovo R. (MO) SEDE LEGALE: via C.Costa,182 - 41123 Modena (MO)
tel. 059/3967169; 059/828367 - FAX 059/5960176 p. Iva e C.F.02981500362
Email: info@geogroupmodena.it Pec: geo.group@winpec.it Sito: www.geogroupmodena.it
Operatore APR certificato ENAC per operazioni non critiche – Rif. ENAC 18627

Allegato n.2

Indagini sismiche

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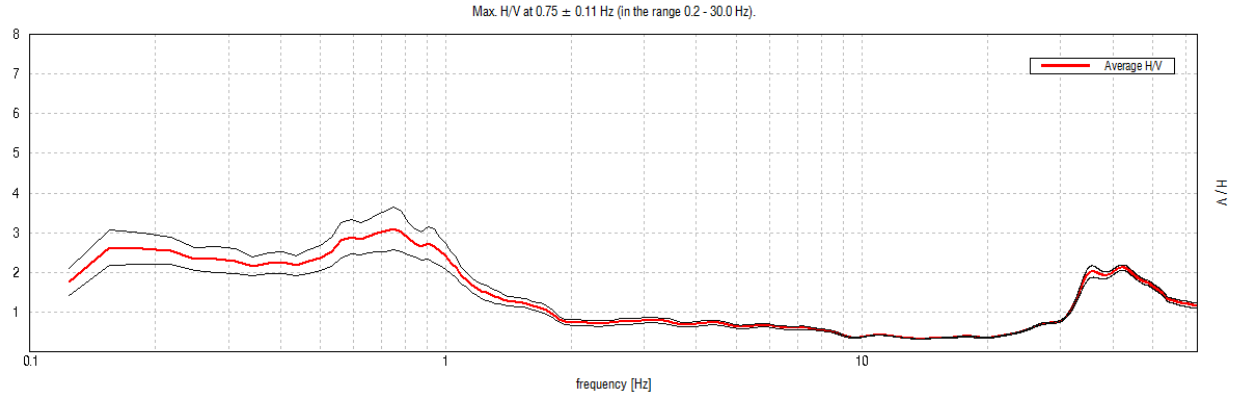
REDÙ DI NONANTOLA, REDÙ 0001

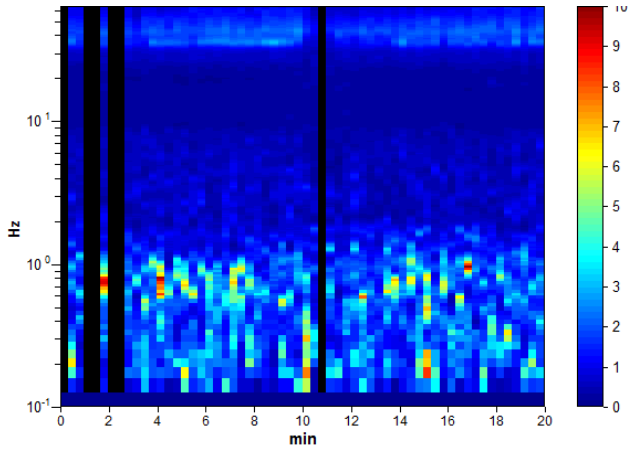
Instrument: TE3-0303/01-17
Data format: 32 bit
Full scale [mV]: 51
Start recording: 07/12/2021 12:35:41 End recording: 07/12/2021 12:55:41
Channel labels: NORTH SOUTH; EAST WEST ; UP DOWN
GPS data not available

Trace length: 0h20'00''. Analyzed 90% trace (automatic window selection)
Sampling rate: 128 Hz
Window size: 20 s
Smoothing type: Triangular window
Smoothing: 10%

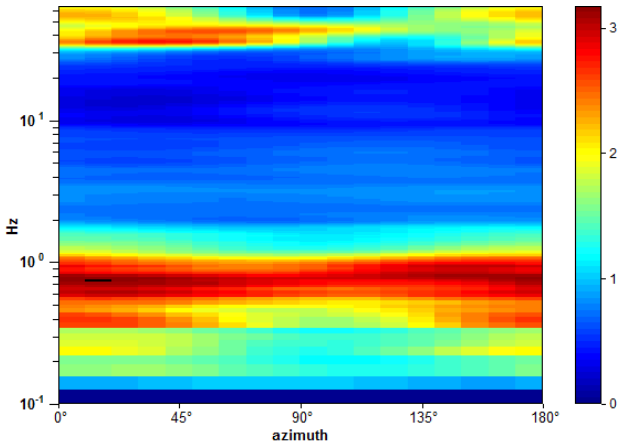
HORIZONTAL TO VERTICAL SPECTRAL RATIO



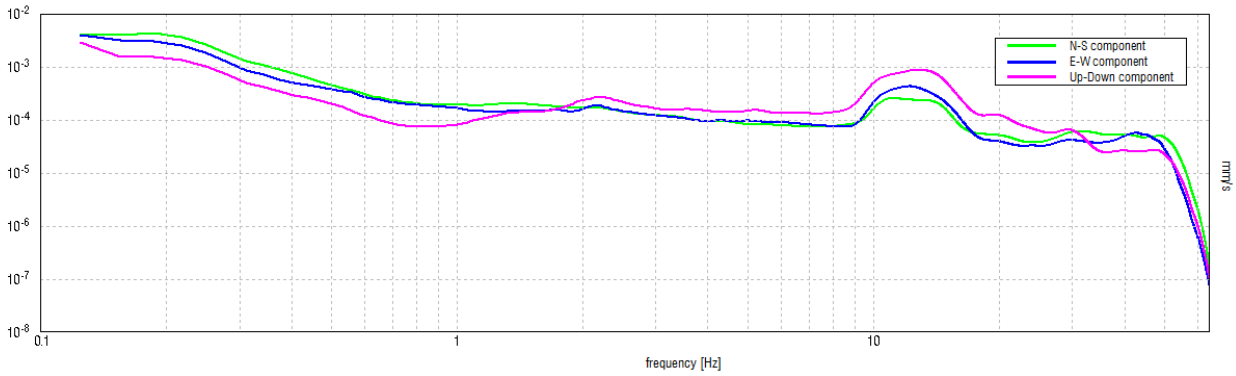
H/V TIME HISTORY



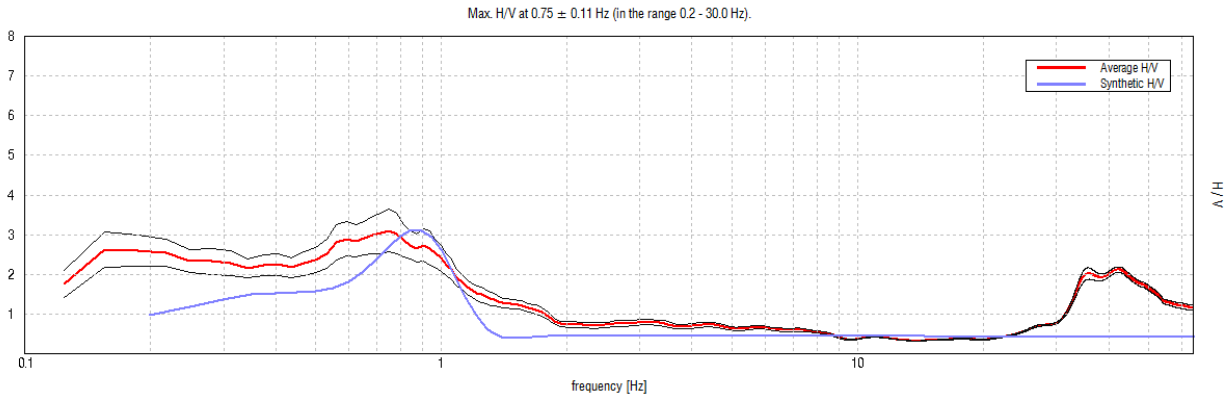
DIRECTIONAL H/V



SINGLE COMPONENT SPECTRA

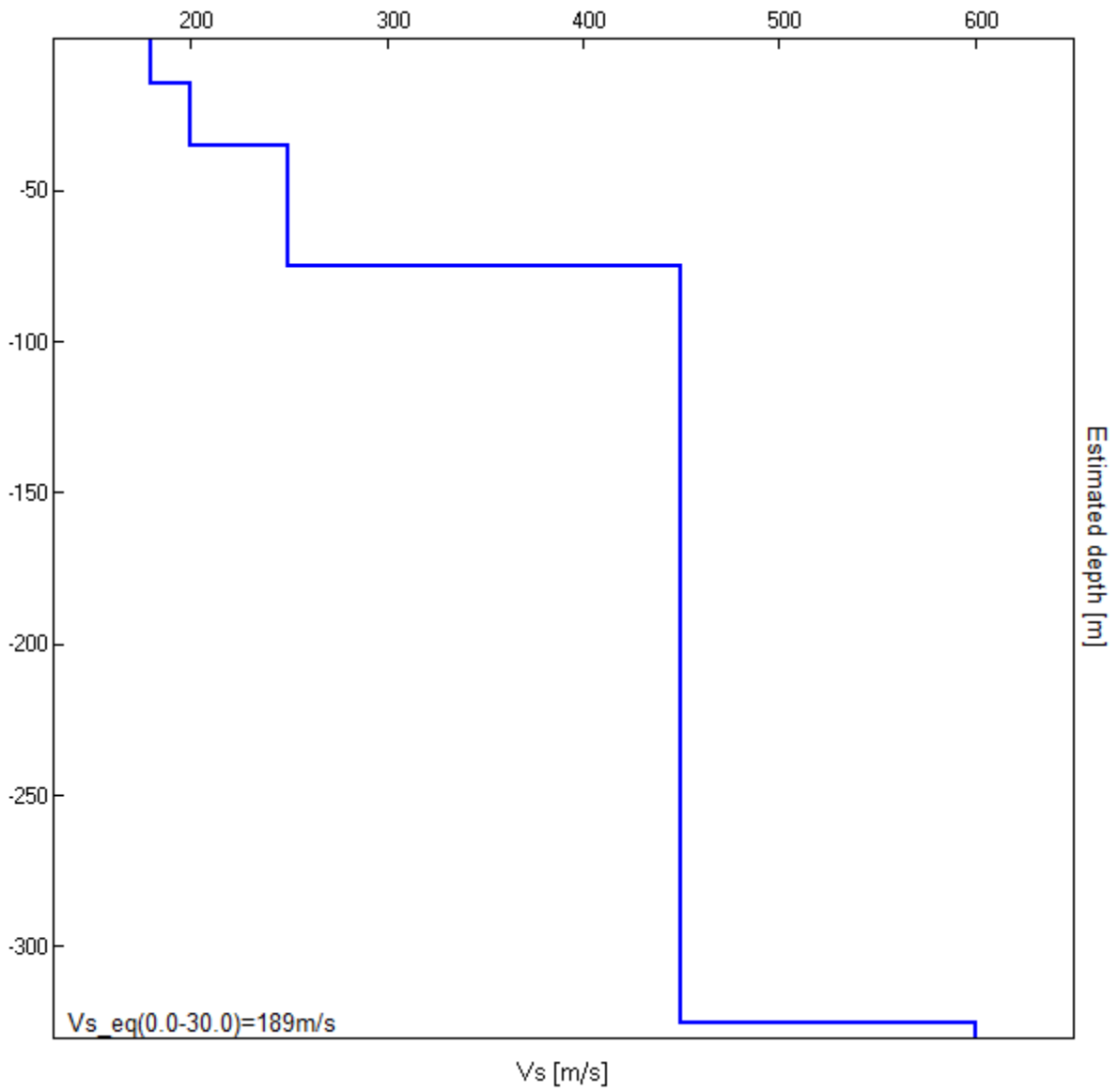


EXPERIMENTAL vs. SYNTHETIC H/V



Depth at the bottom of the layer [m]	Thickness [m]	Vs [m/s]	Poisson ratio
15.00	15.00	180	0.42
35.00	20.00	200	0.42
75.00	40.00	250	0.42
325.00	250.00	450	0.42
inf.	inf.	600	0.42

Vs_eq(0.0-30.0)=189m/s


200
300
400
500
600
-50
-100
-150
-200
-250
-300
Estimated depth [m]
Vs_eq(0.0-30.0)=189m/s
Vs [m/s]

[According to the SESAME, 2005 guidelines. **Please read carefully the** *Grilla* **manual before interpreting the following tables**.]

Max. H/V at 0.75 ± 0.11 Hz (in the range 0.2 - 30.0 Hz).

Criteria for a reliable H/V curve [All 3 should be fulfilled]			
$f_0 > 10 / L_w$	0.75 > 0.50	OK	
$n_c(f_0) > 200$	810.0 > 200	OK	
$\sigma_A(f) < 2$ for $0.5f_0 < f < 2f_0$ if $f_0 > 0.5$Hz **$\sigma_A(f) < 3$ for $0.5f_0 < f < 2f_0$ if $f_0 < 0.5$Hz**	Exceeded 0 out of 37 times	OK	
Criteria for a clear H/V peak [At least 5 out of 6 should be fulfilled]			
Exists f^- in $[f_0/4, f_0]$ | $A_{H/V}(f^-) < A_0 / 2$			NO
Exists f^+ in $[f_0, 4f_0]$ | $A_{H/V}(f^+) < A_0 / 2$	1.219 Hz	OK	
$A_0 > 2$	3.11 > 2	OK	
$f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	|0.1471| < 0.05		NO
$\sigma_f < \varepsilon(f_0)$	0.11032 < 0.1125	OK	
$\sigma_A(f_0) < \theta(f_0)$	0.5331 < 2.0	OK	

L_w	window length
n_w	number of windows used in the analysis
$n_c = L_w n_w f_0$	number of significant cycles
f	current frequency
f_0	H/V peak frequency
σ_f	standard deviation of H/V peak frequency
$\varepsilon(f_0)$	threshold value for the stability condition $\sigma_f < \varepsilon(f_0)$
A_0	H/V peak amplitude at frequency f_0
$A_{H/V}(f)$	H/V curve amplitude at frequency f
f^-	frequency between $f_0/4$ and f_0 for which $A_{H/V}(f^-) < A_0/2$
f^+	frequency between f_0 and $4f_0$ for which $A_{H/V}(f^+) < A_0/2$
$\sigma_A(f)$	standard deviation of $A_{H/V}(f)$, $\sigma_A(f)$ is the factor by which the mean $A_{H/V}(f)$ curve should be multiplied or divided
$\sigma_{logH/V}(f)$	standard deviation of log $A_{H/V}(f)$ curve
$\theta(f_0)$	threshold value for the stability condition $\sigma_A(f) < \theta(f_0)$

Threshold values for σ_f and $\sigma_A(f_0)$					
Freq. range [Hz]	< 0.2	0.2 – 0.5	0.5 – 1.0	1.0 – 2.0	> 2.0
$\varepsilon(f_0)$ [Hz]	0.25 f_0	0.2 f_0	0.15 f_0	0.10 f_0	0.05 f_0
$\theta(f_0)$ for $\sigma_A(f_0)$	3.0	2.5	2.0	1.78	1.58
log $\theta(f_0)$ for $\sigma_{logH/V}(f_0)$	0.48	0.40	0.30	0.25	0.20

TROMINO
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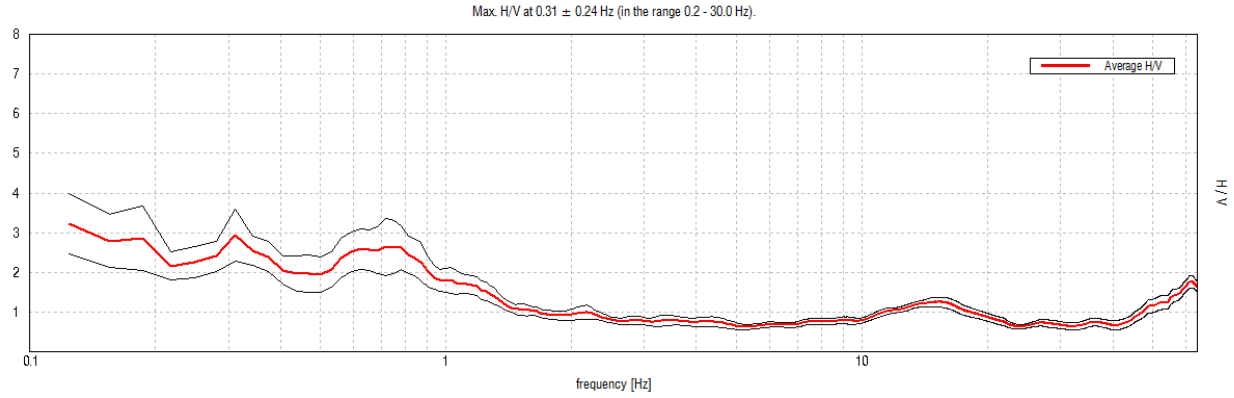
REDÙ DI NONANTOLA, REDÙ 0002

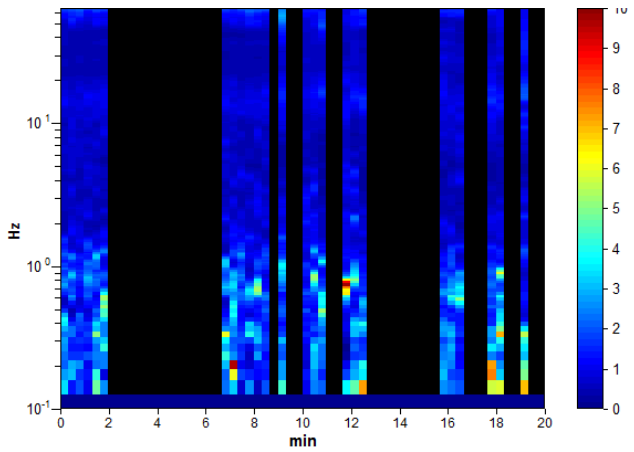
Instrument: TE3-0303/01-17
Data format: 32 bit
Full scale [mV]: 51
Start recording: 07/12/2021 13:08:56 End recording: 07/12/2021 13:28:56
Channel labels: NORTH SOUTH; EAST WEST ; UP DOWN
GPS data not available

Trace length: 0h20'00''. Analyzed 42% trace (automatic window selection)
Sampling rate: 128 Hz
Window size: 20 s
Smoothing type: Triangular window
Smoothing: 10%

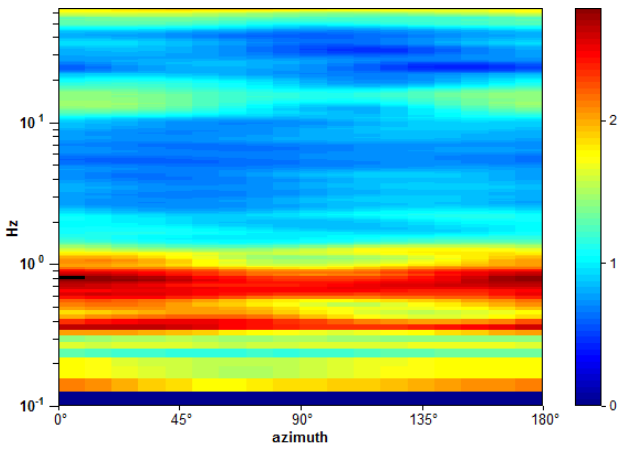
HORIZONTAL TO VERTICAL SPECTRAL RATIO



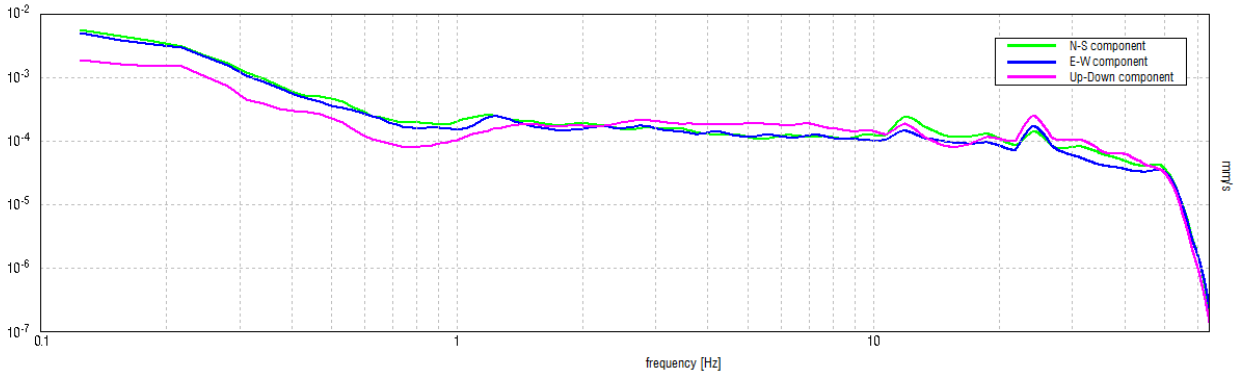
H/V TIME HISTORY



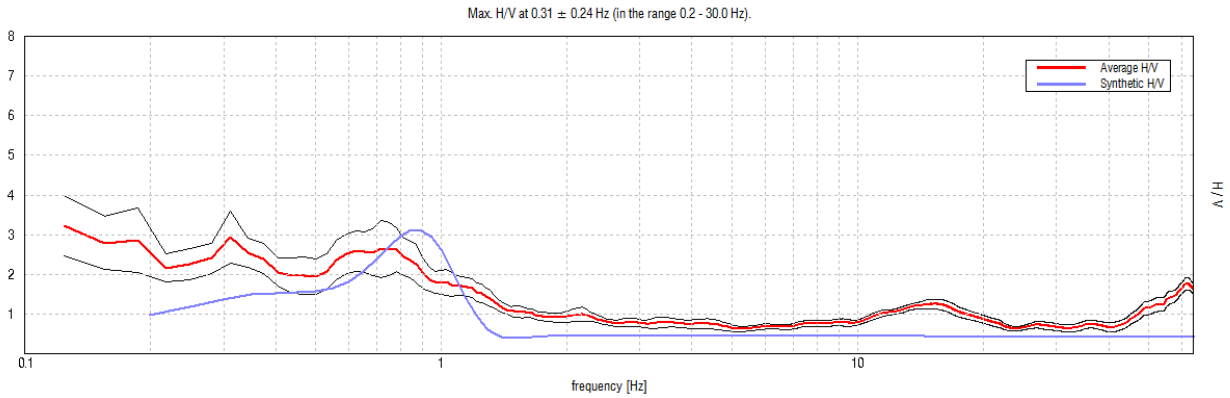
DIRECTIONAL H/V



SINGLE COMPONENT SPECTRA

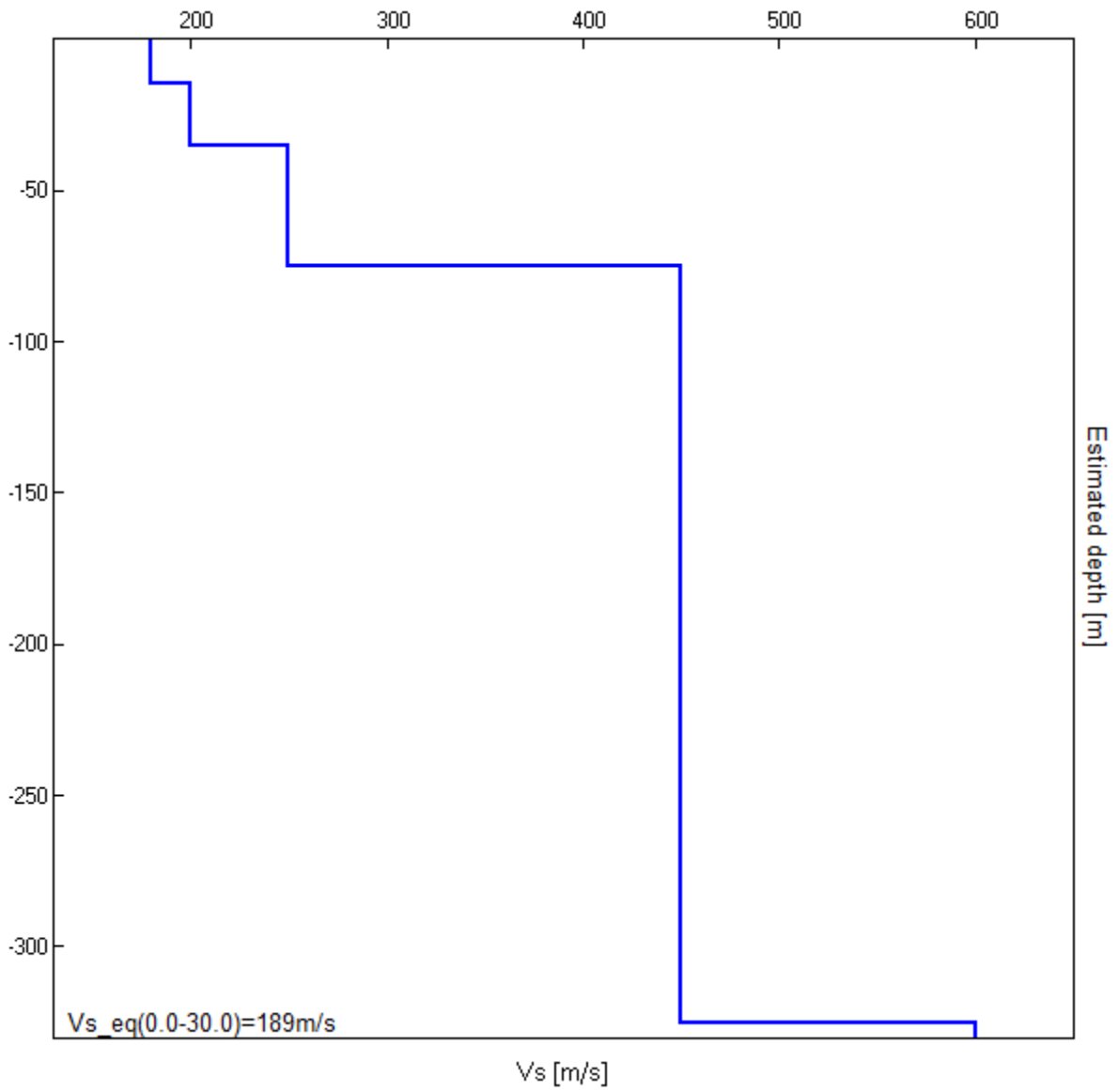


EXPERIMENTAL vs. SYNTHETIC H/V



Depth at the bottom of the layer [m]	Thickness [m]	Vs [m/s]	Poisson ratio
15.00	15.00	180	0.42
35.00	20.00	200	0.42
75.00	40.00	250	0.42
325.00	250.00	450	0.42
inf.	inf.	600	0.42

Vs_eq(0.0-30.0)=189m/s


200
300
400
500
600
-50
-100
-150
-200
-250
-300
Estimated depth [m]
Vs_eq(0.0-30.0)=189m/s
Vs [m/s]

[According to the SESAME, 2005 guidelines. **Please read carefully the** *Grilla* **manual before interpreting the following tables**.]

Max. H/V at 0.31 ± 0.24 Hz (in the range 0.2 - 30.0 Hz).

Criteria for a reliable H/V curve [All 3 should be fulfilled]			
$f_0 > 10 / L_w$	0.31 > 0.50		NO
$n_c(f_0) > 200$	156.3 > 200		NO
$\sigma_A(f) < 2$ for $0.5f_0 < f < 2f_0$ if $f_0 > 0.5$Hz **$\sigma_A(f) < 3$ for $0.5f_0 < f < 2f_0$ if $f_0 < 0.5$Hz**	Exceeded 0 out of 16 times	OK	
Criteria for a clear H/V peak [At least 5 out of 6 should be fulfilled]			
Exists f^- in $[f_0/4, f_0]$ | $A_{H/V}(f^-) < A_0 / 2$	0.094 Hz	OK	
Exists f^+ in $[f_0, 4f_0]$ | $A_{H/V}(f^+) < A_0 / 2$			NO
$A_0 > 2$	2.93 > 2	OK	
$f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	|0.77717| < 0.05		NO
$\sigma_f < \varepsilon(f_0)$	0.24287 < 0.0625		NO
$\sigma_A(f_0) < \theta(f_0)$	0.6533 < 2.5	OK	

L_w	window length
n_w	number of windows used in the analysis
$n_c = L_w n_w f_0$	number of significant cycles
f	current frequency
f_0	H/V peak frequency
σ_f	standard deviation of H/V peak frequency
$\varepsilon(f_0)$	threshold value for the stability condition $\sigma_f < \varepsilon(f_0)$
A_0	H/V peak amplitude at frequency f_0
$A_{H/V}(f)$	H/V curve amplitude at frequency f
f^-	frequency between $f_0/4$ and f_0 for which $A_{H/V}(f^-) < A_0/2$
f^+	frequency between f_0 and $4f_0$ for which $A_{H/V}(f^+) < A_0/2$
$\sigma_A(f)$	standard deviation of $A_{H/V}(f)$, $\sigma_A(f)$ is the factor by which the mean $A_{H/V}(f)$ curve should be multiplied or divided
$\sigma_{logH/V}(f)$	standard deviation of log $A_{H/V}(f)$ curve
$\theta(f_0)$	threshold value for the stability condition $\sigma_A(f) < \theta(f_0)$

Threshold values for σ_f and $\sigma_A(f_0)$					
Freq. range [Hz]	< 0.2	0.2 – 0.5	0.5 – 1.0	1.0 – 2.0	> 2.0
$\varepsilon(f_0)$ [Hz]	0.25 f_0	0.2 f_0	0.15 f_0	0.10 f_0	0.05 f_0
$\theta(f_0)$ for $\sigma_A(f_0)$	3.0	2.5	2.0	1.78	1.58
log $\theta(f_0)$ for $\sigma_{logH/V}(f_0)$	0.48	0.40	0.30	0.25	0.20

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tel. 059/3967169; 059/828367 - FAX 059/5960176 p. Iva e C.F.02981500362
Email: info@geogroupmodena.it Pec: geo.group@winpec.it Sito: www.geogroupmodena.it
Operatore APR certificato ENAC per operazioni non critiche – Rif. ENAC 18627

Allegato n.3

Verifica della suscettività del sito al fenomeno della liquefazione

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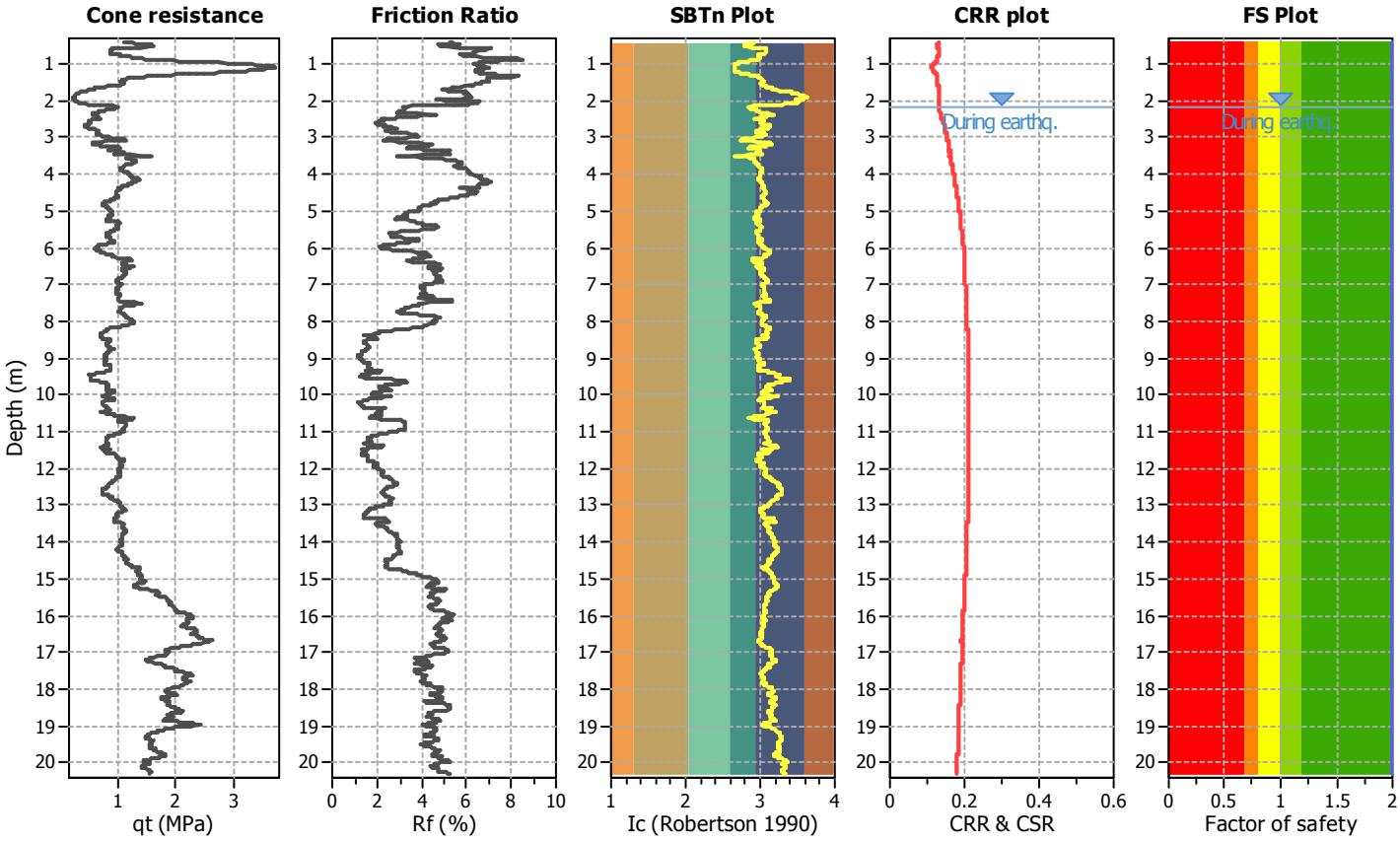
LIQUEFACTION ANALYSIS REPORT

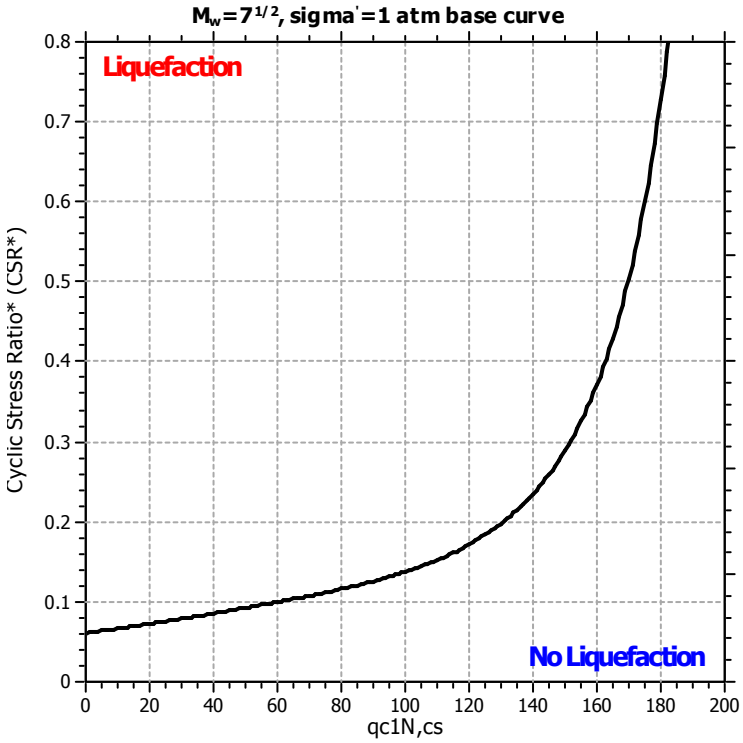
Project title : **Location :**

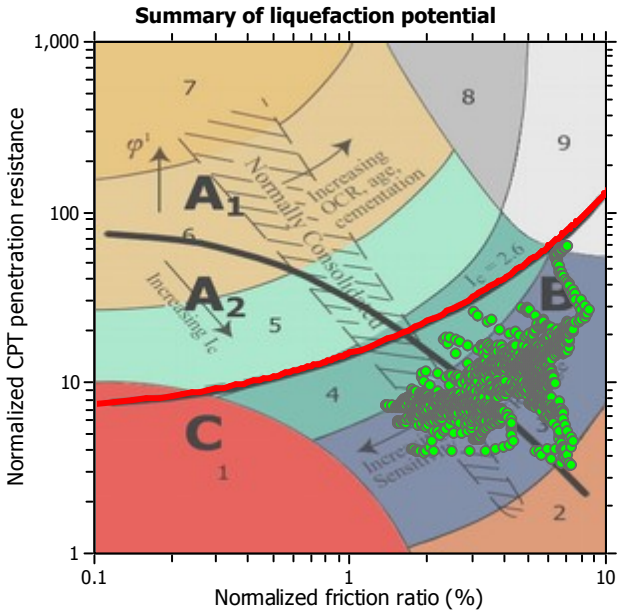
CPT file : CPTU1

Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	2.20 m	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	2.20 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	20.00 m
Earthquake magnitude M_w:	6.14	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method based
Peak ground acceleration:	0.24	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

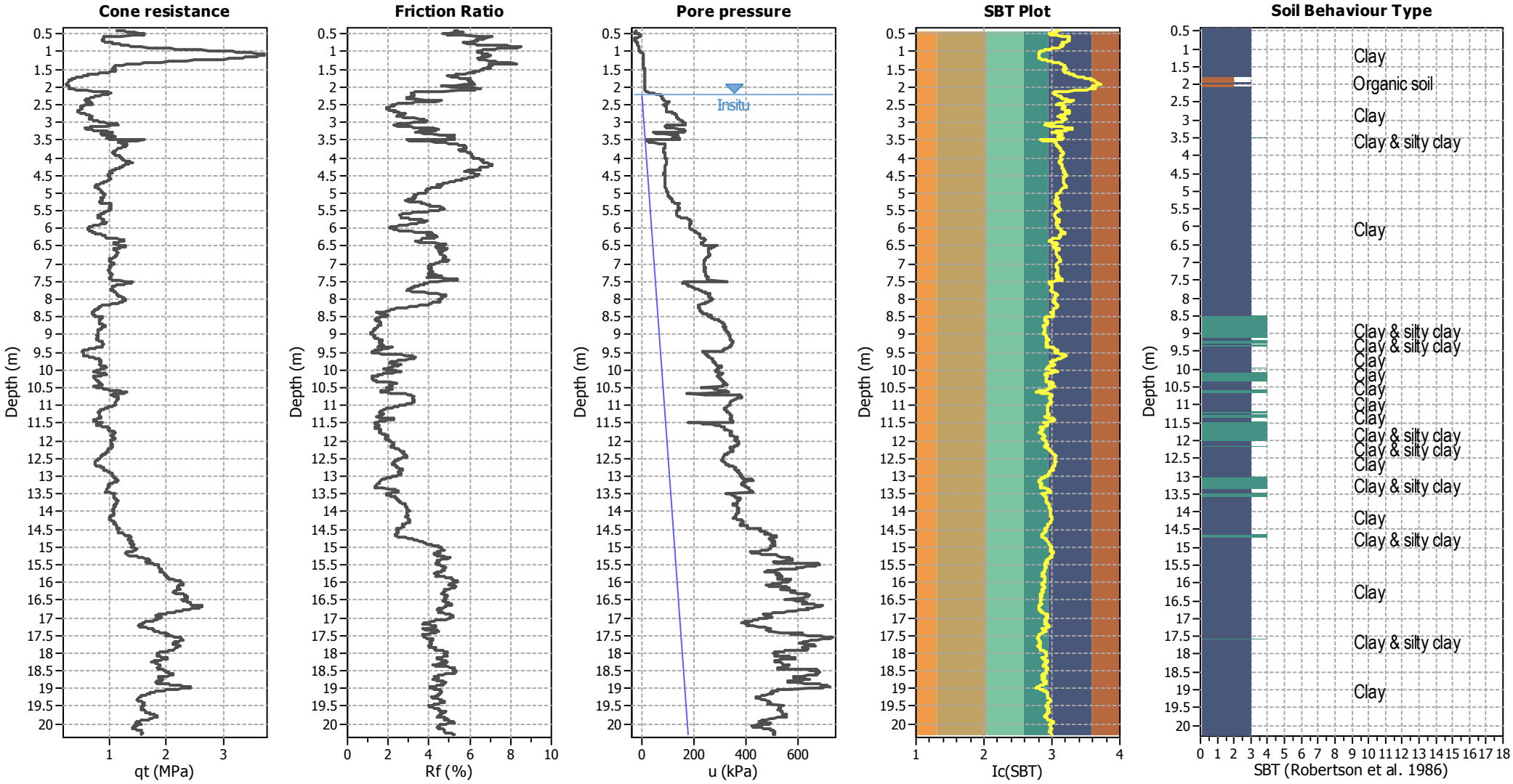






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

CPT basic interpretation plots



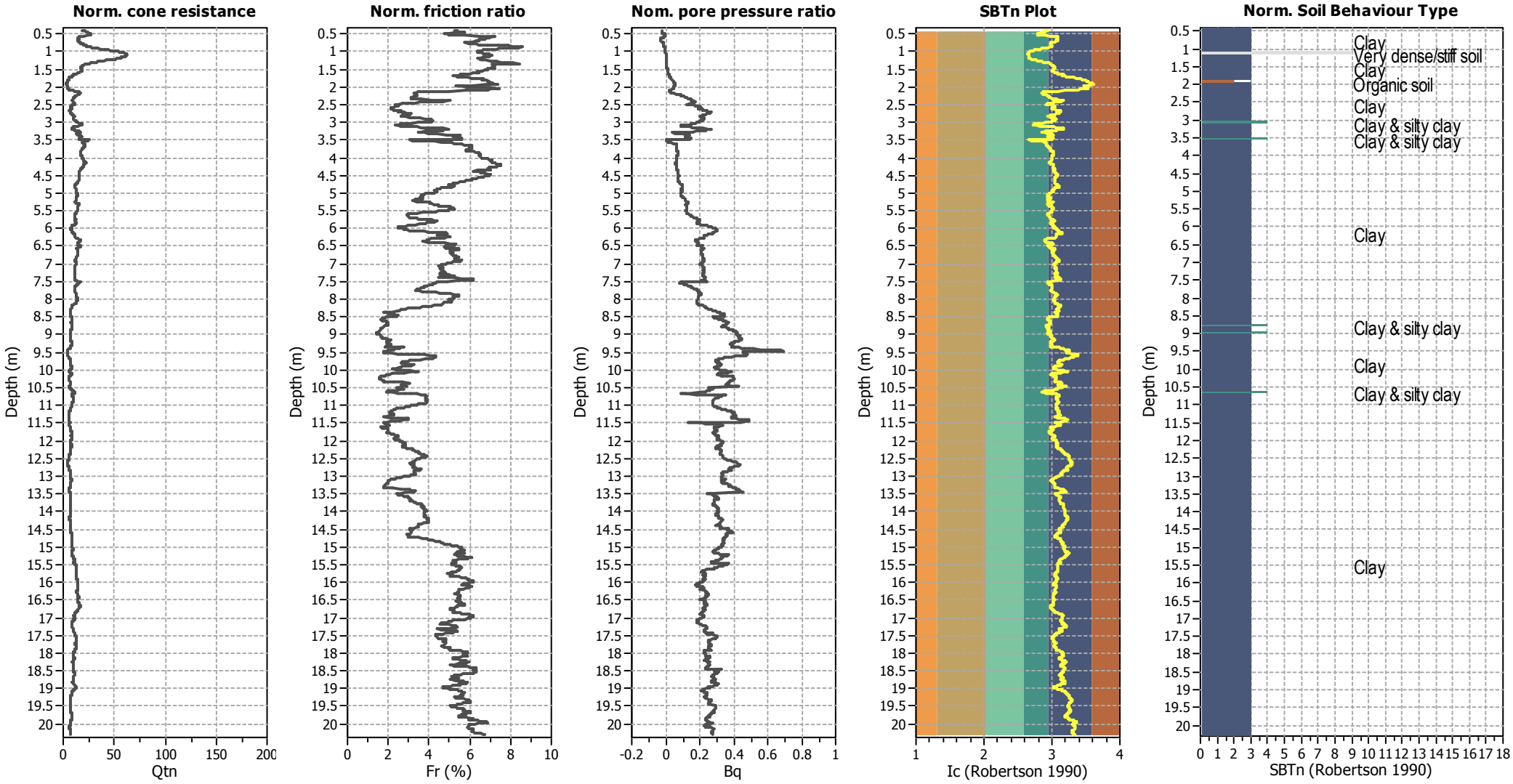
Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	2.20 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	6.14	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.24	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	2.20 m	Fill height:	N/A	Limit depth:	20.00 m

SBT legend

1. Sensitive fine grained
2. Organic material
3. Clay to silty clay
4. Clayey silt to silty
5. Silty sand to sandy silt
6. Clean sand to silty sand
7. Gravely sand to sand
8. Very stiff sand to
9. Very stiff fine grained

CPT basic interpretation plots (normalized)



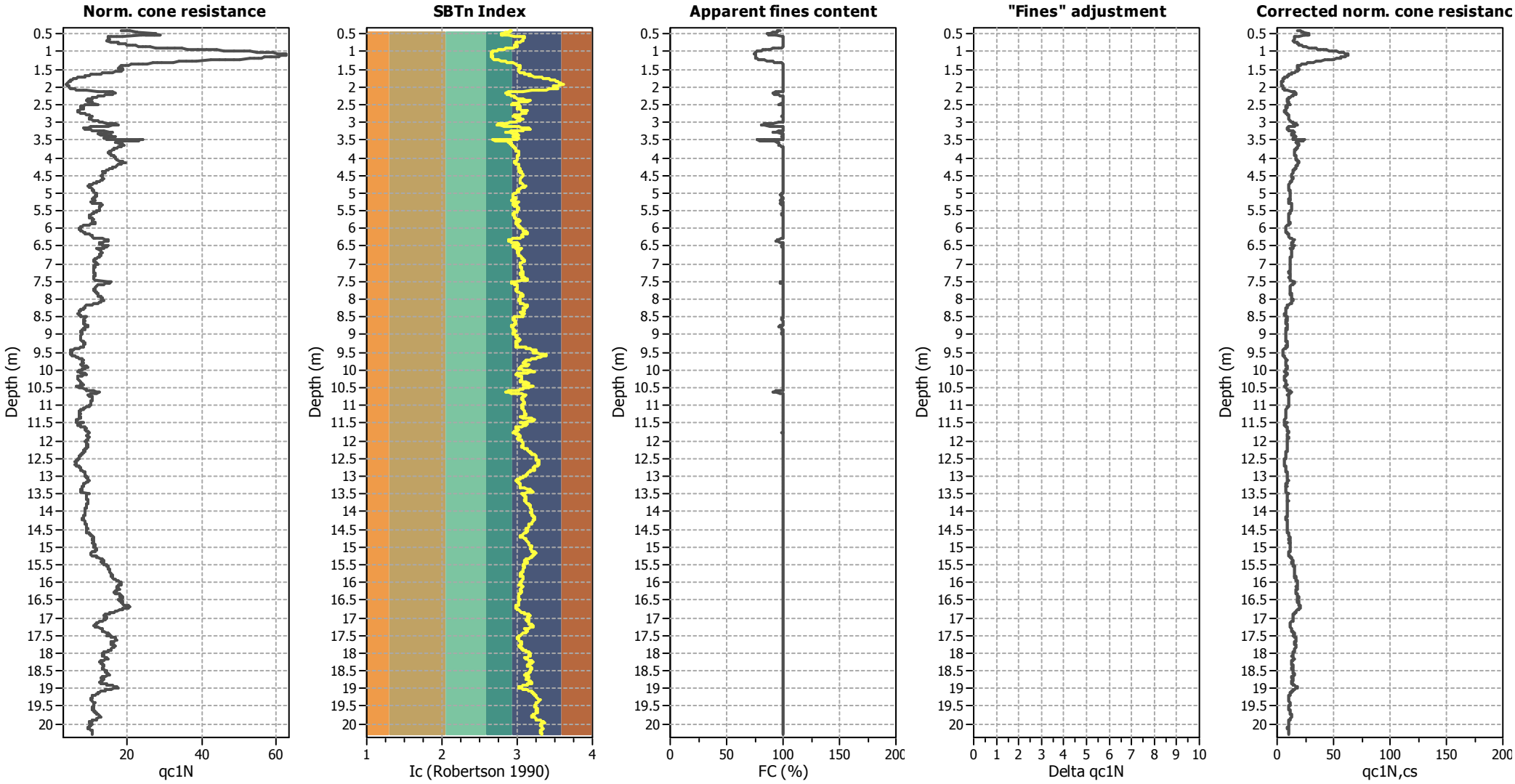
Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	2.20 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	6.14	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.24	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	2.20 m	Fill height:	N/A	Limit depth:	20.00 m

SBTn legend

1. Sensitive fine grained
2. Organic material
3. Clay to silty clay
4. Clayey silt to silty
5. Silty sand to sandy silt
6. Clean sand to silty sand
7. Gravely sand to sand
8. Very stiff sand to
9. Very stiff fine grained

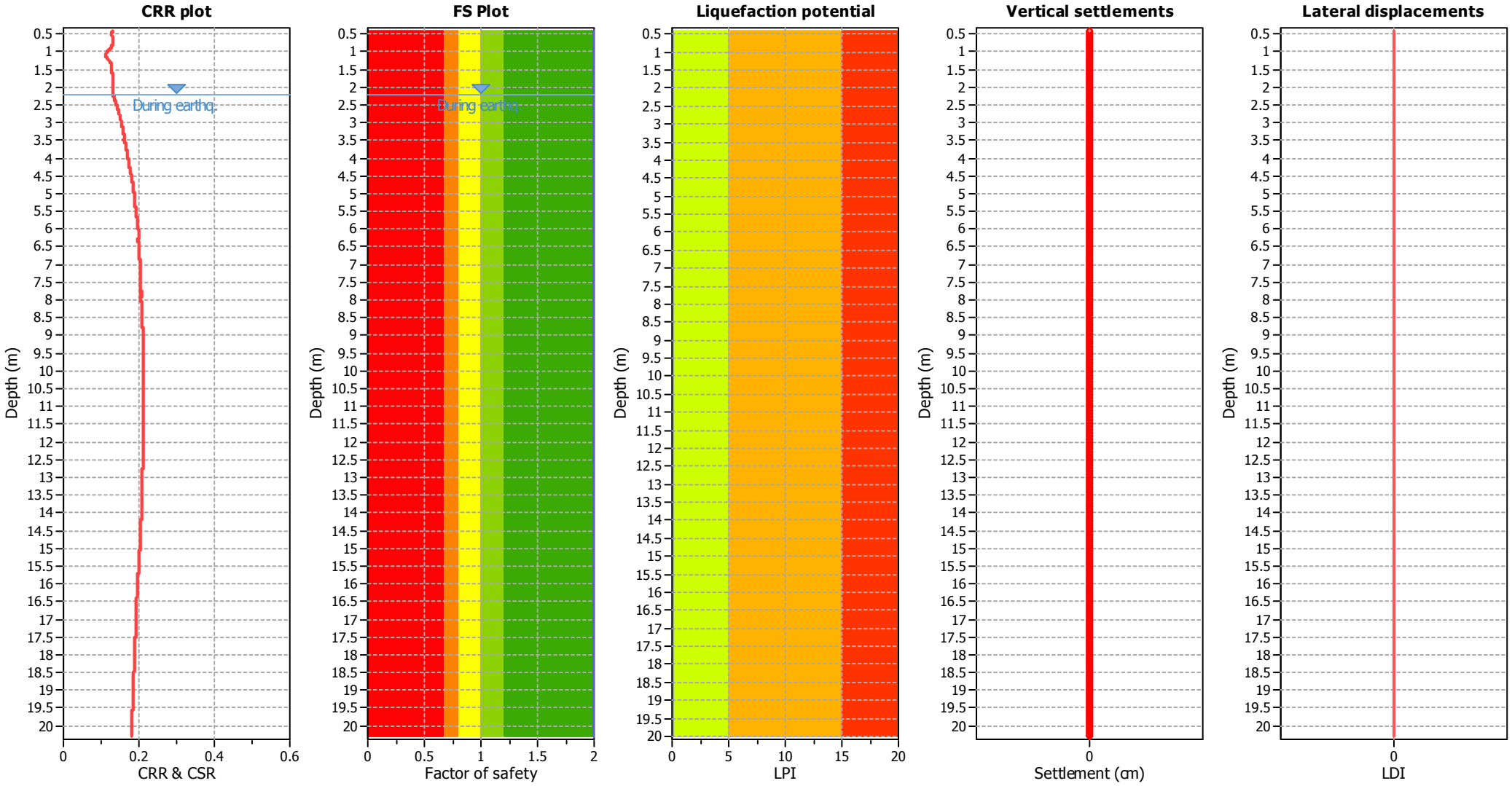
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	2.20 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	6.14	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.24	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	2.20 m	Fill height:	N/A	Limit depth:	20.00 m

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	2.20 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	6.14	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.24	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	2.20 m	Fill height:	N/A	Limit depth:	20.00 m

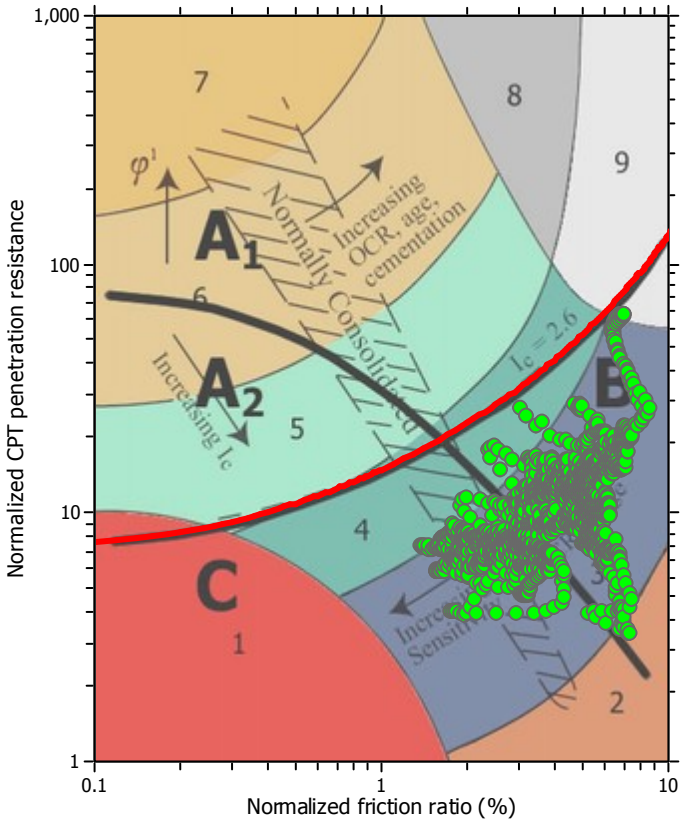
F.S. color scheme

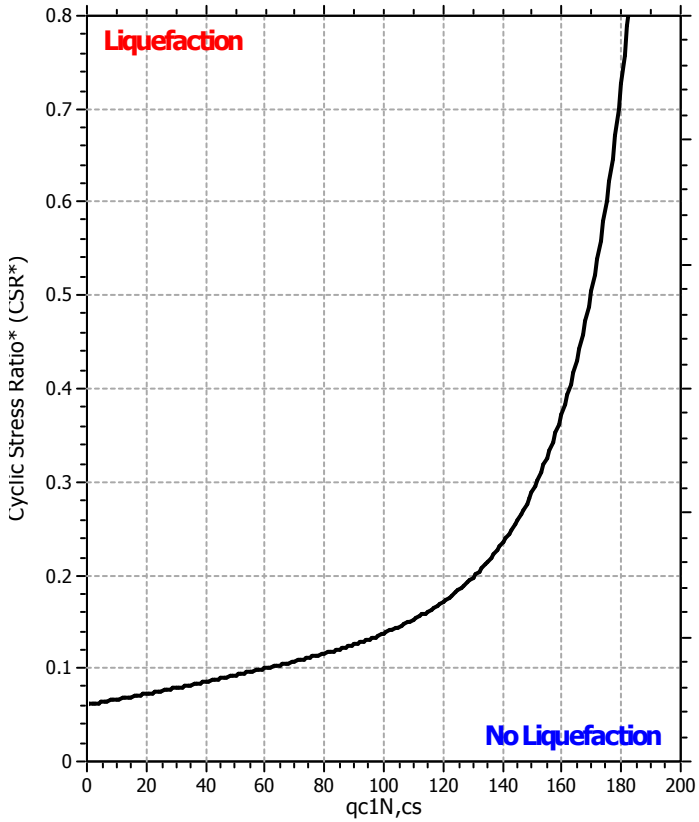
- Almost certain it will liquefy
- Very likely to liquefy
- Liquefaction and no liq. are equally likely
- Unlike to liquefy
- Almost certain it will not liquefy

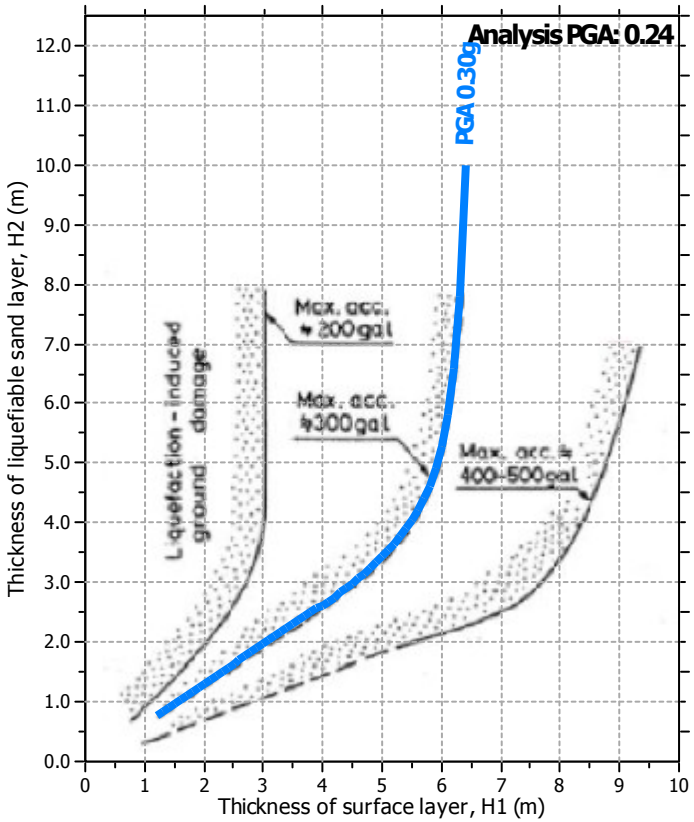
LPI color scheme

- Very high risk
- High risk
- Low risk

Liquefaction analysis summary plots







Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	2.20 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	6.14	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.24	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	2.20 m	Fill height:	N/A	Limit depth:	20.00 m

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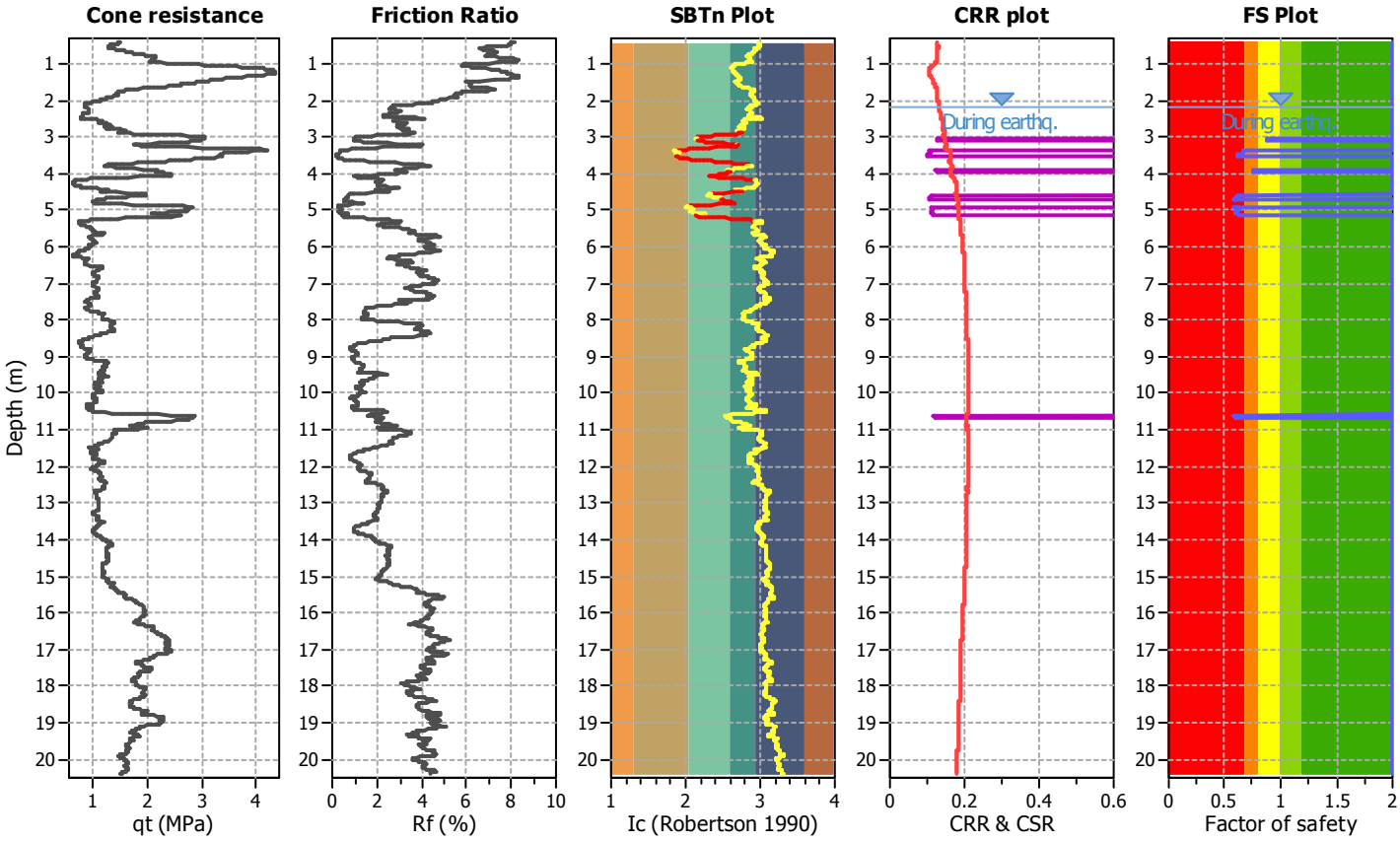
LIQUEFACTION ANALYSIS REPORT

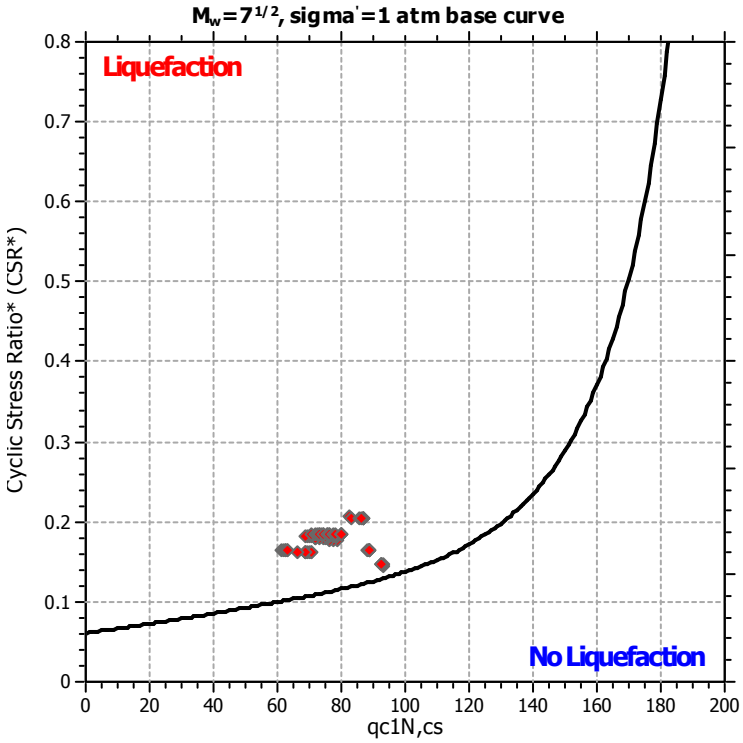
Project title : **Location :**

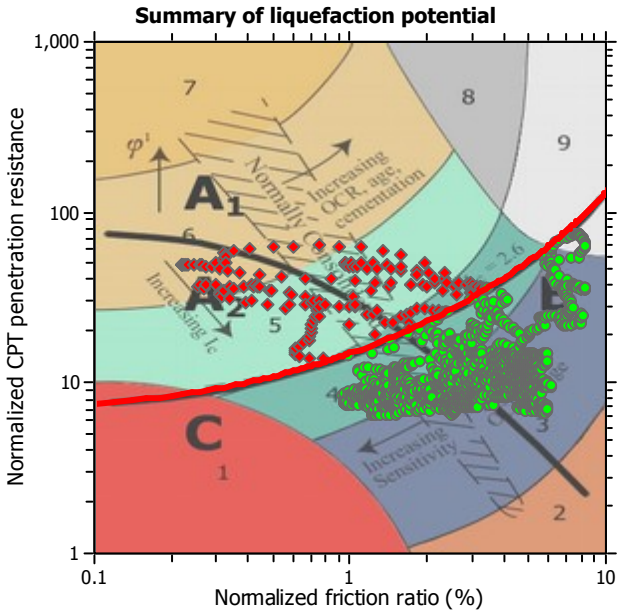
CPT file : CPTU2

Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	2.20 m	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	2.20 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	20.00 m
Earthquake magnitude M_w:	6.14	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method based
Peak ground acceleration:	0.24	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

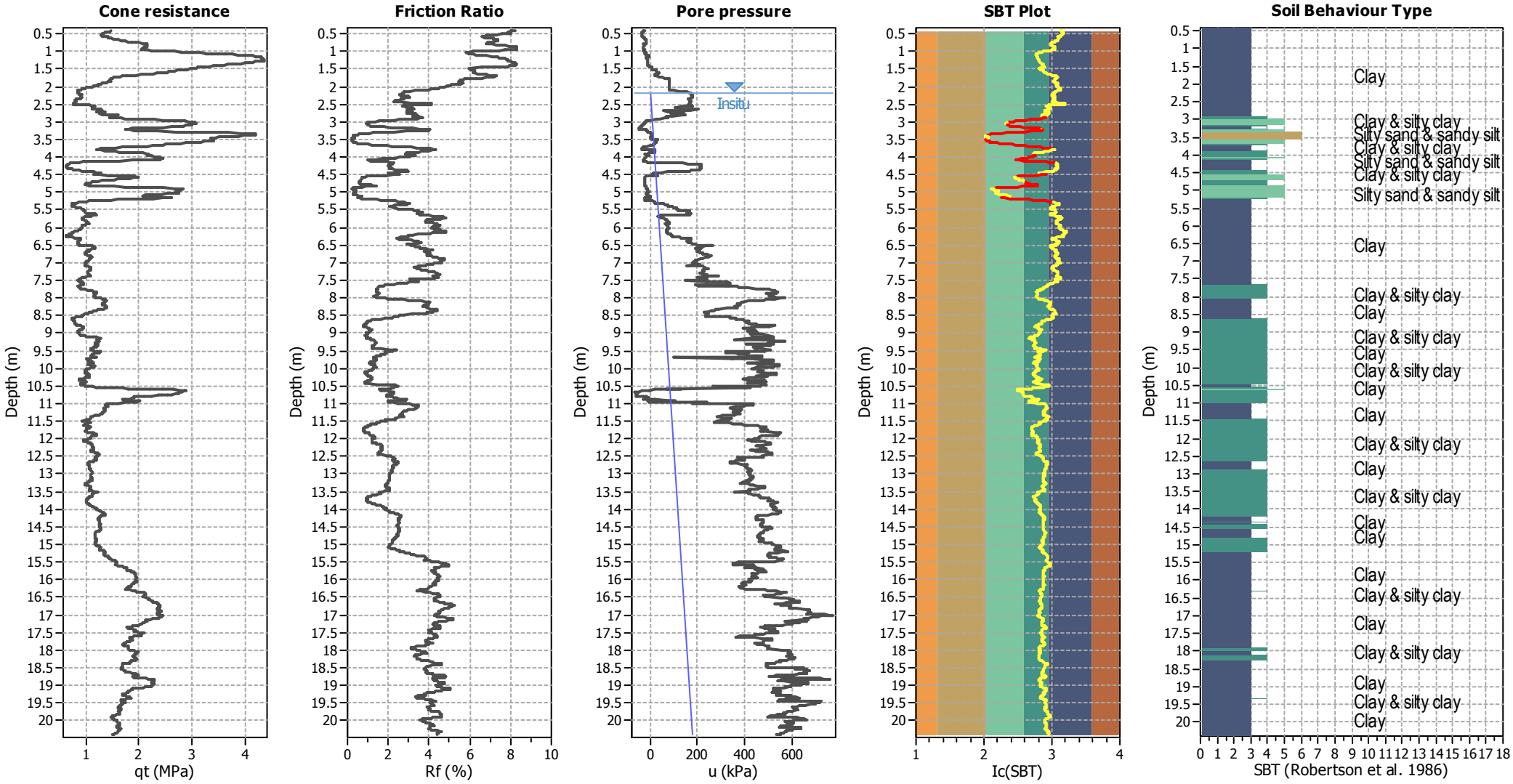






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

CPT basic interpretation plots



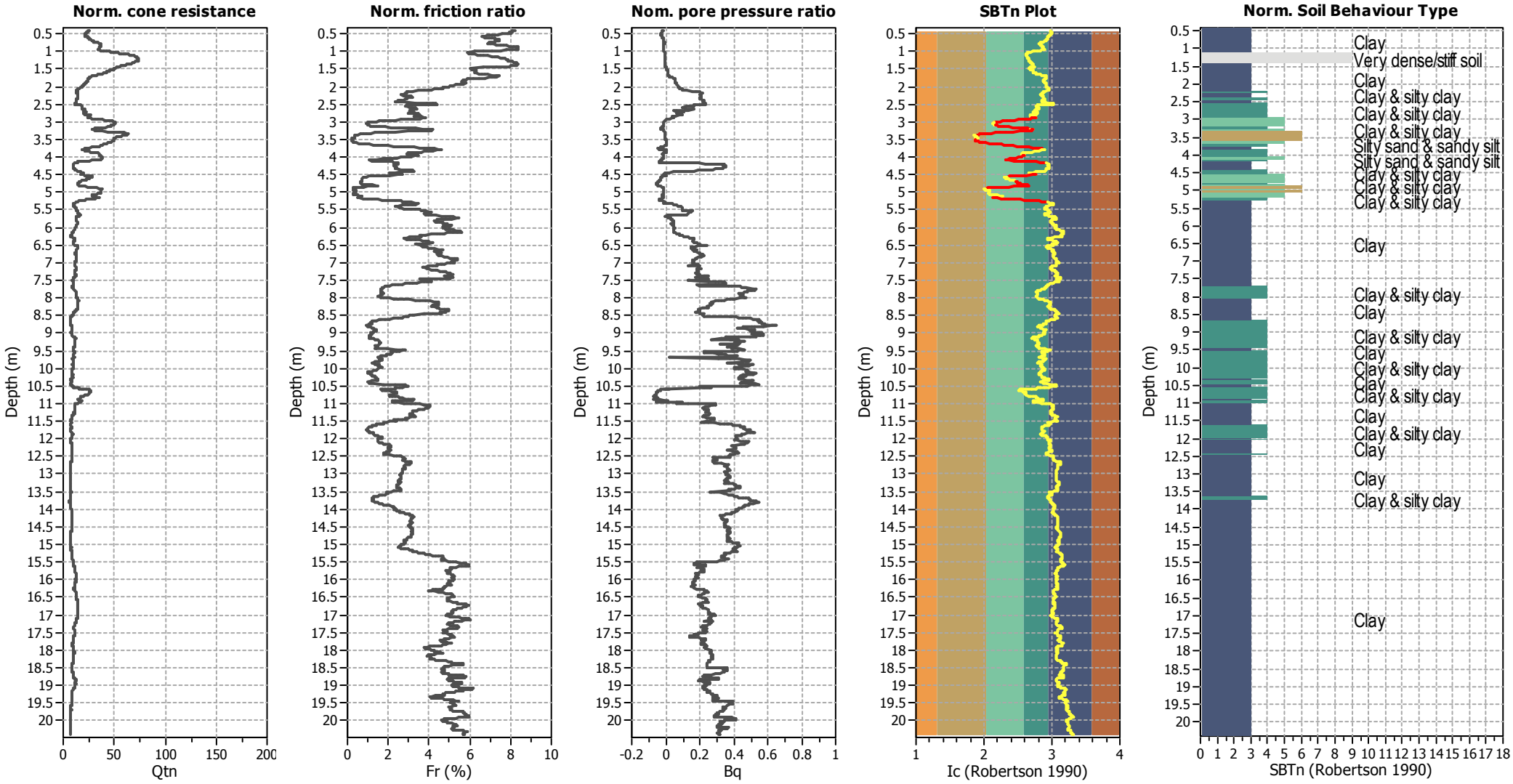
Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	2.20 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	6.14	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.24	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	2.20 m	Fill height:	N/A	Limit depth:	20.00 m

SBT legend

1. Sensitive fine grained
2. Organic material
3. Clay to silty clay
4. Clayey silt to silty
5. Silty sand to sandy silt
6. Clean sand to silty sand
7. Gravely sand to sand
8. Very stiff sand to
9. Very stiff fine grained

CPT basic interpretation plots (normalized)



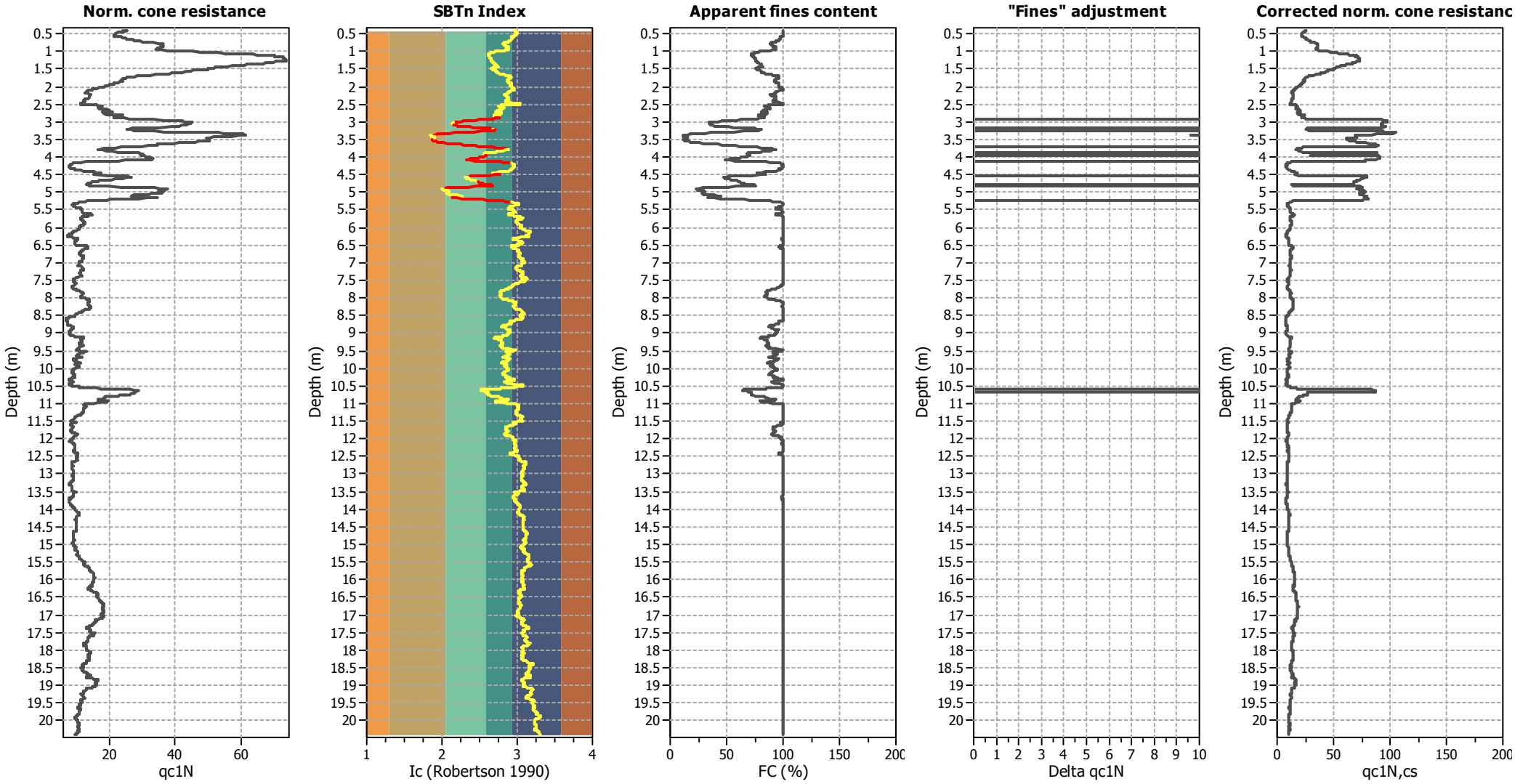
Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	2.20 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	6.14	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.24	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	2.20 m	Fill height:	N/A	Limit depth:	20.00 m

SBTn legend

1. Sensitive fine grained
2. Organic material
3. Clay to silty clay
4. Clayey silt to silty
5. Silty sand to sandy silt
6. Clean sand to silty sand
7. Gravely sand to sand
8. Very stiff sand to
9. Very stiff fine grained

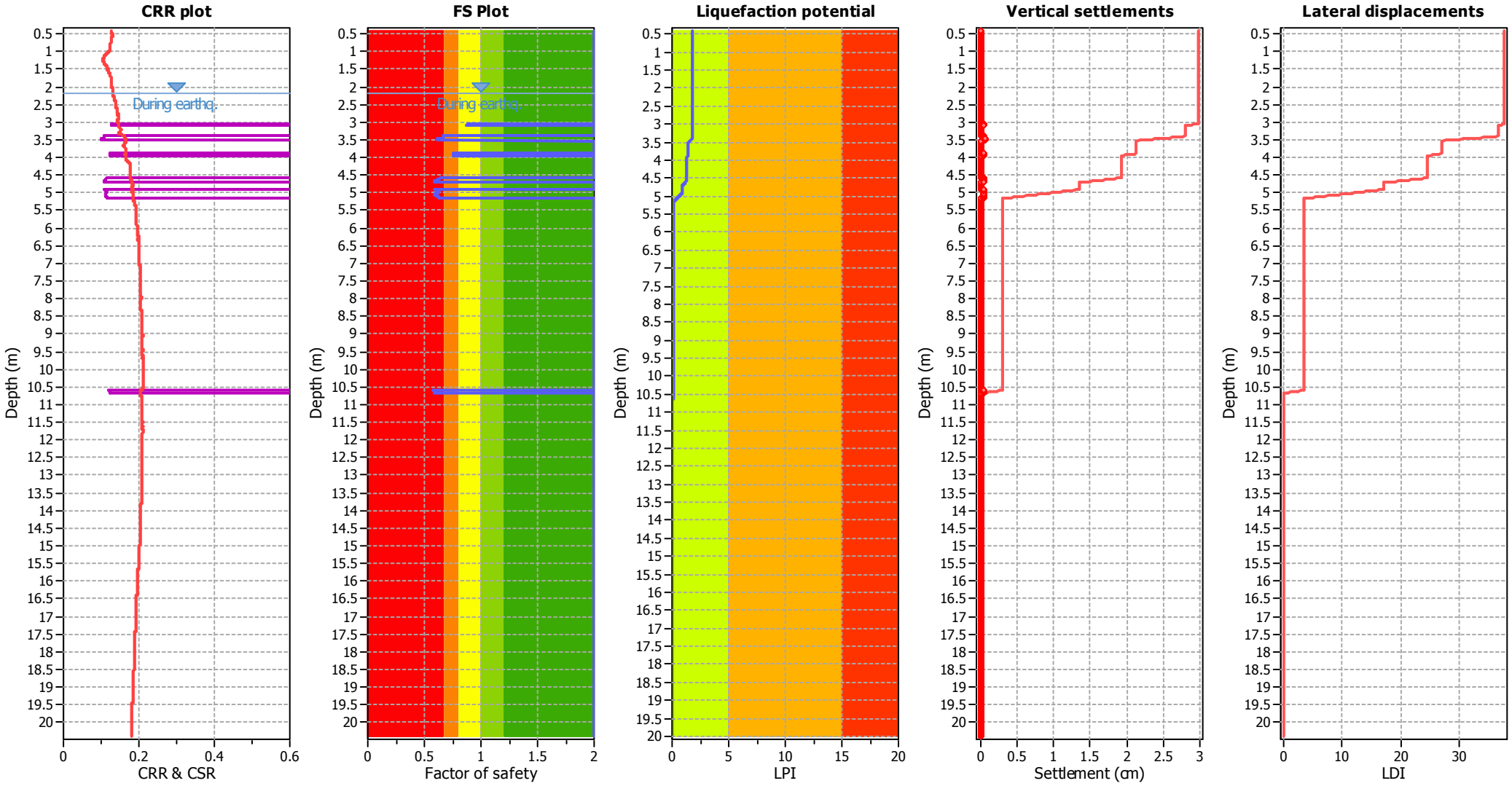
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	2.20 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	6.14	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.24	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	2.20 m	Fill height:	N/A	Limit depth:	20.00 m

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	2.20 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	6.14	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.24	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	2.20 m	Fill height:	N/A	Limit depth:	20.00 m

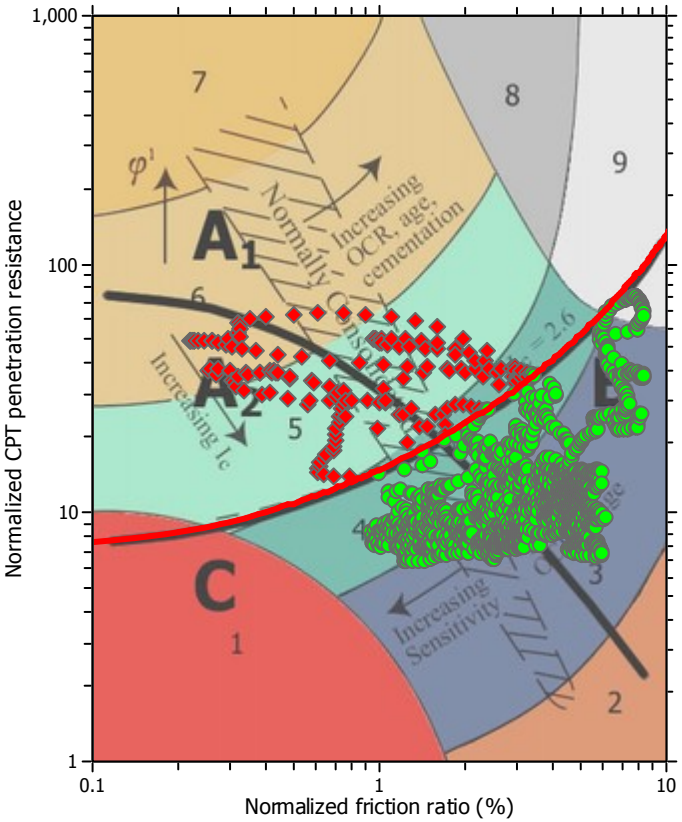
F.S. color scheme

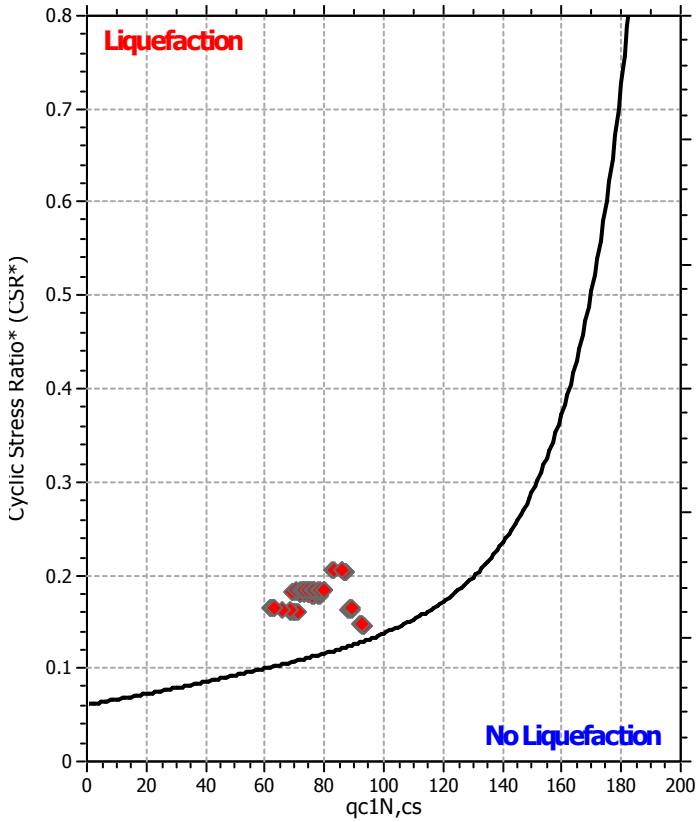
- Almost certain it will liquefy
- Very likely to liquefy
- Liquefaction and no liq. are equally likely
- Unlike to liquefy
- Almost certain it will not liquefy

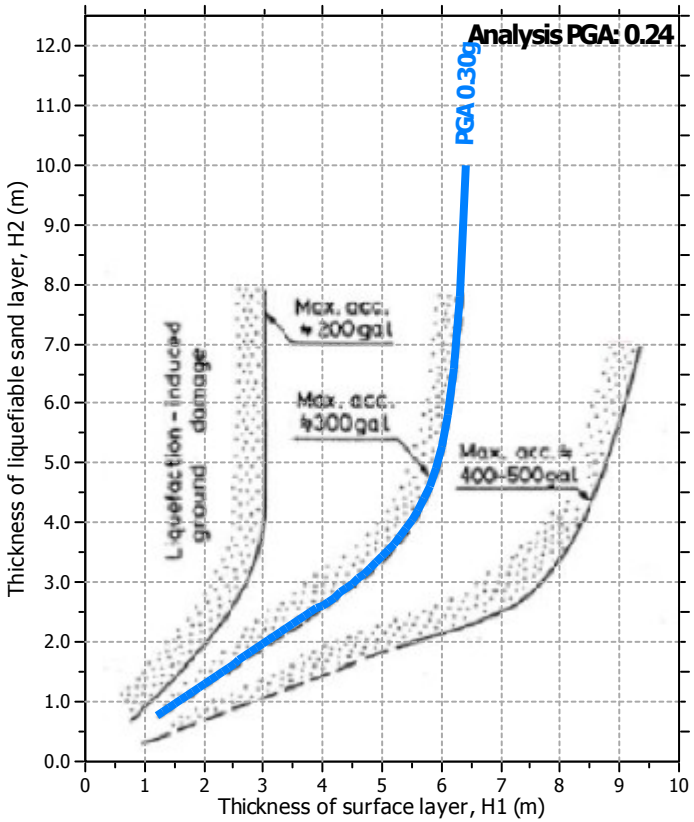
LPI color scheme

- Very high risk
- High risk
- Low risk

Liquefaction analysis summary plots







Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	2.20 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	6.14	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.24	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	2.20 m	Fill height:	N/A	Limit depth:	20.00 m

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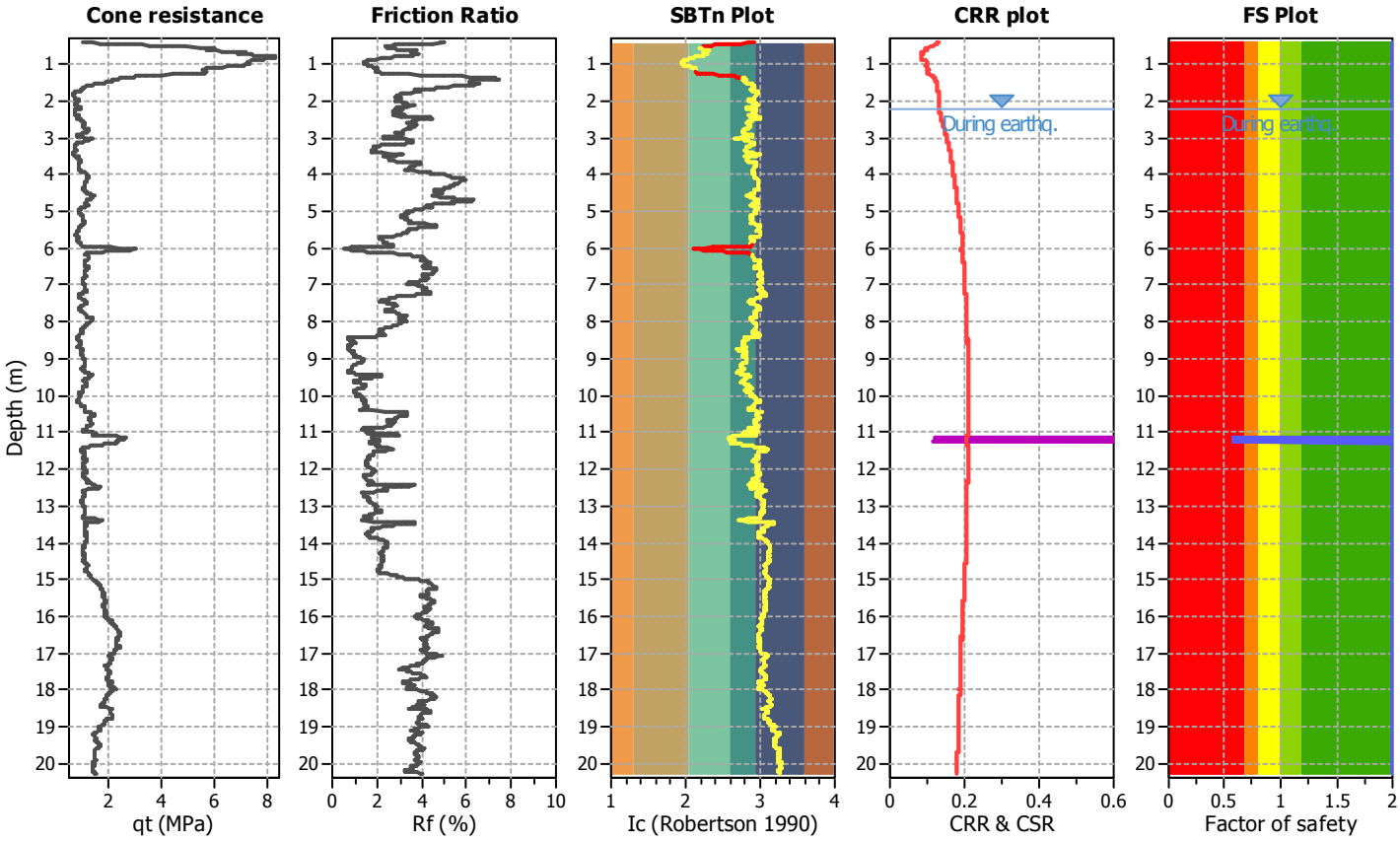
LIQUEFACTION ANALYSIS REPORT

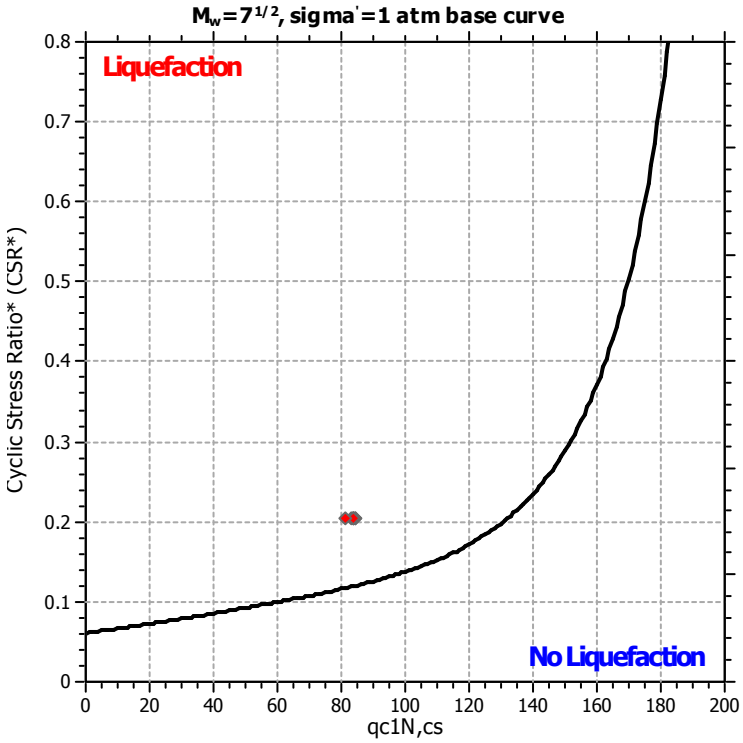
Project title : **Location :**

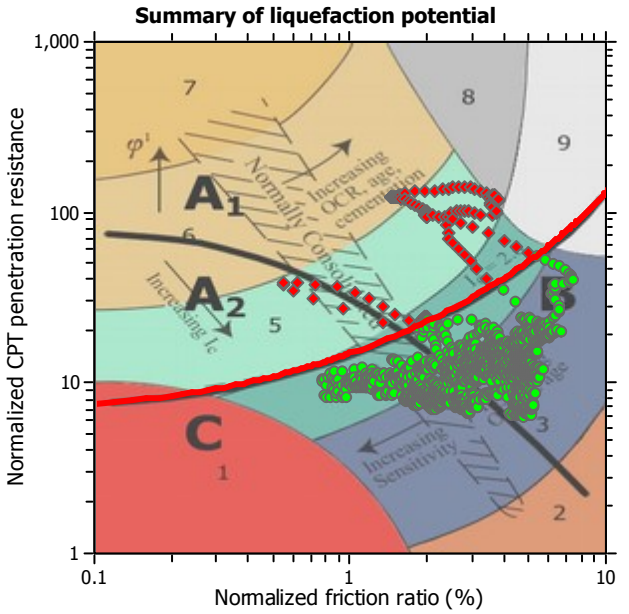
CPT file : CPTU3

Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	2.20 m	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	2.20 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	20.00 m
Earthquake magnitude M_w:	6.14	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method based
Peak ground acceleration:	0.24	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

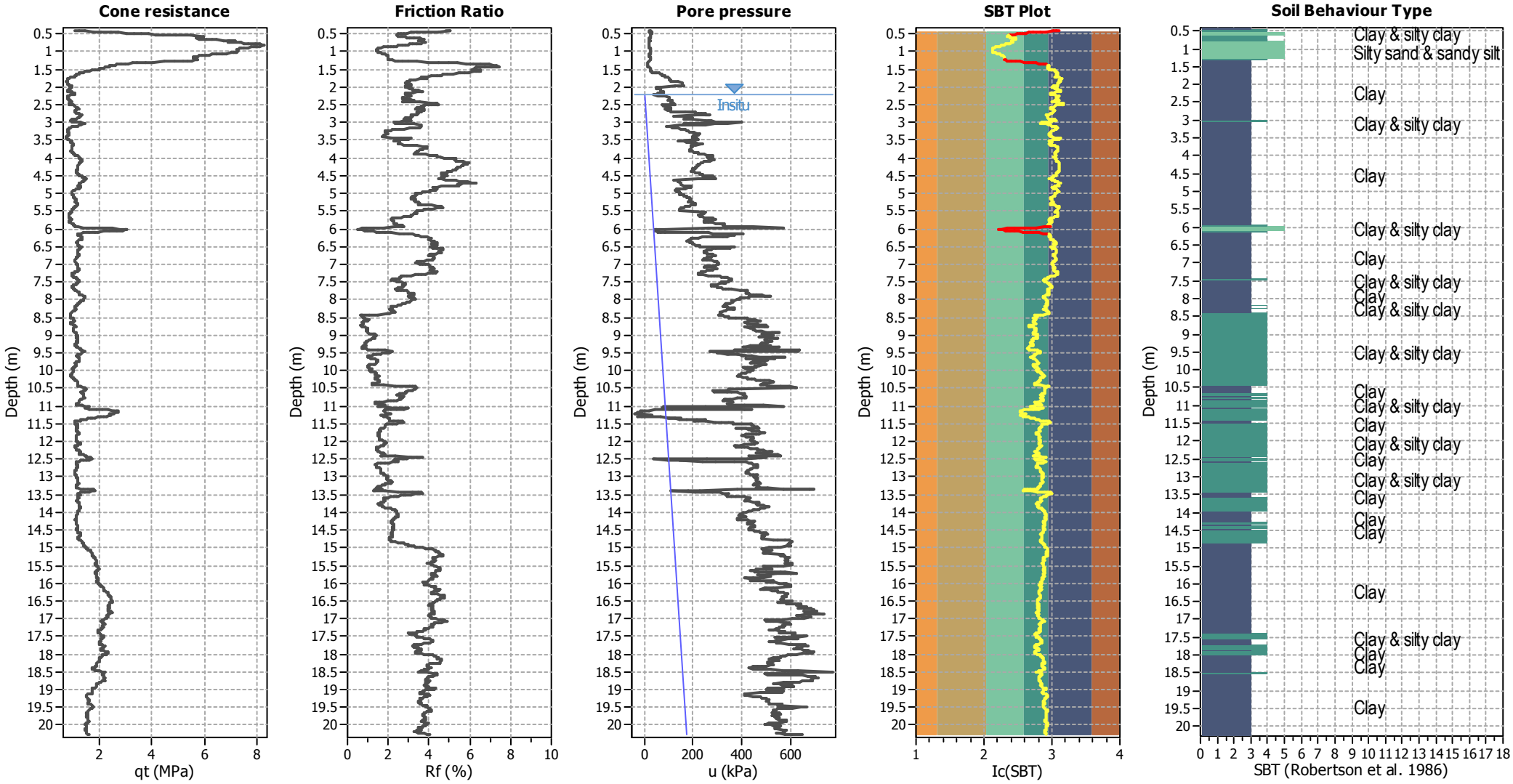






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

CPT basic interpretation plots



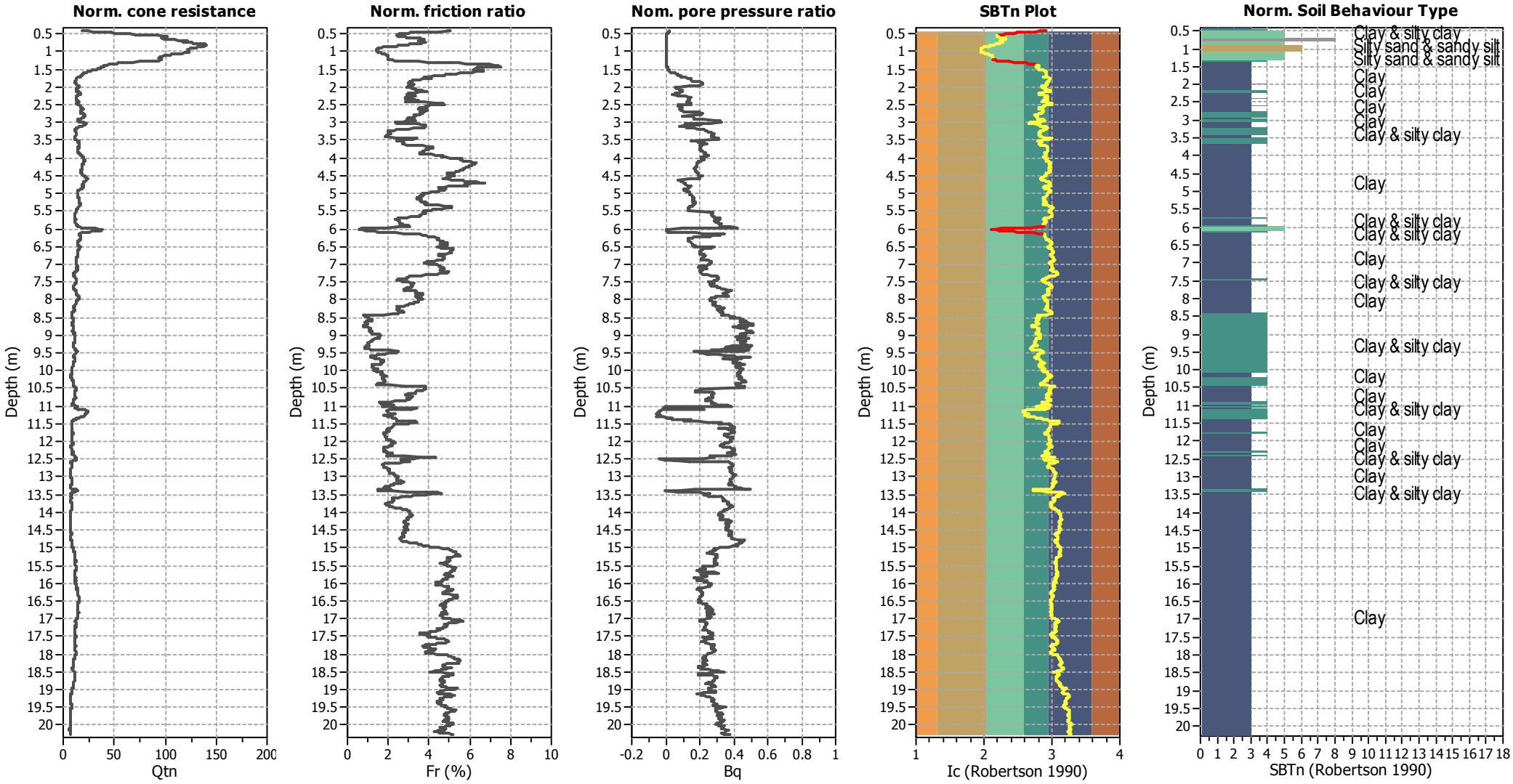
Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	2.20 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	6.14	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.24	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	2.20 m	Fill height:	N/A	Limit depth:	20.00 m

SBT legend

1. Sensitive fine grained
2. Organic material
3. Clay to silty clay
4. Clayey silt to silty
5. Silty sand to sandy silt
6. Clean sand to silty sand
7. Gravely sand to sand
8. Very stiff sand to
9. Very stiff fine grained

CPT basic interpretation plots (normalized)



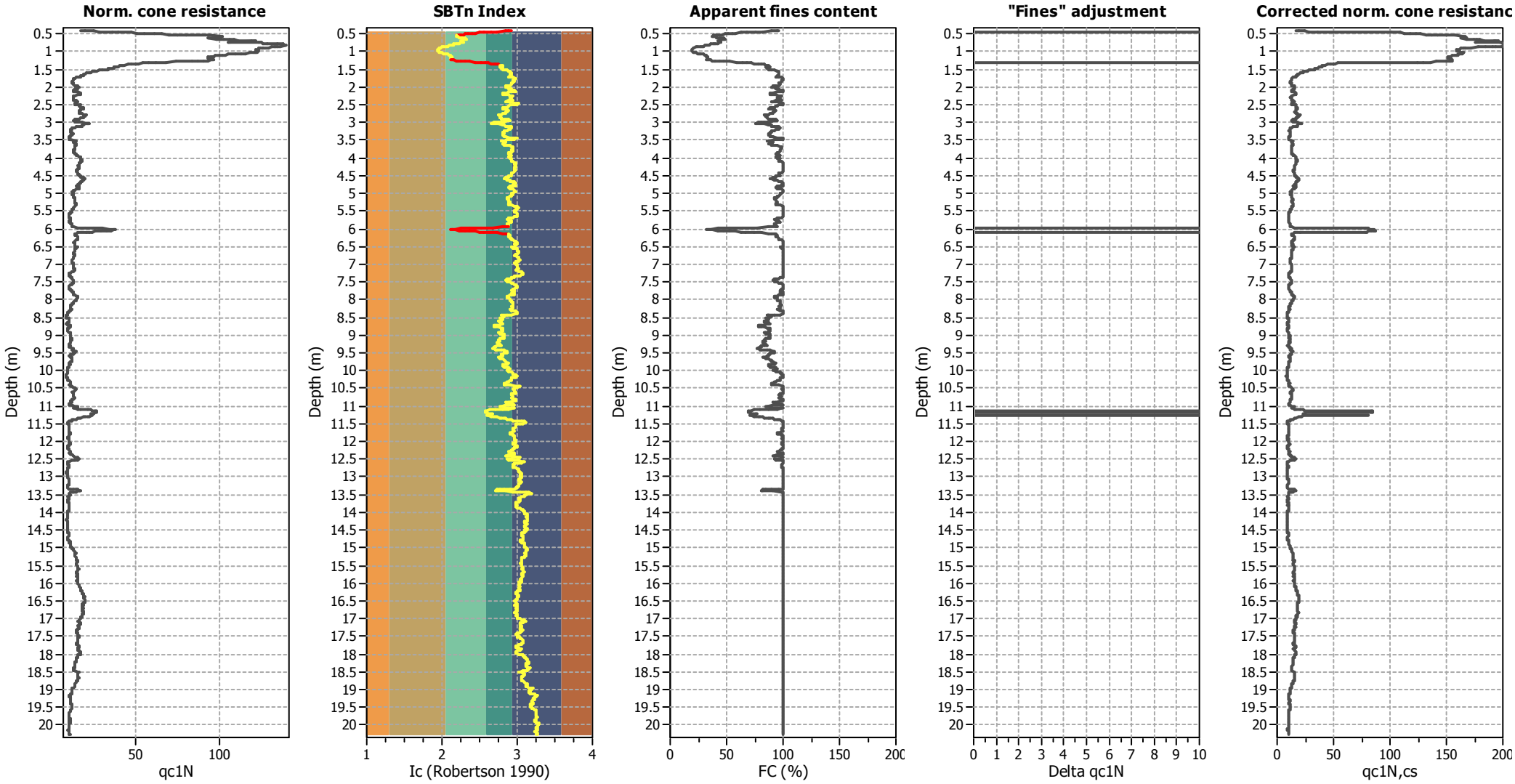
Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	2.20 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	6.14	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.24	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	2.20 m	Fill height:	N/A	Limit depth:	20.00 m

SBTn legend

1. Sensitive fine grained
2. Organic material
3. Clay to silty clay
4. Clayey silt to silty
5. Silty sand to sandy silt
6. Clean sand to silty sand
7. Gravely sand to sand
8. Very stiff sand to
9. Very stiff fine grained

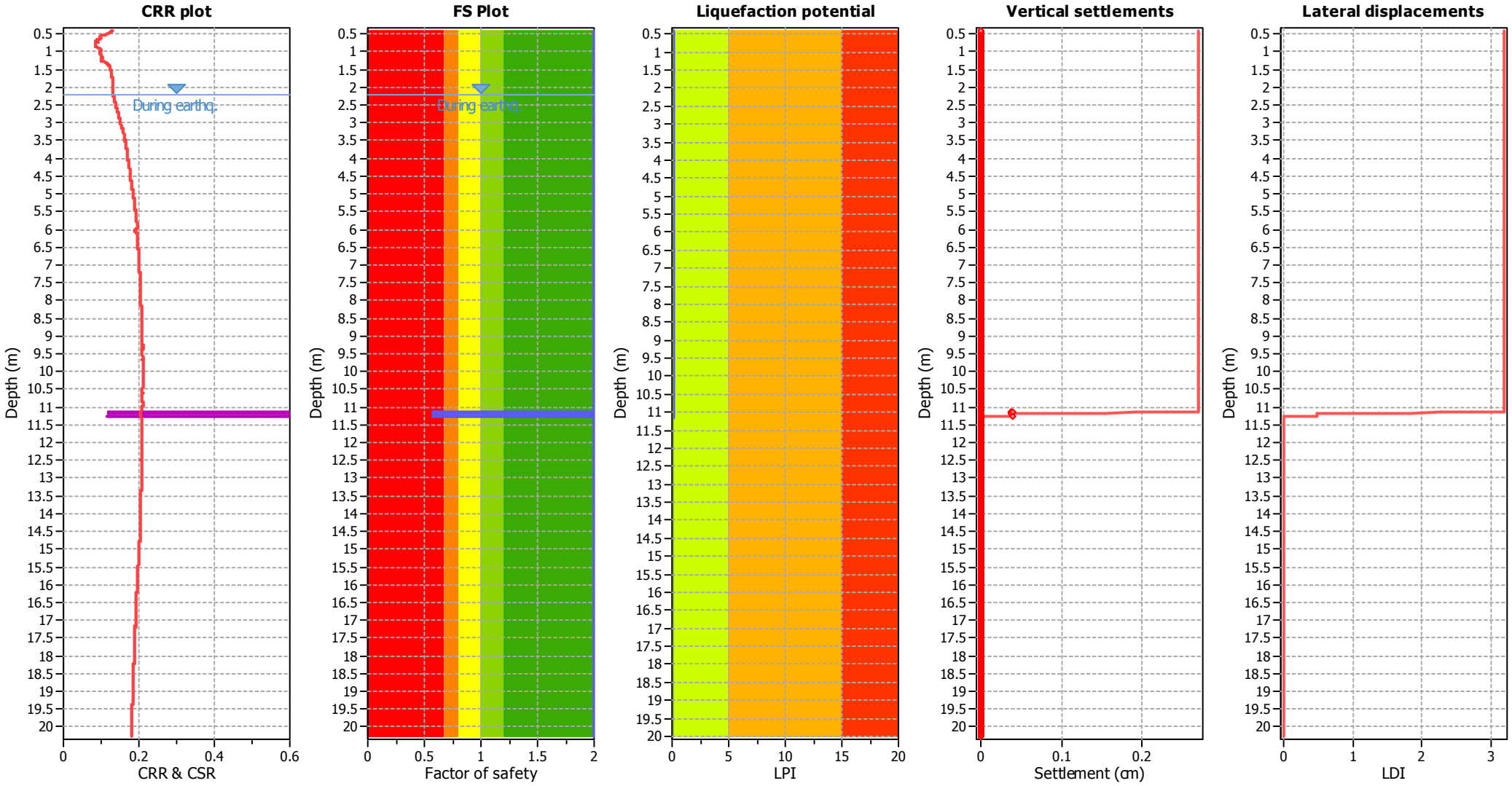
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	2.20 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	6.14	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.24	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	2.20 m	Fill height:	N/A	Limit depth:	20.00 m

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	2.20 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	6.14	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.24	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	2.20 m	Fill height:	N/A	Limit depth:	20.00 m

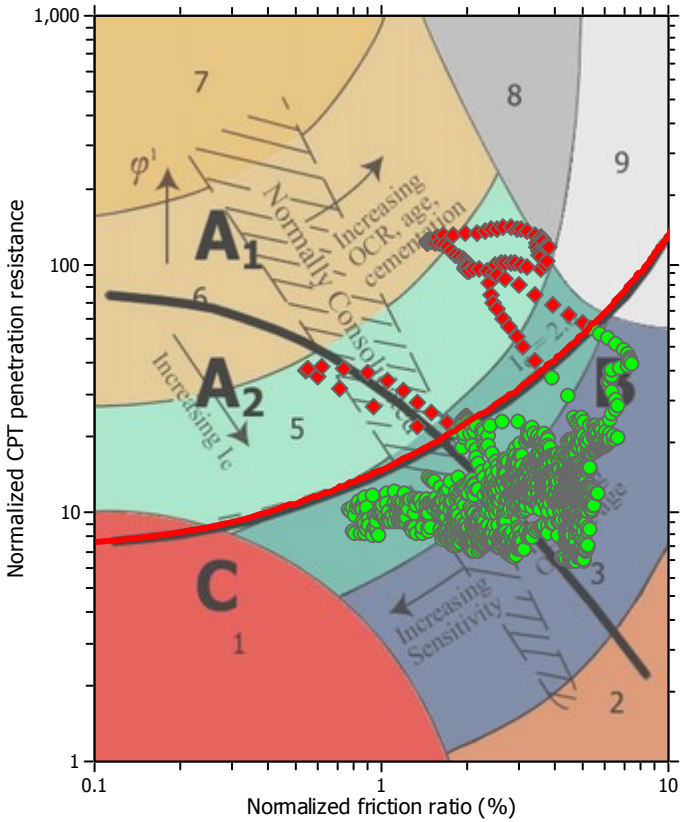
F.S. color scheme

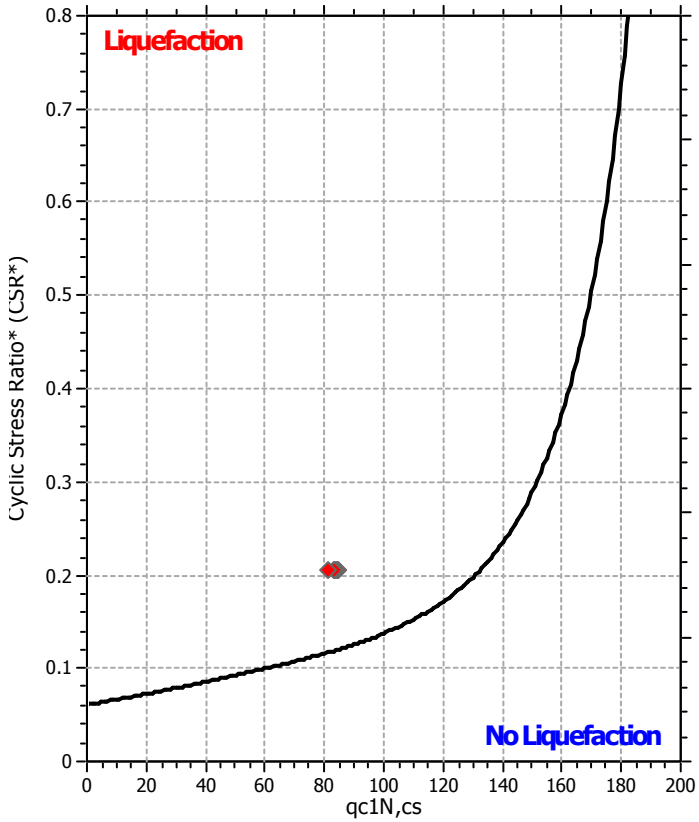
- Almost certain it will liquefy
- Very likely to liquefy
- Liquefaction and no liq. are equally likely
- Unlike to liquefy
- Almost certain it will not liquefy

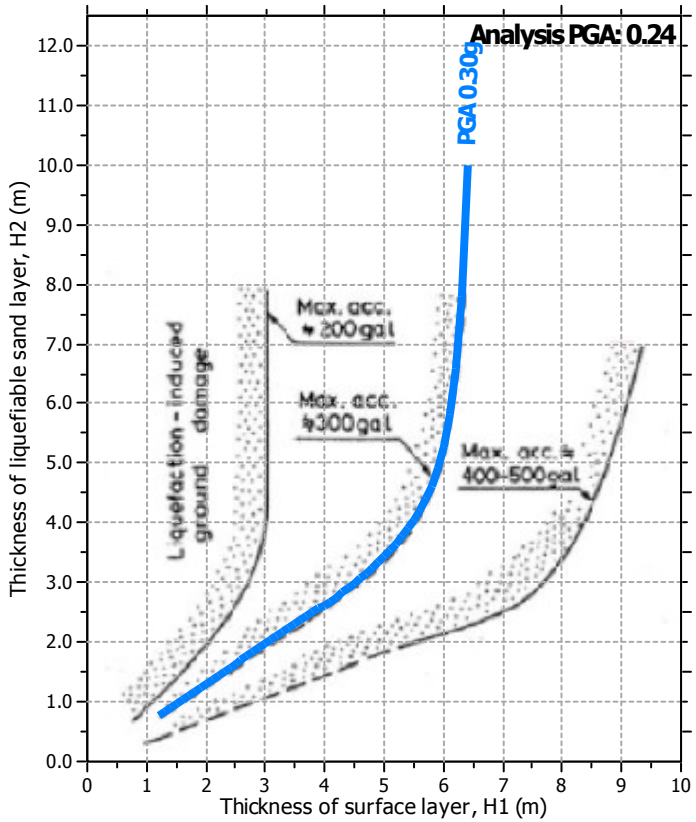
LPI color scheme

- Very high risk
- High risk
- Low risk

Liquefaction analysis summary plots







Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	2.20 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	Yes
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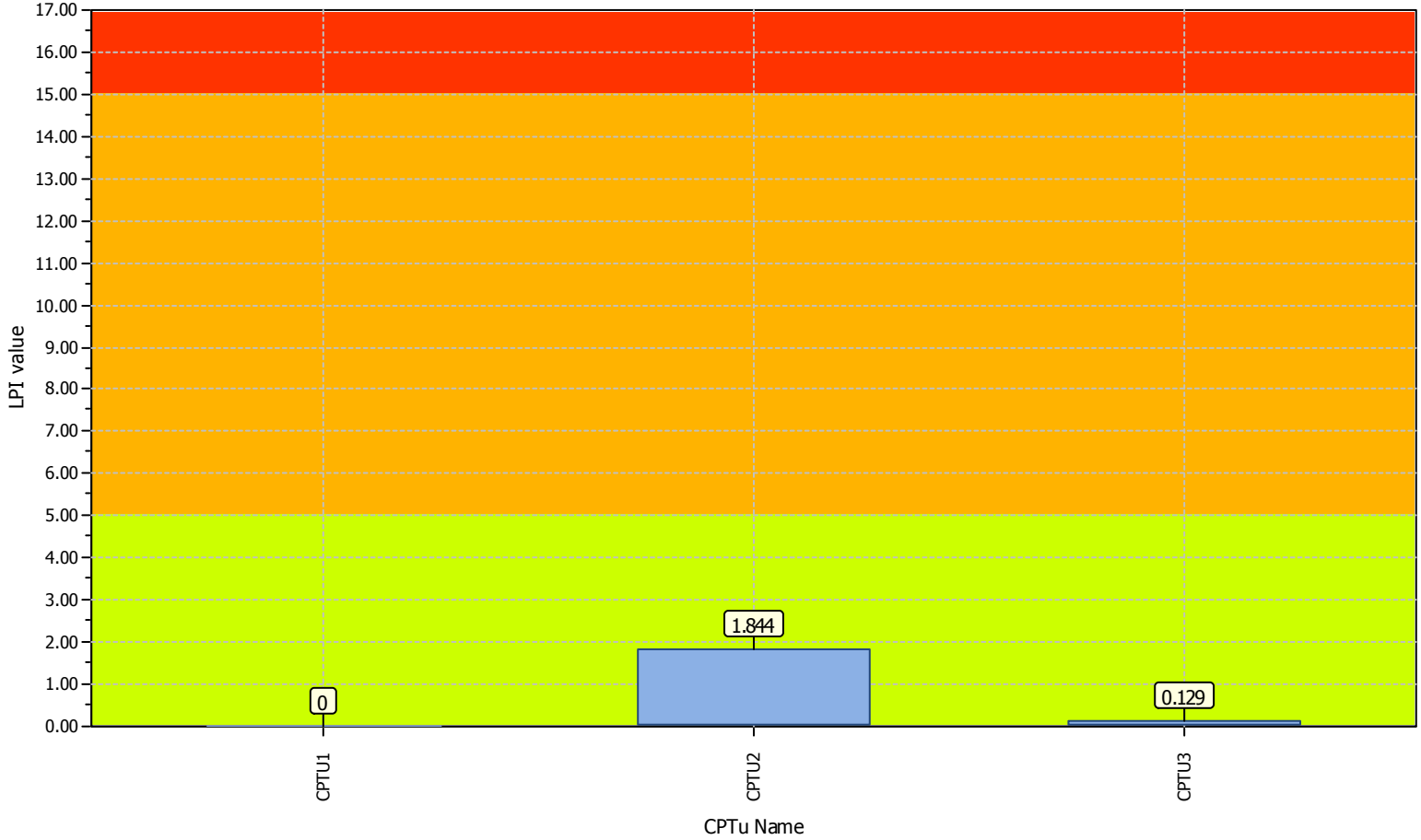
Geo Group Srl
GEOLOGIA E AMBIENTE
Via Cesare Costa 182
www.geogroupmodena.it

Project title :

Location :

Overall Liquefaction Potential Index report



LPI color scheme

- Very high risk
- High risk
- Low risk

Basic statistics

Total CPT number: 3

100% low risk

0% high risk

0% very high risk