ConeTec Inc.

Geotechnical and Environmental Site Investigation Contractors

606-S Roxbury Industrial Center, Charles City, VA 23030 • Tel: (804) 966-5696 • Fax: (804) 966-5697
• E-mail: virginia@conetec.com • Website: www.conetec.com

March 10, 2011

Mr. Glynn M. Ellen
F&ME Consultants
3112 Devine Street
Columbia, SC 29205

Dear Mr. Ellen,

Re: CPTu and SCPTu Testing
SC-41 Replacement Bridge; Charleston, SC

We are pleased to enclose our data submission for the CPTu and SCPTu testing that ConeTec performed for you at the above referenced site on March 8, 2011.

Three cone penetration tests (CPTu) and two seismic cone penetration test (SCPTu), were completed to depths ranging from approximately 30 feet to 120 feet beneath the existing ground surface. A compression model electronic piezo cone penetrometer, with a 15 cm^2 tip and a 225 cm^2 friction sleeve, was used. The cone is designed with an equal end area friction sleeve and a tip end area ratio of 0.80. At the beginning of the sounding, the cone was outfitted with a vacuum-saturated, six millimeter-thick, porous plastic pore pressure element that is located immediately behind the tip (the U_2 location).

A 25-ton truck-mounted cone penetration rig was used to performed tests CPT-1, CPT-2, and CPT-3 while a 12-ton multi-truck was used to advance the cones for CPT-4 and CPT-5. As the cone was advanced into the ground, tip resistance (qc), sleeve friction (fs) and dynamic pore water pressure (U) were recorded every five centimeters (approximately every two inches) and are included in the attached file. A tabular output of this data and summary of engineering parameters is included in the .xls files. Additionally, shear wave measurements were taken in soundings CPT-2, and CPT-3 at 1-m intervals. The resulting shear wave velocity calculations are plotted and tabulated in the attached -Vs.pdfs.

Thank you very much for using ConeTec. It was a pleasure working with you and your staff and we look forward to working with you again in the future. If you have any questions or require additional information, please do not hesitate to contact us.

Best regards,

Fernando Illingworth
ConeTec, Inc.

SC-41 Replacement Bridge

Thursday, March 10, 2011
11-920

Table 1: Sounding Information Table

Test Type	Sounding Number	Filename	Depth (ft)	Estimated GWT (ft)	Comments
CPTu	CPT-1	920CP01	52.5	6	
SCPTu	CPT-2	920CP02	121.4	5	Seismic
SCPTu	CPT-3	920CP03	121.4	5	Seismic
CPTu	CPT-4	920CP04	52.0	4	
CPTu	CPT-5	920CP05	32.8	1	

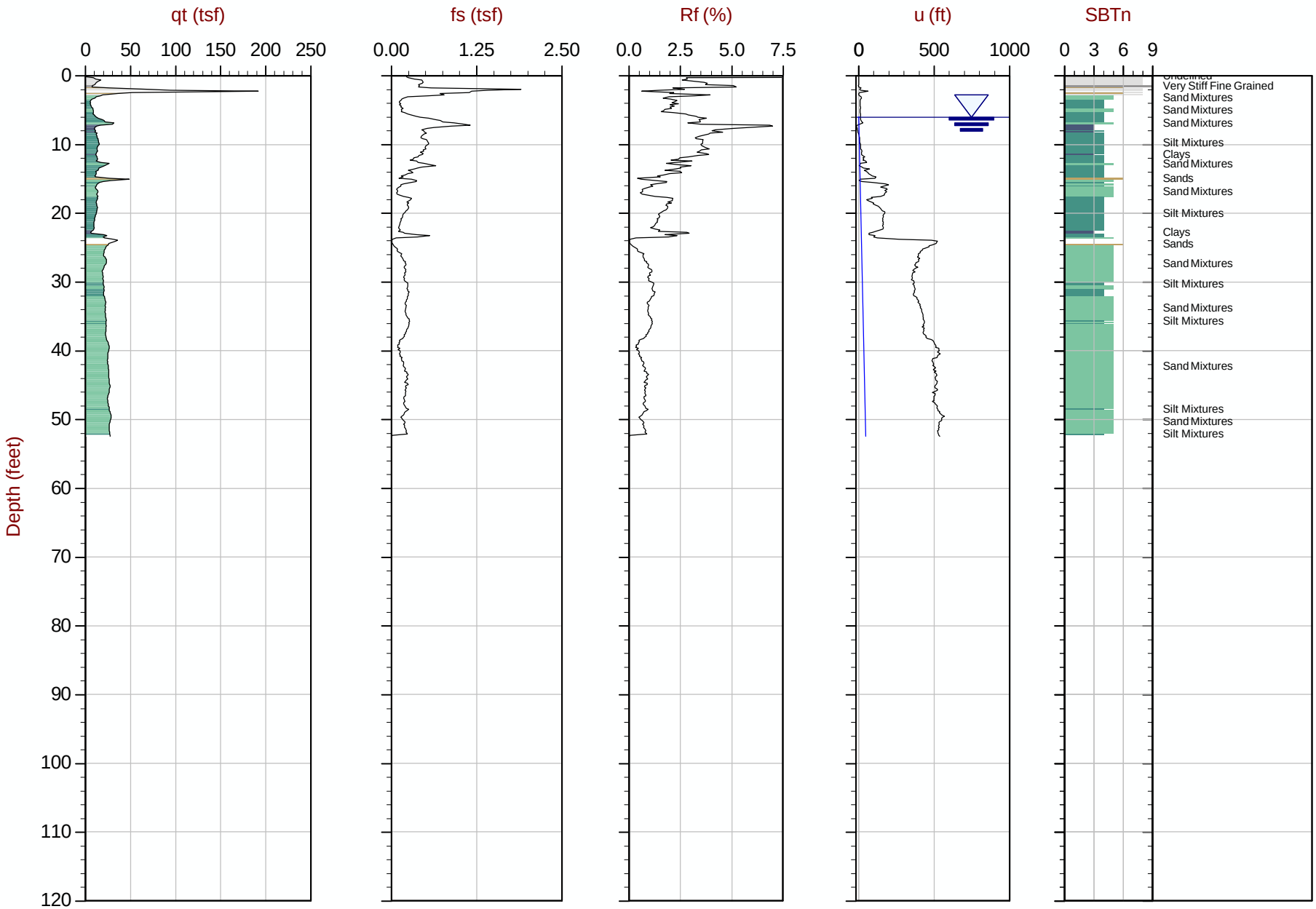
CPTu Plots

CONETEC

F&ME

Job No: 11-920
Date: 03:08:11 16:18
Site: SC 41 Replacement Bridge

Sounding: CPT-1
Cone: 214:T1500F15U500



Max Depth: 16.000 m / 52.49 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: Every Point

File: 920CP01.COR
Unit Wt: SBT Chart Soil Zones

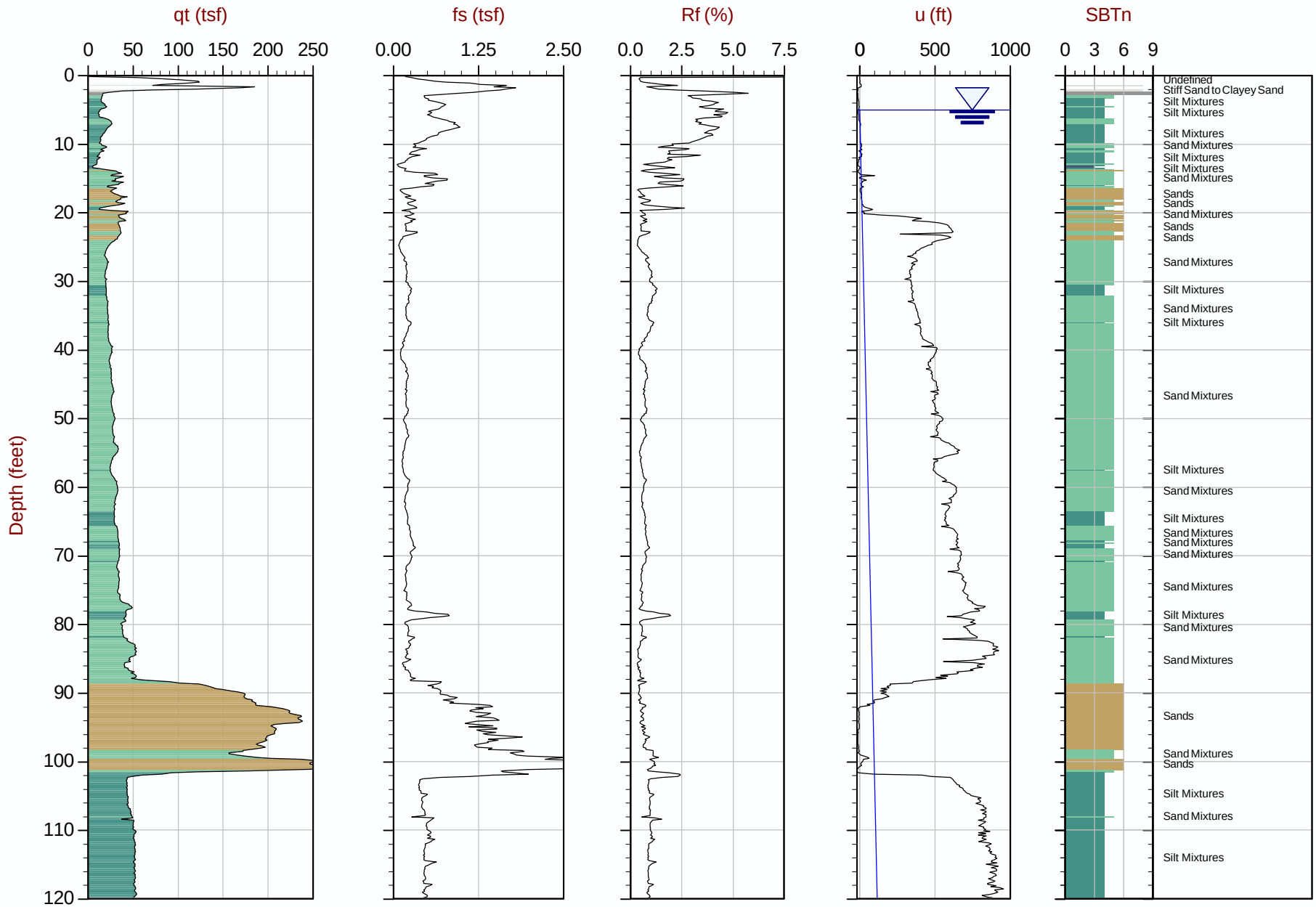
SBT: Lunne, Robertson and Powell, 1997
Coords: Lat: 32.92143 Long: -79.82807

CONETEC

F&ME

Job No: 11-920
Date: 03:08:11 13:54
Site: SC 41 Replacement Bridge

Sounding: CPT-2
Cone: 214:T1500F15U500



Max Depth: 37.000 m / 121.39 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: Every Point

File: 920CP02.COR
Unit Wt: SBT Chart Soil Zones

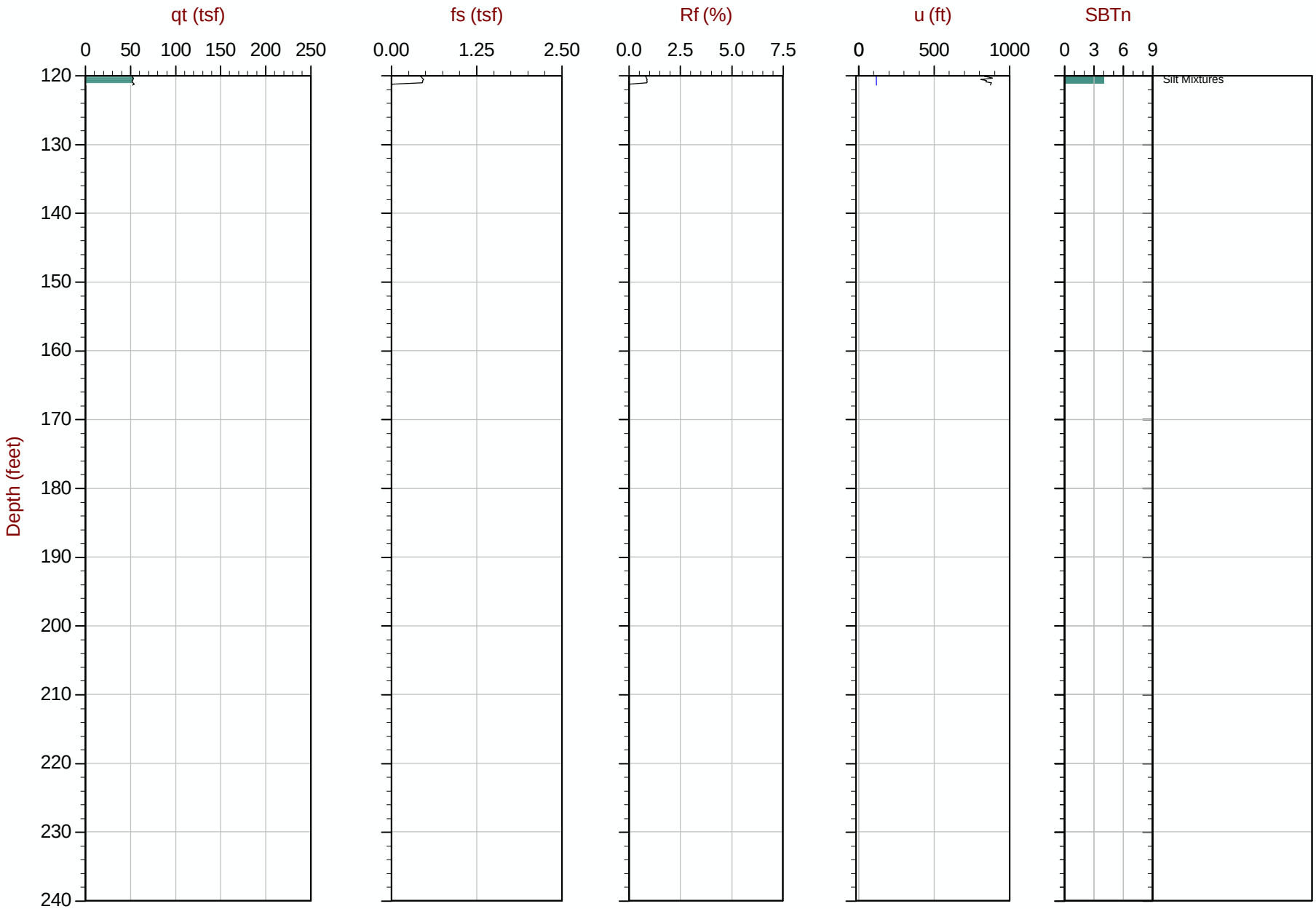
SBT: Lunne, Robertson and Powell, 1997
Coords: Lat: 32.92202 Long: -79.82738

CONETEC

F&ME

Job No: 11-920
Date: 03:08:11 13:54
Site: SC 41 Replacement Bridge

Sounding: CPT-2
Cone: 214:T1500F15U500



Max Depth: 37.000 m / 121.39 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: Every Point

File: 920CP02.COR
Unit Wt: SBT Chart Soil Zones

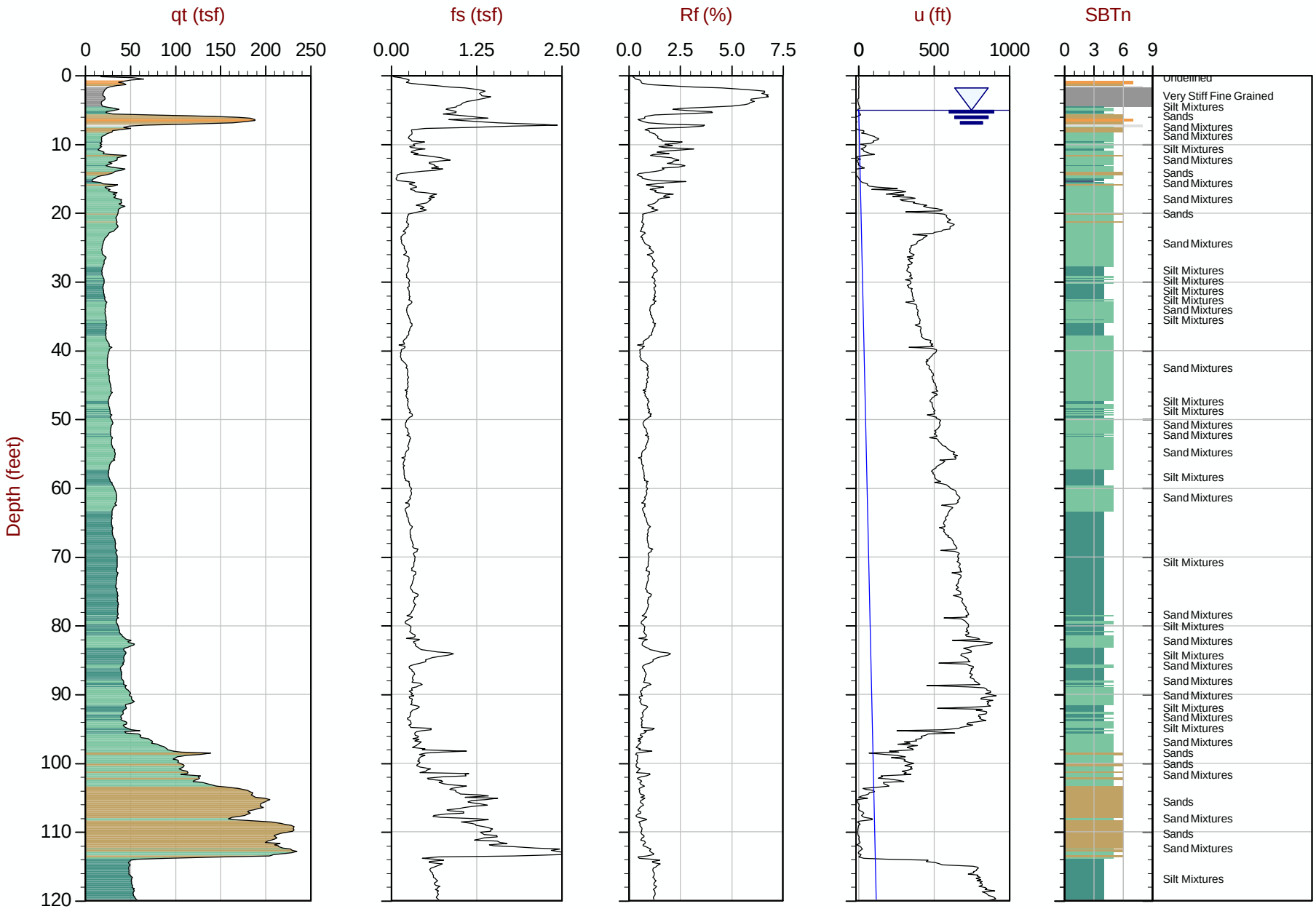
SBT: Lunne, Robertson and Powell, 1997
Coords: Lat: 32.92202 Long: -79.82738

CONETEC

F&ME

Job No: 11-920
Date: 03:08:11 10:56
Site: SC 41 Replacement Bridge

Sounding: CPT-3
Cone: 214:T1500F15U500



Max Depth: 37.000 m / 121.39 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: Every Point

File: 920CP03.COR
Unit Wt: SBT Chart Soil Zones

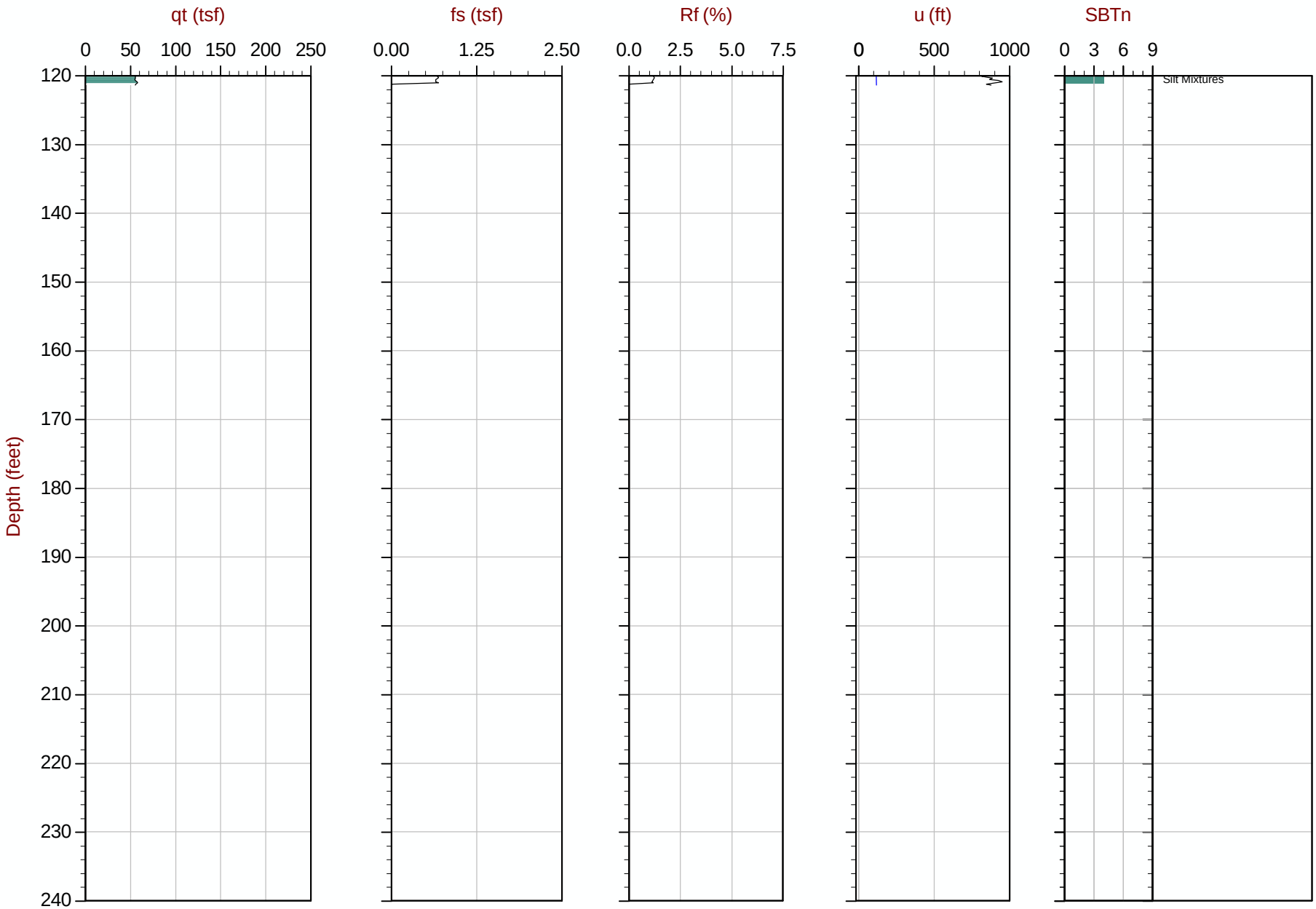
SBT: Lunne, Robertson and Powell, 1997
Coords: Lat: 32.92577 Long: -79.82300

CONETEC

F&ME

Job No: 11-920
Date: 03:08:11 10:56
Site: SC 41 Replacement Bridge

Sounding: CPT-3
Cone: 214:T1500F15U500



Max Depth: 37.000 m / 121.39 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: Every Point

File: 920CP03.COR
Unit Wt: SBT Chart Soil Zones

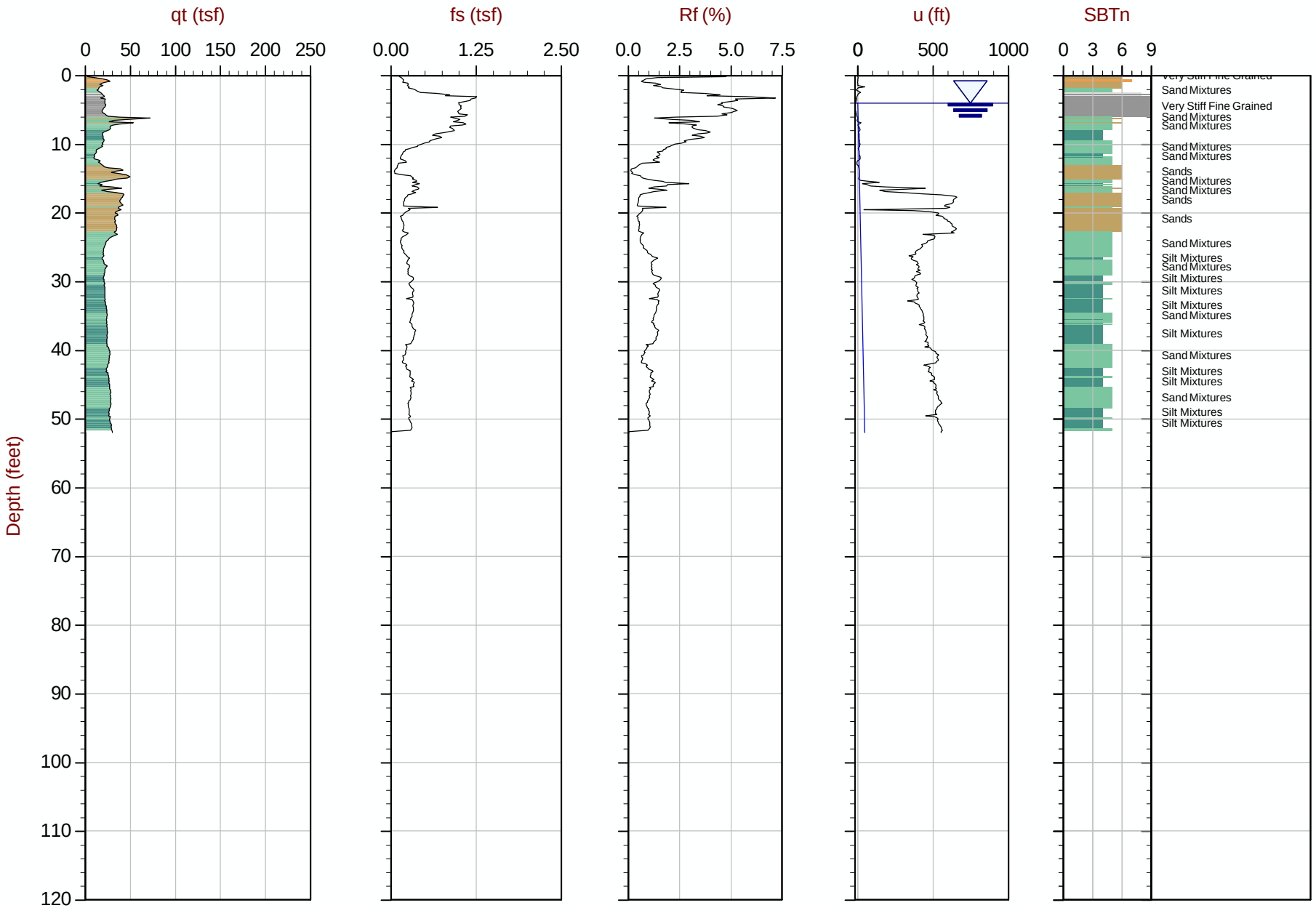
SBT: Lunne, Robertson and Powell, 1997
Coords: Lat: 32.92577 Long: -79.82300

CONETEC

F&ME

Job No: 11-920
Date: 03:08:11 09:20
Site: SC-41 Bridge Replacement

Sounding: CPT-4
Cone: 184:T1500F15U500



Max Depth: 15.850 m / 52.00 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: Every Point

File: 920CP04.COR
Unit Wt: SBT Chart Soil Zones

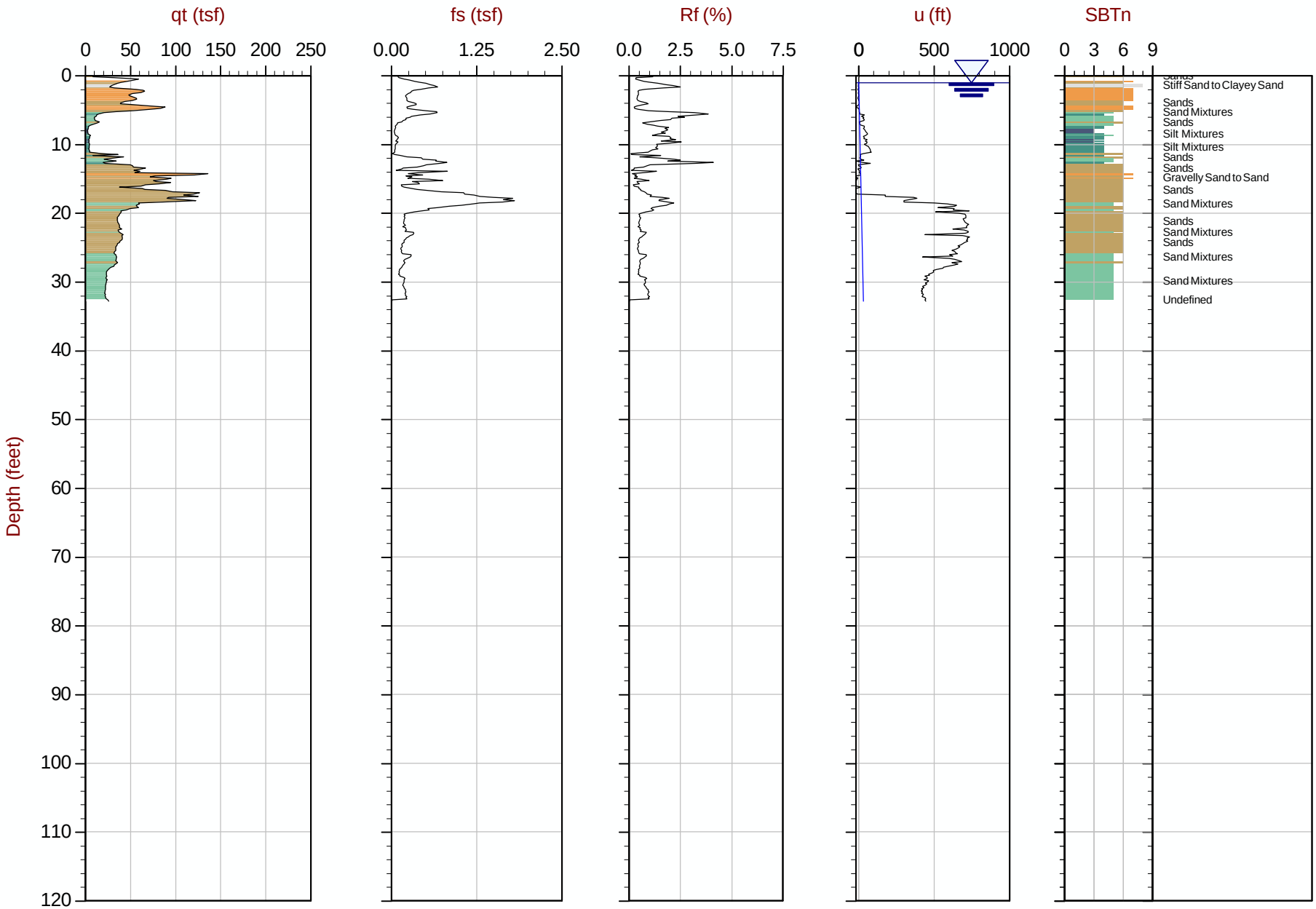
SBT: Lunne, Robertson and Powell, 1997
Coords: N: 32.927 E: -79.822

CONETEC

F&ME

Job No: 11-920
Date: 03:08:11 12:08
Site: SC-41 Bridge Replacement

Sounding: CPT-5
Cone: 184:T1500F15U500



Max Depth: 10.000 m / 32.81 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: Every Point

File: 920CP05.COR
Unit Wt: SBT Chart Soil Zones

SBT: Lunne, Robertson and Powell, 1997
Coords: Lat: 32.93186 Long: -79.82088

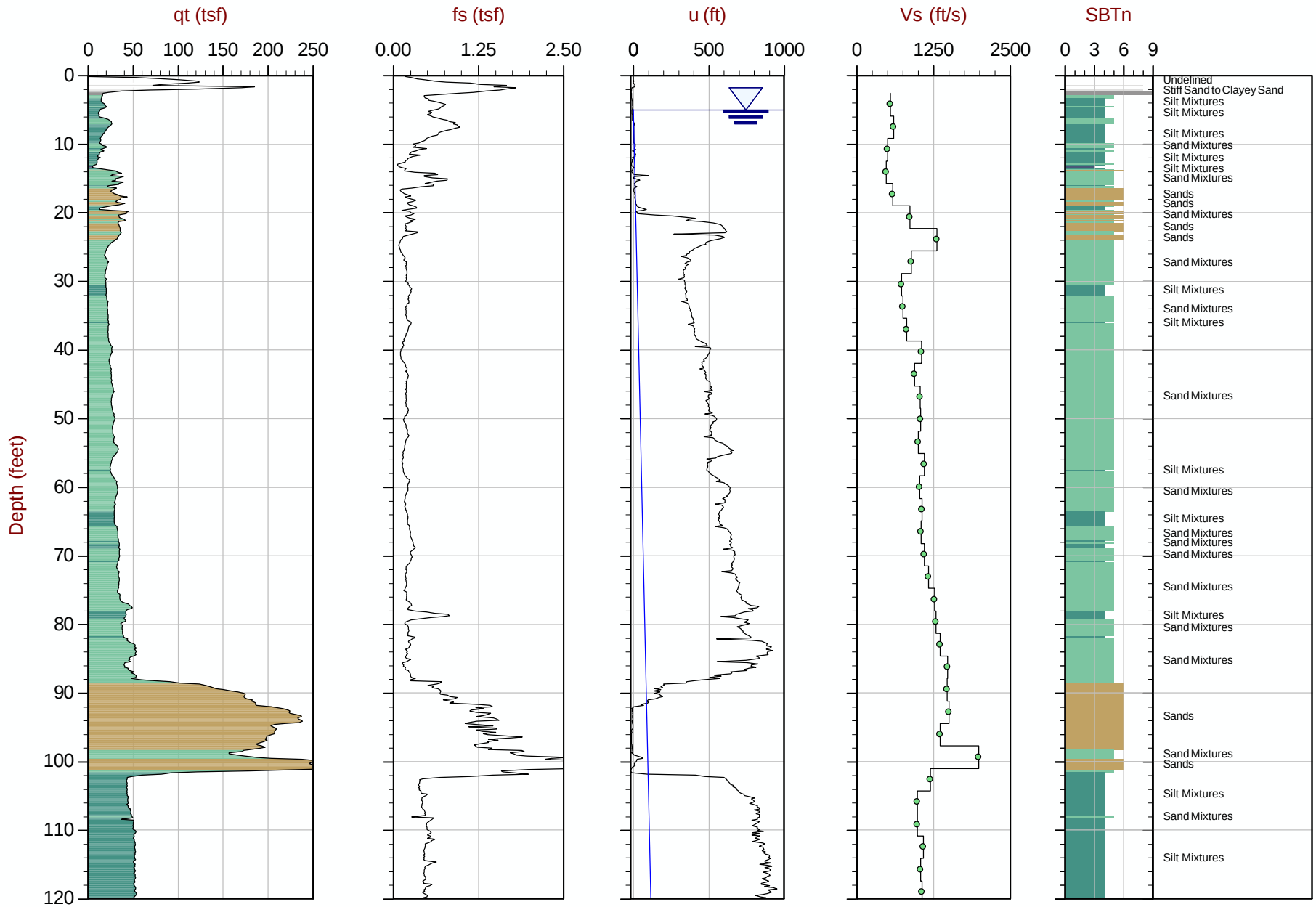
Shear Wave Data and Velocity Estimates

CONETEC

F&ME

Job No: 11-920
Date: 03:08:11 13:54
Site: SC 41 Replacement Bridge

Sounding: CPT-2
Cone: 214:T1500F15U500



Max Depth: 37.000 m / 121.39 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: Every Point

File: 920CP02.COR
Unit Wt: SBT Chart Soil Zones

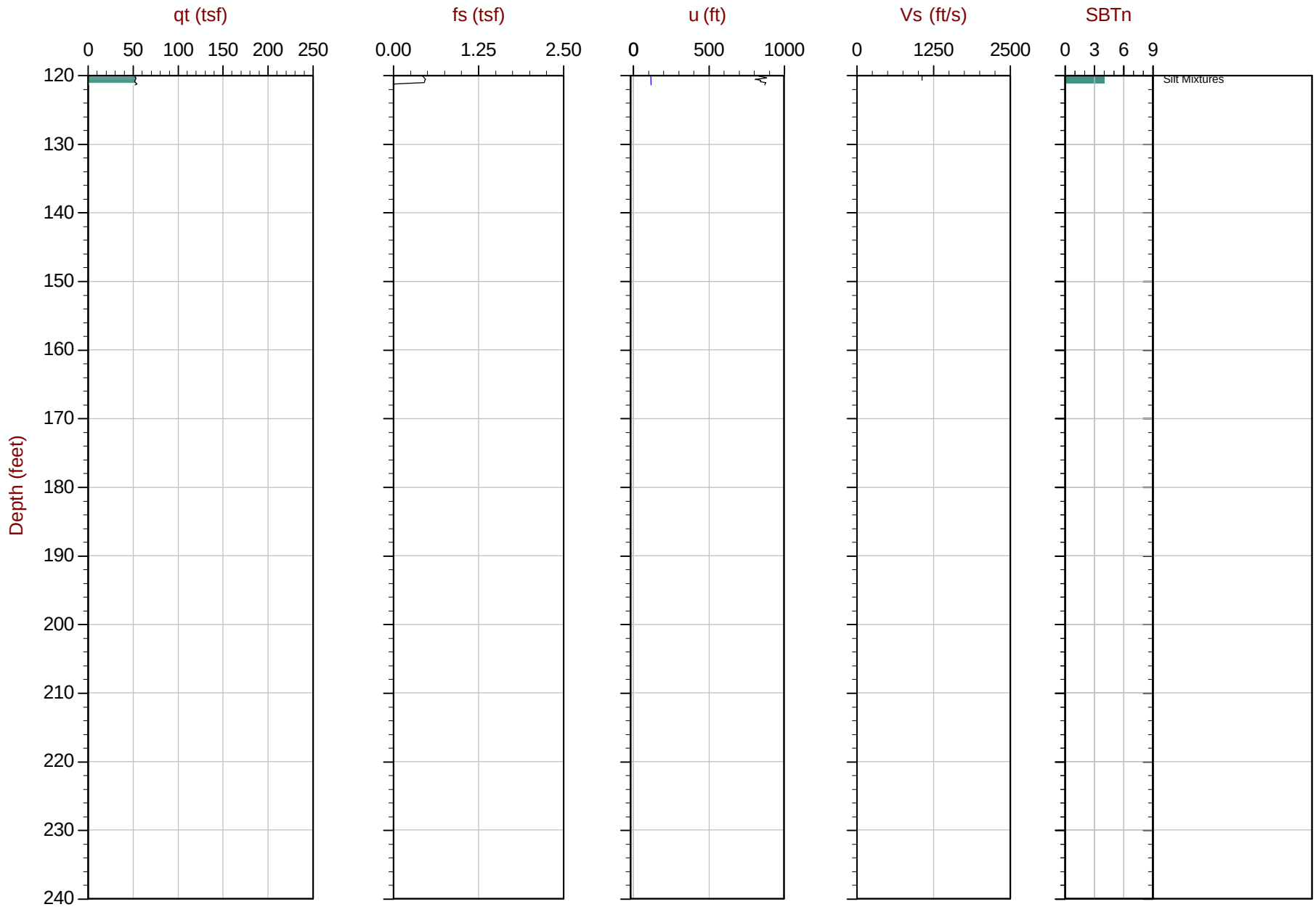
SBT: Lunne, Robertson and Powell, 1997
Coords: Lat: 32.92202 Long: -79.82738

CONETEC

F&ME

Job No: 11-920
Date: 03:08:11 13:54
Site: SC 41 Replacement Bridge

Sounding: CPT-2
Cone: 214:T1500F15U500

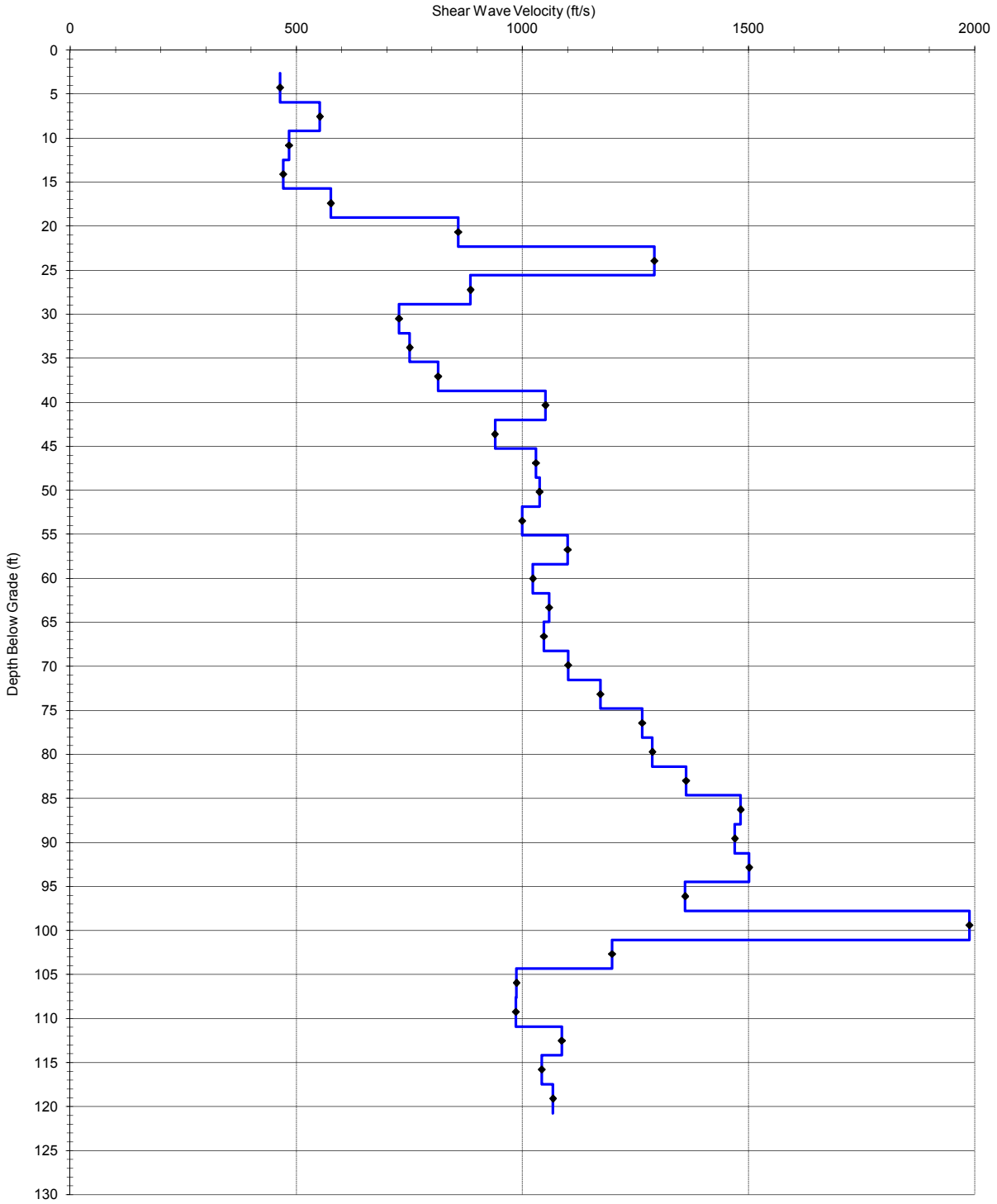


Max Depth: 37.000 m / 121.39 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: Every Point

File: 920CP02.COR
Unit Wt: SBT Chart Soil Zones

SBT: Lunne, Robertson and Powell, 1997
Coords: Lat: 32.92202 Long: -79.82738

Shear Wave Velocity- CPT-2
SC-41 Replacement Bridge
11-920
March 8 2011

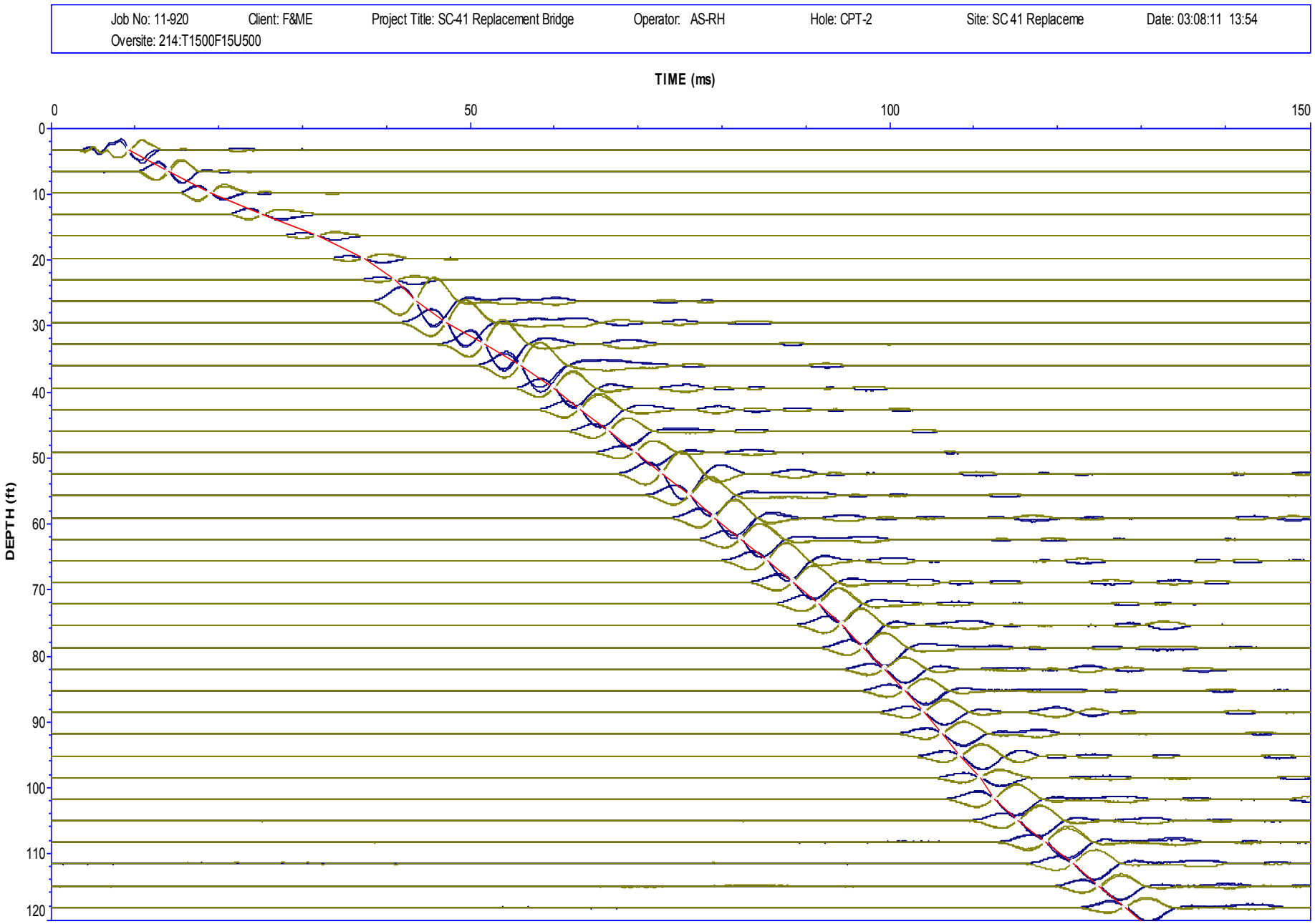


ConeTec Shear Wave Velocity Data Reduction Sheet

Hole: CPT-2
Location: SC-41 Replacement Bridge
Cone: AD214
Date: 8-Mar-11
Source: Beam

Source Depth	0.00 m
Source Offset	1.45 m

Tip Depth (m)	Geophone Depth(m)	Travel Path (m)	Interval time (ms)	Velocity (m/s)	Velocity (ft/s)	Interval Depth (m)	Interval Depth (ft)
0.00							
1.00	0.80	1.66					
2.00	1.80	2.31	4.63	141.5	464.3	1.30	4.27
3.00	2.80	3.15	5.00	168.4	552.4	2.30	7.55
4.00	3.80	4.07	6.20	147.4	483.7	3.30	10.83
5.00	4.80	5.01	6.60	143.6	471.1	4.30	14.11
6.00	5.80	5.98	5.49	175.8	576.7	5.30	17.39
7.00	6.80	6.95	3.73	261.4	857.8	6.30	20.67
8.00	7.80	7.93	2.49	393.7	1291.7	7.30	23.95
9.00	8.80	8.92	3.65	269.9	885.6	8.30	27.23
10.00	9.80	9.91	4.46	221.6	727.2	9.30	30.51
11.00	10.80	10.90	4.33	228.9	751.1	10.30	33.79
12.00	11.80	11.89	4.00	247.9	813.3	11.30	37.07
13.00	12.80	12.88	3.10	320.4	1051.3	12.30	40.35
14.00	13.80	13.88	3.47	286.3	939.4	13.30	43.63
15.00	14.80	14.87	3.17	313.8	1029.6	14.30	46.92
16.00	15.80	15.87	3.15	316.3	1037.7	15.30	50.20
17.00	16.80	16.86	3.27	304.6	999.3	16.30	53.48
18.00	17.80	17.86	2.97	335.3	1100.1	17.30	56.76
19.00	18.80	18.86	3.20	311.9	1023.3	18.30	60.04
20.00	19.80	19.85	3.09	322.8	1059.0	19.30	63.32
21.00	20.80	20.85	3.12	319.3	1047.7	20.30	66.60
22.00	21.80	21.85	2.97	335.5	1100.8	21.30	69.88
23.00	22.80	22.85	2.79	357.3	1172.3	22.30	73.16
24.00	23.80	23.84	2.59	385.5	1264.6	23.30	76.44
25.00	24.80	24.84	2.54	392.5	1287.7	24.30	79.72
26.00	25.80	25.84	2.41	415.0	1361.6	25.30	83.00
27.00	26.80	26.84	2.21	452.0	1482.9	26.30	86.29
28.00	27.80	27.84	2.23	448.0	1470.0	27.30	89.57
29.00	28.80	28.84	2.18	457.6	1501.4	28.30	92.85
30.00	29.80	29.84	2.41	414.6	1360.2	29.30	96.13
31.00	30.80	30.83	1.65	606.0	1988.1	30.30	99.41
32.00	31.80	31.83	2.74	365.1	1197.9	31.30	102.69
33.00	32.80	32.83	3.32	300.9	987.2	32.30	105.97
34.00	33.80	33.83	3.33	300.3	985.2	33.30	109.25
35.00	34.80	34.83	3.02	331.2	1086.7	34.30	112.53
36.00	35.80	35.83	3.14	317.9	1042.9	35.30	115.81
37.00	36.80	36.83	3.07	325.5	1067.9	36.30	119.09

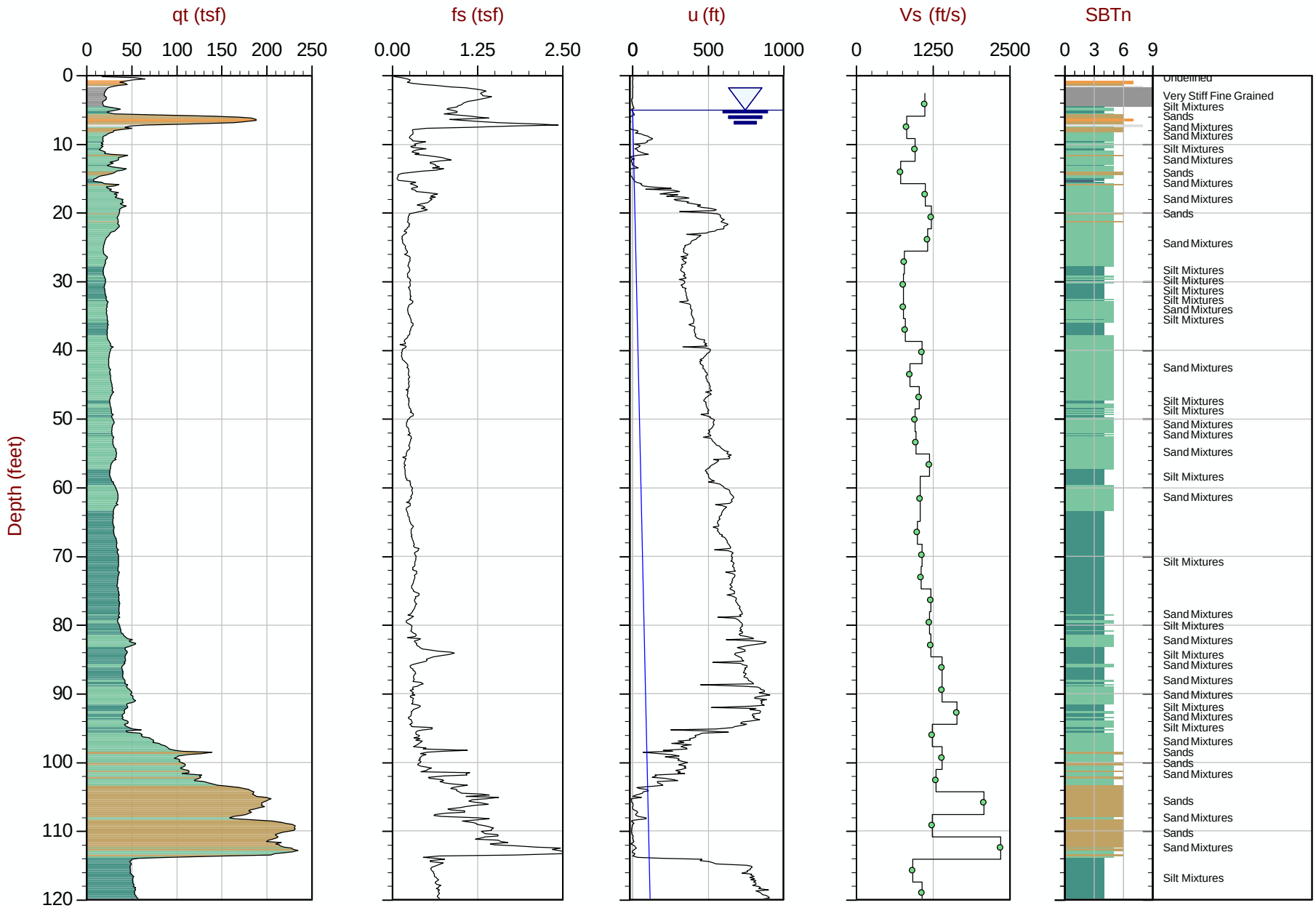

Job No: 11-920
Client: F&ME
Project Title: SC-41 Replacement Bridge
Operator: AS-RH
Hole: CPT-2
Site: SC 41 Replaceme
Date: 03:08:11 13:54
Oversite: 214:T1500F15U500
TIME (ms)
0
50
100
150
DEPTH (ft)
0
10
20
30
40
50
60
70
80
90
100
110
120

CONETEC

F&ME

Job No: 11-920
Date: 03:08:11 10:56
Site: SC 41 Replacement Bridge

Sounding: CPT-3
Cone: 214:T1500F15U500



Max Depth: 37.000 m / 121.39 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: Every Point

File: 920CP03.COR
Unit Wt: SBT Chart Soil Zones

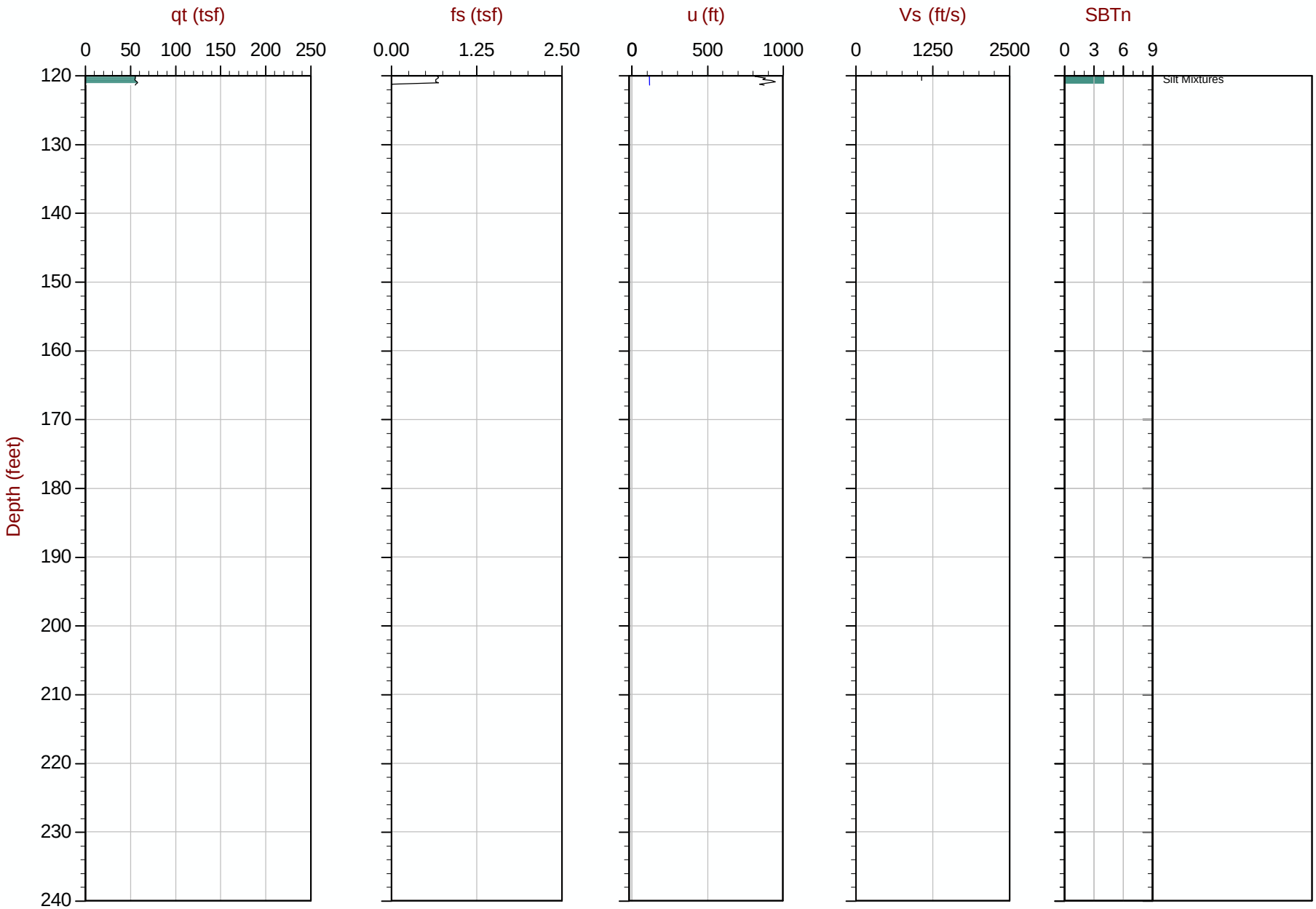
SBT: Lunne, Robertson and Powell, 1997
Coords: Lat: 32.92577 Long: -79.82300

CONETEC

F&ME

Job No: 11-920
Date: 03:08:11 10:56
Site: SC 41 Replacement Bridge

Sounding: CPT-3
Cone: 214:T1500F15U500

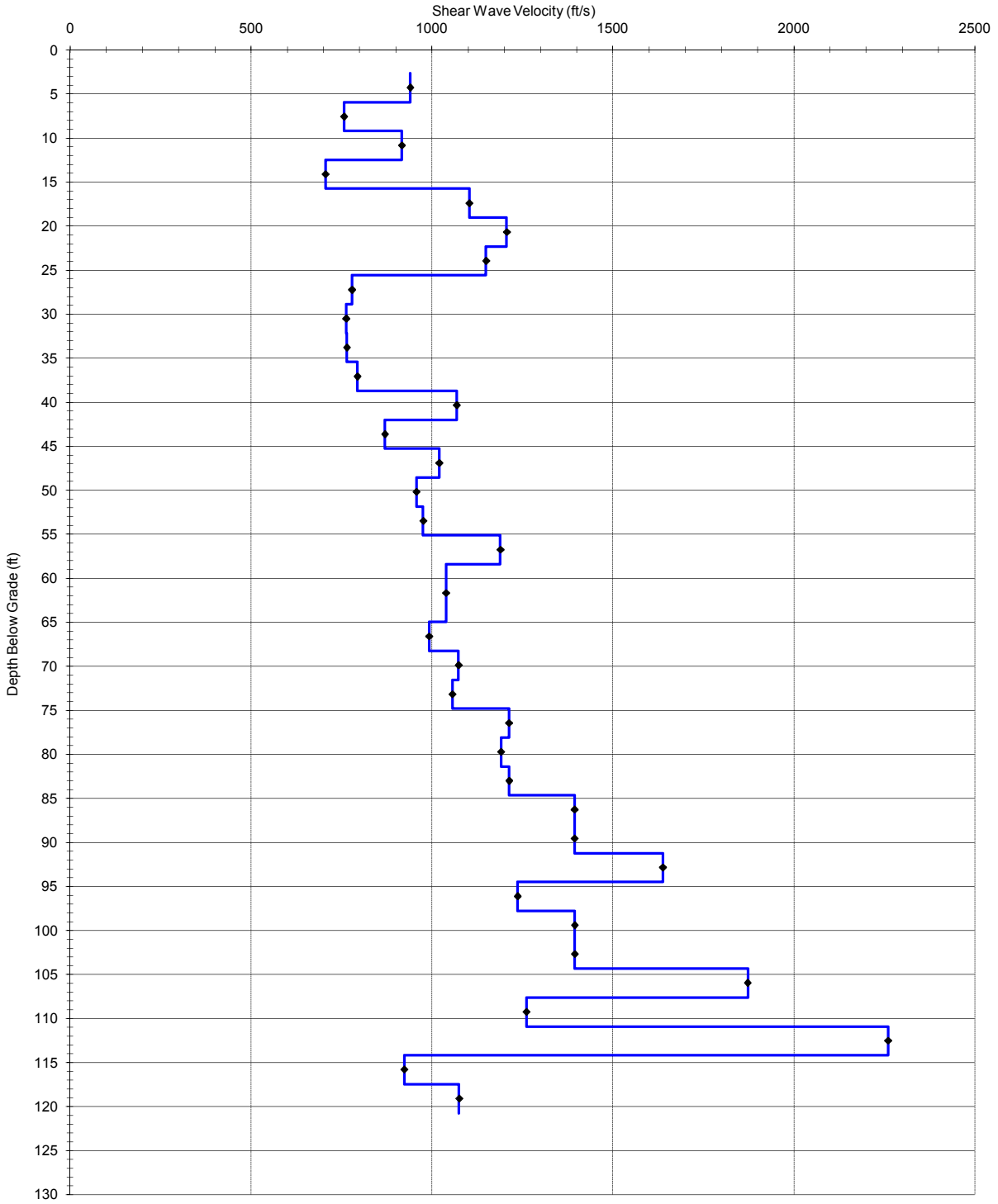


Max Depth: 37.000 m / 121.39 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: Every Point

File: 920CP03.COR
Unit Wt: SBT Chart Soil Zones

SBT: Lunne, Robertson and Powell, 1997
Coords: Lat: 32.92577 Long: -79.82300

Shear Wave Velocity- CPT-3
SC-41 Replacement Bridge
11-920
March 8 2011

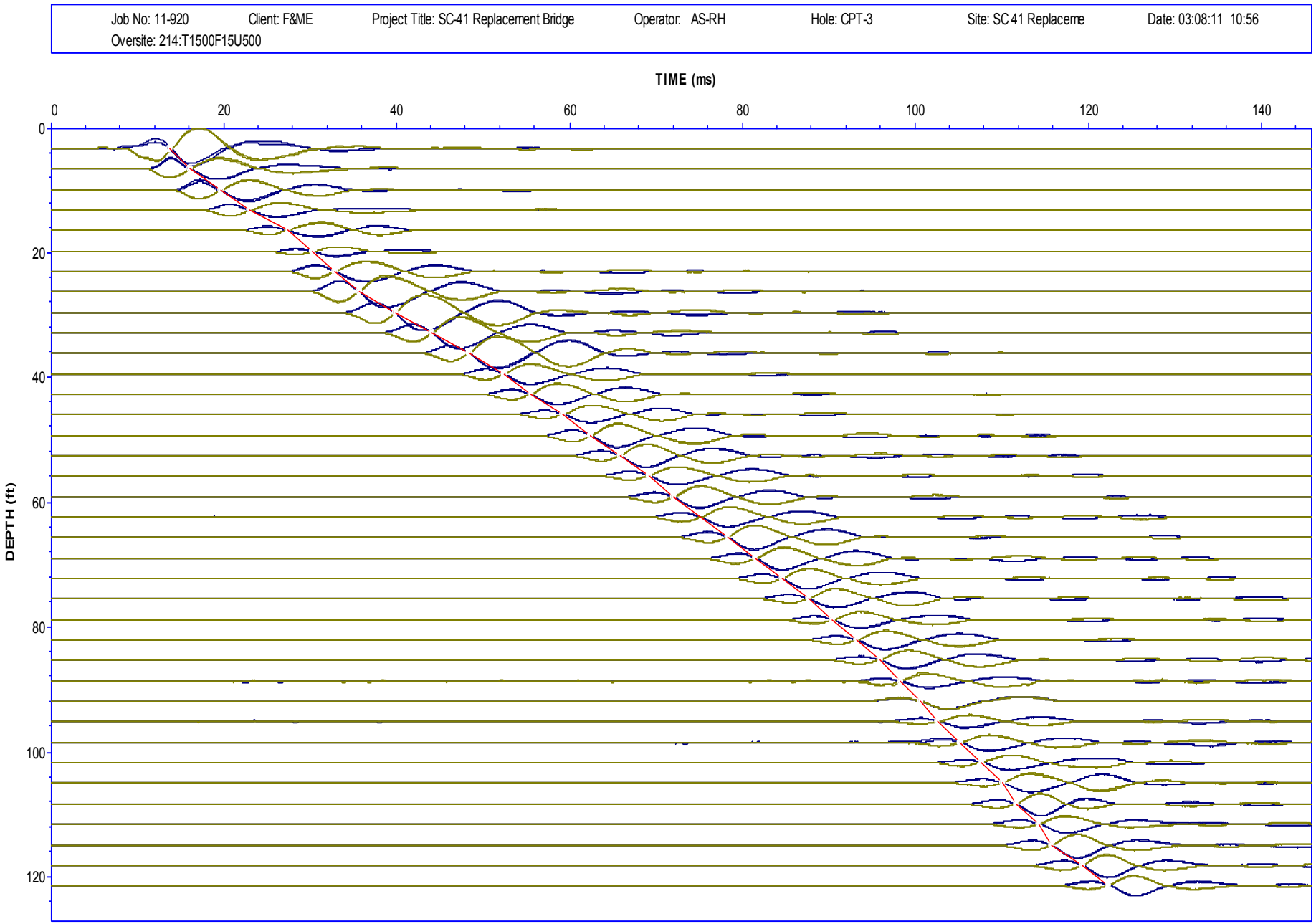


ConeTec Shear Wave Velocity Data Reduction Sheet

Hole: CPT-3
Location: SC-41 Replacement Bridge
Cone: AD214
Date: 8-Mar-11
Source: Beam

Source Depth	0.00 m
Source Offset	1.45 m

Tip Depth (m)	Geophone Depth(m)	Travel Path (m)	Interval time (ms)	Velocity (m/s)	Velocity (ft/s)	Interval Depth (m)	Interval Depth (ft)
0.00							
1.00	0.80	1.66					
2.00	1.80	2.31	2.29	286.5	939.9	1.30	4.27
3.00	2.80	3.15	3.65	230.7	756.8	2.30	7.55
4.00	3.80	4.07	3.27	279.4	916.6	3.30	10.83
5.00	4.80	5.01	4.40	215.0	705.4	4.30	14.11
6.00	5.80	5.98	2.87	336.2	1102.9	5.30	17.39
7.00	6.80	6.95	2.65	367.7	1206.3	6.30	20.67
8.00	7.80	7.93	2.80	350.3	1149.2	7.30	23.95
9.00	8.80	8.92	4.15	237.4	778.7	8.30	27.23
10.00	9.80	9.91	4.25	232.5	762.7	9.30	30.51
11.00	10.80	10.90	4.25	233.0	764.4	10.30	33.79
12.00	11.80	11.89	4.10	241.9	793.7	11.30	37.07
13.00	12.80	12.88	3.05	325.6	1068.3	12.30	40.35
14.00	13.80	13.88	3.75	265.1	869.7	13.30	43.63
15.00	14.80	14.87	3.20	310.9	1020.0	14.30	46.92
16.00	15.80	15.87	3.41	291.6	956.5	15.30	50.20
17.00	16.80	16.86	3.35	297.3	975.4	16.30	53.48
18.00	17.80	17.86	2.75	362.3	1188.8	17.30	56.76
20.00	19.80	19.85	6.30	316.5	1038.4	18.80	61.68
21.00	20.80	20.85	3.30	302.2	991.6	20.30	66.60
22.00	21.80	21.85	3.05	327.1	1073.1	21.30	69.88
23.00	22.80	22.85	3.10	321.9	1056.0	22.30	73.16
24.00	23.80	23.84	2.70	369.6	1212.7	23.30	76.44
25.00	24.80	24.84	2.75	363.0	1190.8	24.30	79.72
26.00	25.80	25.84	2.70	369.7	1213.0	25.30	83.00
27.00	26.80	26.84	2.35	424.9	1393.9	26.30	86.29
28.00	27.80	27.84	2.35	424.9	1394.0	27.30	89.57
29.00	28.80	28.84	2.00	499.3	1638.2	28.30	92.85
30.00	29.80	29.84	2.65	376.9	1236.4	29.30	96.13
31.00	30.80	30.83	2.35	425.0	1394.4	30.30	99.41
32.00	31.80	31.83	2.35	425.0	1394.5	31.30	102.69
33.00	32.80	32.83	1.75	570.8	1872.7	32.30	105.97
34.00	33.80	33.83	2.60	384.2	1260.6	33.30	109.25
35.00	34.80	34.83	1.45	689.0	2260.5	34.30	112.53
36.00	35.80	35.83	3.55	281.4	923.3	35.30	115.81
37.00	36.80	36.83	3.05	327.6	1074.8	36.30	119.09


Job No: 11-920
Client: F&ME
Project Title: SC-41 Replacement Bridge
Operator: AS-RH
Hole: CPT-3
Site: SC 41 Replaceme
Date: 03:08:11 10:56
Oversite: 214:T1500F15U500
TIME (ms)
0
20
40
60
80
100
120
140
DEPTH (ft)
0
20
40
60
80
100
120

Interpretation Methods

CONETEC INTERPRETATION METHODS

A Detailed Description of the Methods Used in ConeTec's CPT Interpretation and Plotting Software

Revision SZW-Rev 02
March 12, 2008

Prepared by Jim Greig

ConeTec Interpretations as of March 12, 2008

ConeTec's interpretation routine provides a tabular output of geotechnical parameters based on current published CPT correlations and is subject to change to reflect the current state of practice. The interpreted values are not considered valid for all soil types. The interpretations are presented only as a guide for geotechnical use and should be carefully scrutinized for consideration in any geotechnical design. Reference to current literature is strongly recommended. ConeTec does not warranty the correctness or the applicability of any of the geotechnical parameters interpreted by the program and does not assume liability for any use of the results in any design or review. Representative hand calculations should be made for any parameter that is critical for design purposes. The end user of the interpreted output should also be fully aware of the techniques and the limitations of any method used in this program. The purpose of this document is to inform the user as to which methods were used and what the appropriate papers and/or publications are for further reference.

The CPT interpretations are based on values of tip, sleeve friction and pore pressure averaged over a user specified interval (e.g. 0.20m). Note that q_t is the tip resistance corrected for pore pressure effects and q_c is the recorded tip resistance. Since all ConeTec cones have equal end area friction sleeves, pore pressure corrections to sleeve friction, f_s, are not required.

The tip correction is: $q_t = q_c + (1-a) \bullet u_2$

where: q_t is the corrected tip resistance
q_c is the recorded tip resistance
u_2 is the recorded dynamic pore pressure behind the tip (u_2 position)
a is the Net Area Ratio for the cone (typically 0.80 for ConeTec cones)

The total stress calculations are based on soil unit weights that have been assigned to the Soil Behavior Type zones, from a user defined unit weight profile or by using a single value throughout the profile. Effective vertical overburden stresses are calculated based on a hydrostatic distribution of equilibrium pore pressures below the water table or from a user defined equilibrium pore pressure profile (this can be obtained from CPT dissipation tests). For over water projects the effects of the column of water have been taken into account as has the appropriate unit weight of water. How this is done depends on where the instruments were zeroed (i.e. on deck or at mud line).

Details regarding the interpretation methods for all of the interpreted parameters are provided in Table 1. The appropriate references cited in Table 1 are listed in Table 2. Where methods are based on charts or techniques that are too complex to describe in this summary the user should refer to the cited material.

The estimated Soil Behavior Types (normalized and non-normalized) are based on the charts developed by Robertson and Campanella shown in Figures 1 and 2. The Bq classification charts are not reproduced in this document but can be reviewed in Lunne, Robertson and Powell (1997) or Robertson (1990).

Where the results of a calculation/interpretation are declared *'invalid'* the value will be represented by the text strings "-9999" or "-9999.0". In some cases the value 0 will be used. Invalid results will occur because of (and not limited to) one or a combination of:

1. Invalid or undefined CPT data (e.g. drilled out section or data gap).

2. Where the interpretation method is inappropriate, for example, drained parameters in an undrained material (and vice versa).

3. Where interpretation input values are beyond the range of the referenced charts or specified limitations of the interpretation method.

4. Where pre-requisite or intermediate interpretation calculations are invalid.

The parameters selected for output from the program are often specific to a particular project. As such, not all of the interpreted parameters listed in Table 1 may be included in the output files delivered with this report.

The output files are provided in Microsoft Excel XLS format. The ConeTec software has several options for output depending on the number or types of interpreted parameters desired. Each output file will be named using the original COR file basename followed by a three or four letter indicator of the interpretation set selected (e.g. BSC, TBL, NLI or IFI) and possibly followed by an operator selected suffix identifying the characteristics of the particular interpretation run.

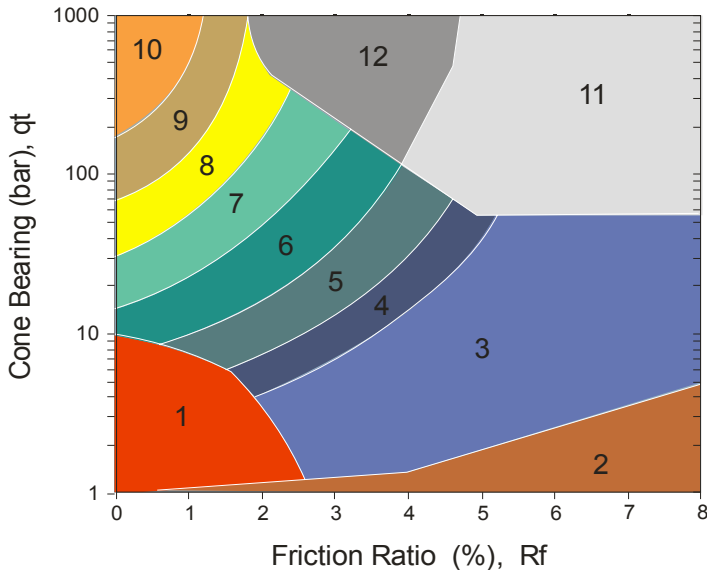
Table 1
CPT Interpretation Methods

Interpreted Parameter	Description	Equation	Ref
Depth	Mid Layer Depth *(where interpretations are done at each point then Mid Layer Depth = Recorded Depth)*	*Depth (Layer Top) + Depth (Layer Bottom) / 2.0*	
Elevation	Elevation of Mid Layer based on sounding collar elevation supplied by client	Elevation = Collar Elevation - Depth	
Avgqc	Averaged recorded tip value (q_c)	$Avgqc = \frac{1}{n}\sum_{i=1}^{n} q_c$ *n=1 when interpretations are done at each point*	
Avgqt	Averaged corrected tip (q_t) where: $q_t = q_c + (1-a) \bullet u$	$Avgqt = \frac{1}{n}\sum_{i=1}^{n} q_t$ *n=1 when interpretations are done at each point*	
Avgfs	Averaged sleeve friction (f_s)	$Avgfs = \frac{1}{n}\sum_{i=1}^{n} fs$ *n=1 when interpretations are done at each point*	
AvgRf	Averaged friction ratio (Rf) where friction ratio is defined as: $Rf = 100\% \bullet \frac{fs}{qt}$	$AvgRf = 100\% \bullet \frac{Avgfs}{Avgqt}$ *n=1 when interpretations are done at each point*	
Avgu	Averaged dynamic pore pressure *(u)*	$Avgu = \frac{1}{n}\sum_{i=1}^{n} u_i$ *n=1 when interpretations are done at each point*	
AvgRes	Averaged Resistivity (this data is not always available since it is a specialized test requiring an additional module)	$Avgu = \frac{1}{n}\sum_{i=1}^{n} RESISTIVITY_i$ *n=1 when interpretations are done at each point*	
AvgUVIF	Averaged UVIF ultra-violet induced fluorescence (this data is not always available since it is a specialized test requiring an additional module)	$Avgu = \frac{1}{n}\sum_{i=1}^{n} UVIF_i$ *n=1 when interpretations are done at each point*	
AvgTemp	Averaged Temperature (this data is not always available since it is a specialized test)	$Avgu = \frac{1}{n}\sum_{i=1}^{n} TEMPERATURE_i$ *n=1 when interpretations are done at each point*	
AvgGamma	Averaged Gamma Counts (this data is not always available since it is a specialized test requiring an additional module)	$Avgu = \frac{1}{n}\sum_{i=1}^{n} GAMMA_i$ *n=1 when interpretations are done at each point*	
SBT	Soil Behavior Type as defined by Robertson and Campanella	See Figure 1	2, 5

Interpreted Parameter	Description	Equation	Ref
U.Wt.	Unit Weight of soil determined from one of the following user selectable options: 1) uniform value 2) value assigned to each SBT zone 3) user supplied unit weight profile	See references	5
T. Stress σ_v	Total vertical overburden stress at Mid Layer Depth. *A layer is defined as the averaging interval specified by the user. For data interpreted at each point the Mid Layer Depth is the same as the recorded depth.*	$TStress = \sum_{i=1}^{n} \gamma_i h_i$ *where* γ_i is layer unit weight h_i is layer thickness	
E. Stress σ_v'	Effective vertical overburden stress at Mid Layer Depth	$Estress = Tstress - u_{eq}$	
Ueq	Equilibrium pore pressure determined from one of the following user selectable options: 1) hydrostatic from water table depth 2) user supplied profile	For hydrostatic option: $u_{eq} = \gamma_w \bullet (D - D_{wt})$ where u_{eq} is equilibrium pore pressure γ_w is unit weight of water D is the current depth D_{wt} is the depth to the water table	
Cn	SPT N_{60} overburden correction factor	$Cn=(\sigma_v')^{-0.5}$ where σ_v' *is in tsf* $0.5 < C_n < 2.0$	
N_{60}	SPT N value at 60% energy calculated from qt/N ratios assigned to each SBT zone. This method has abrupt N value changes at zone boundaries.	*See Figure 1*	4, 5
$(N_1)_{60}$	SPT N_{60} value corrected for overburden pressure	$(N_1)_{60} = Cn \bullet N_{60}$	4
$N_{60}I_c$	SPT N_{60} values based on the Ic parameter	(qt/pa)/ N_{60} = 8.5 (1 – Ic/4.6)	5
$(N_1)_{60}Ic$	SPT N_{60} value corrected for overburden pressure (using N_{60} $I_{c)}$. User has 2 options.	1) $(N_1)_{60}Ic = Cn \bullet (N_{60} Ic)$ 2) $q_{c1n}/ (N_1)_{60}Ic$ = 8.5 (1 – Ic/4.6)	4 5
$(N_1)_{60cs}Ic$	Clean sand equivalent SPT $(N_1)_{60}Ic$. User has 3 options.	1) $(N_1)_{60cs}Ic = \alpha + \beta((N_1)_{60}Ic)$ 2) $(N_1)_{60cs}Ic = K_{SPT} * ((N_1)_{60}Ic)$ 3) $q_{c1ncs}/ (N_1)_{60cs}Ic$ = 8.5 (1 – Ic/4.6) FC ≤ 5%: α = 0, β=1.0 FC ≥ 35% α = 5.0, β=1.2 5% < FC < 35% α = exp[1.76 – (190/FC^2)] β = [0.99 + ($FC^{1.5}$/1000)]	10 10 5
Su	Undrained shear strength - N_{kt} is user selectable	$Su = \frac{qt - \sigma_v}{N_{kt}}$	1, 5
k	Coefficient of permeability (assigned to each SBT zone)		5
Bq	Pore pressure parameter	$Bq = \frac{\Delta u}{qt - \sigma_v}$ *where:* $\Delta u = u - u_{eq}$ *and u = dynamic pore pressure* *u_{eq} = equilibrium pore pressure*	1, 5
Q_t	Normalized q_t for Soil Behavior Type classification as defined by Robertson, 1990	$Qt = \frac{qt - \sigma_v}{\sigma_v'}$	2, 5

Interpreted Parameter	Description	Equation	Ref
F_r	Normalized Friction Ratio for Soil Behavior Type classification as defined by Robertson, 1990	$Fr = 100\% \bullet \frac{fs}{qt - \sigma_v}$	2, 5
SBTn	Normalized Soil Behavior Type as defined by Robertson and Campanella	See Figure 2	2, 5
SBT-BQ	Non-normalized soil behavior type based on the Bq parameter	See Figure 5.7 (reference 5)	2, 5
SBT-BQn	Normalized Soil Behavior base on the Bq parameter	See Figure 5.8 (reference 5) or Figure 3 (reference 2)	2, 5
I_c	Soil index for estimating grain characteristics	$Ic = [(3.47 - log_{10}Q)^2 + (log_{10} Fr + 1.22)^2]^{0.5}$ *Where:* $Q = \left(\frac{qt - \sigma_v}{P_{a2}}\right)\left(\frac{P_a}{\sigma_v'}\right)^n$ *And* *Fr is in percent* *P_a = atmospheric pressure* *P_{a2} = atmospheric pressure* *n varies from 0.5 to 1.0 and is selected in an iterative manner based on the resulting I_c*	3, 8
FC	Apparent fines content (%)	*$FC=1.75(Ic^{3.25}) - 3.7$* *FC=100 for Ic > 3.5* *FC=0 for Ic < 1.26* *FC = 5% if 1.64 < Ic < 2.6 AND F_r<0.5*	3
Ic Zone	This parameter is the Soil Behavior Type zone based on the Ic parameter (valid for zones 2 through 7 on SBTn chart)	Ic < 1.31 Zone = 7 1.31 < Ic < 2.05 Zone = 6 2.05 < Ic < 2.60 Zone = 5 2.60 < Ic < 2.95 Zone = 4 2.95 < Ic < 3.60 Zone = 3 Ic > 3.60 Zone = 2	3
PHI ϕ	Friction Angle determined from one of the following user selectable options: a) Campanella and Robertson b) Durgunoglu and Mitchel c) Janbu d) Kulhawy and Mayne	See reference	5 5 5 11
Dr	Relative Density determined from one of the following user selectable options: a) Ticino Sand b) Hokksund Sand c) Schmertmann 1976 d) Jamiolkowski - All Sands	See reference	5
OCR	Over Consolidation Ratio	a) Based on Schmertmann's method involving a plot of $S_u/\sigma_v' / (S_u/\sigma_v')_{NC}$ and OCR where the Su/p' ratio for NC clay is user selectable	9
State Parameter	The state parameter is used to describe whether a soil is contractive (SP is positive) or dilative (SP is negative) at large strains based on the work by Been and Jefferies	See reference	8, 6, 5
Es/qt	Intermediate parameter for calculating Young's Modulus, E, in sands. It is the Y axis of the reference chart.	Based on Figure 5.59 in the reference	5

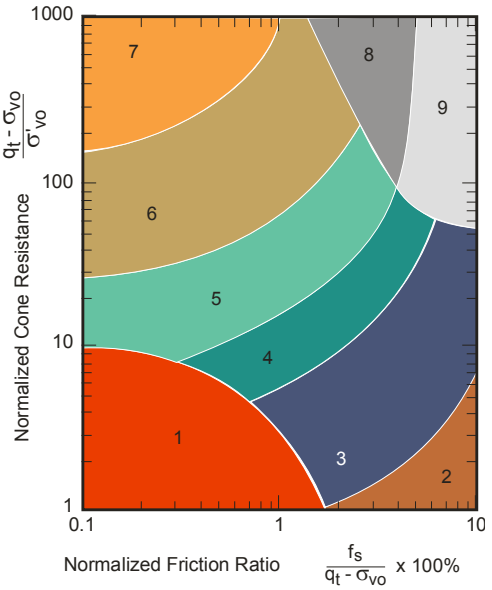
Interpreted Parameter	Description	Equation	Ref
Young's Modulus E	Young's Modulus based on the work done in Italy. There are three types of sands considered in this technique. The user selects the appropriate type for the site from: a) OC Sands b) Aged NC Sands c) Recent NC Sands Each sand type has a family of curves that depend on mean normal stress. The program calculates mean normal stress and linearly interpolates between the two extremes provided in the Es/qt chart.	Mean normal stress is evaluated from: $\sigma'_m = \frac{1}{3} \bullet (\sigma'_v + \sigma'_h + \sigma'_h)^3$ where σ_v'= vertical effective stress σ_h'= horizontal effective stress and $\sigma_h = K_o * \sigma_v'$ with Ko assumed to be 0.5	5
q_{c1}	q_t normalized for overburden stress used for seismic analysis	$q_{c1} = q_t \bullet (Pa/\sigma_v')^{0.5}$ where: Pa = atm. Pressure q_t is in Mpa	3
q_{c1n}	q_{c1} in dimensionless form used for seismic analysis	$q_{c1n} = (q_{c1} / Pa)(Pa/\sigma_v')$ where: Pa = atm. Pressure and n ranges from 0.5 to 0.75 based on Ic.	3
K_{SPT}	Equivalent clean sand factor for $(N_1)60$	$K_{SPT} = 1 + ((0.75/30) * (FC - 5))$	10
K_{CPT}	Equivalent clean sand correction for q_{c1N}	$K_{cpt} = 1.0$ for $I_c \leq 1.64$ $K_{cpt} = f(I_c)$ for $I_c > 1.64$ (see reference)	10
q_{c1ncs}	Clean sand equivalent q_{c1n}	$q_{c1ncs} = q_{c1n} \bullet K_{cpt}$	3
CRR	Cyclic Resistance Ratio (for Magnitude 7.5)	$q_{c1ncs} < 50$: $CRR_{7.5} = 0.833 [(q_{c1ncs}/1000] + 0.05$ $50 \leq q_{c1ncs} < 160$: $CRR_{7.5} = 93 [(q_{c1ncs}/1000]^3 + 0.08$	10
CSR	Cyclic Stress Ratio	$CSR = (\tau_{av}/\sigma_v') = 0.65 (a_{max} / g) (\sigma_v / \sigma_v') r_d$ $r_d = 1.0 - 0.00765 z$ $z \leq 9.15$m $r_d = 1.174 - 0.0267 z$ $9.15 < z \leq 23$m $r_d = 0.744 - 0.008 z$ $23 < z \leq 30$m $r_d = 0.50$ $z > 30$m	10
MSF	Magnitude Scaling Factor	See Reference	10
FofS	Factor of Safety against Liquefaction	$FS = (CRR_{7.5} / CSR) MSF$	10
Liquefaction Status	Statement indicating possible liquefaction	Takes into account FofS and limitations based I_c and q_{c1ncs}.	10



Zone	qt / N	Soil Behavior Type
1	2	sensitive fine grained
2	1	organic material
3	1	clay
4	1.5	silty clay to clay
5	2	clayey silt to silty clay
6	2.5	sandy silt to clayey silt
7	3	silty sand to sandy silt
8	4	sand to silty sand
9	5	sand
10	6	gravelly sand to sand
11	1	very stiff fine grained *
12	2	sand to clayey sand *

* overconsolidated or cemented

Figure 1 Non-Normalized Behavior Type Classification Chart



Zone	Normalized Soil Behavior Type
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 sands to silty sands
7	gravelly sand to sand
8	very stiff sand to clayey sand
9	very stiff fine grained

Figure 2 Normalized Behavior Type Classification Chart

Table 2 References

No.	References
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10	Proceedings of theNCEER Workshop on Evaluation of Liquefaction Resistance of Soils, Salt LakeCity, 1996. Chaired by Leslie Youd. 11
11	Kulhawy, F.H. and Mayne, P.W. ,1990, Manual on Estimating Soil Properties for Foundation Design, *Report No. EL-6800*, Electric Power Research Institute, Palo Alto, CA, August 1990, 306 p.