Frequent-Interval Seismic CPTu

D. Bruce Nothdurft, MSCE, PE, PG

SRS Geotechnical Engineering Department

Savannah River Nuclear Solutions

Alec V. McGillivray, PhD, PE

Geotechnical Consultant

Brent J. Gutierrez, PhD, PE

*NPH Engineering Manager, **DOE-SR***

Motivation

- The seismic piezocone penetration test (SCPTu) utilized at SRS because it provides rapid and thorough site characterization.
- **Evaluation of non-linear soil behavior…**
  - detailed stratigraphy
  - small-strain velocity measurements
  - large-strain non-seismic measurements
- **Depth scale disparity**
  - large-strain non-seismic measurements nearly continuous with depth
  - small-strain velocity measurements over 1 m depth intervals.

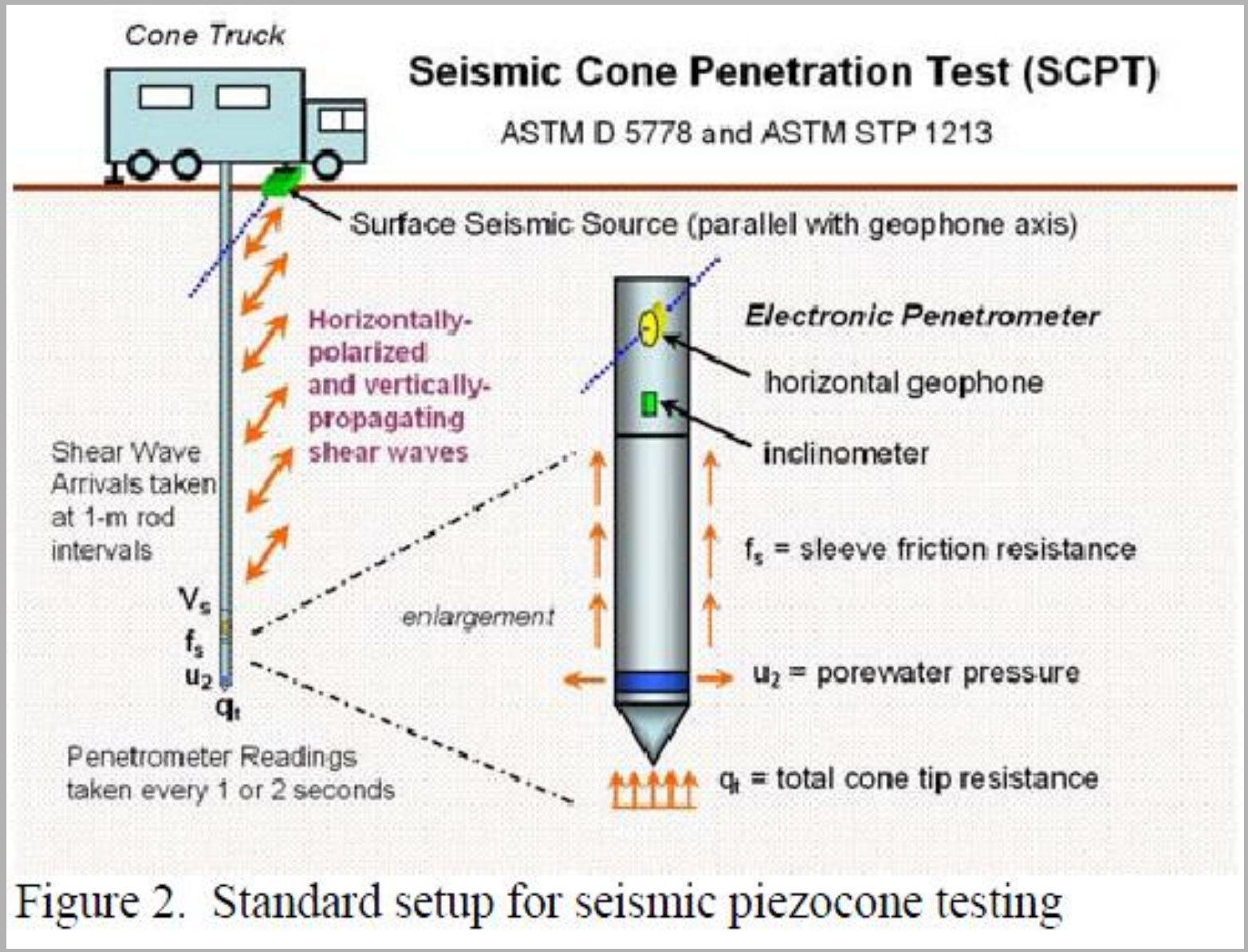


Figure 2. Standard setup for seismic piezocone testing

Mayne & McGillivray, 2000

Introduction

Frequent-Interval vs Standard-Interval Seismic CPTu

- Interval is distance between subjacent receiver depths
- It is the distance D over which the shear wave velocity is measured
  - 1 meter for traditional SCPTu
  - 0.2 meter for Frequent-Interval

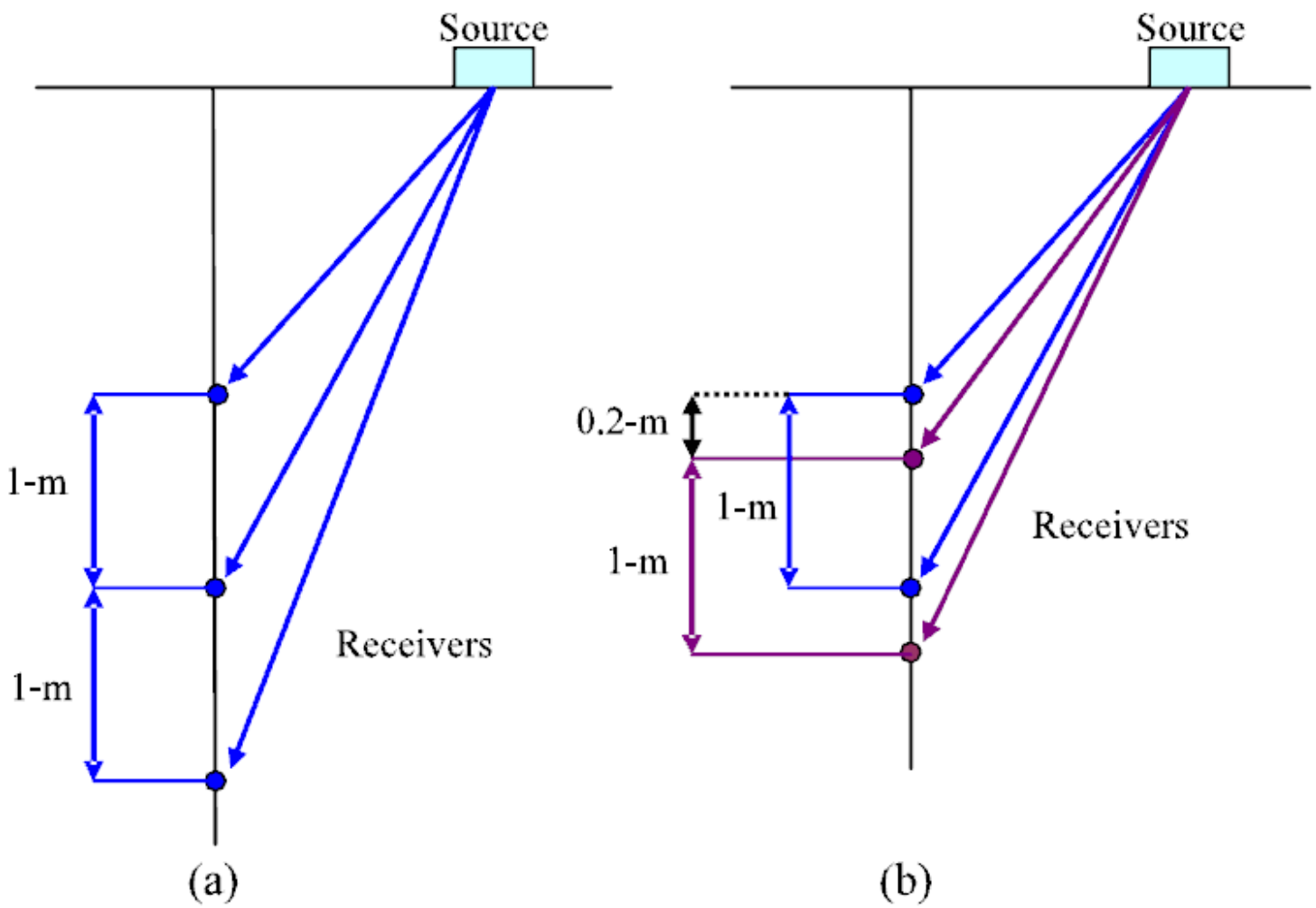


Figure 3.3 Schematic of (a) traditional interval-measurements made end-to-end and (b) frequent-interval with overlapping measurements

Comparison

Frequent-Interval vs Standard-Interval Seismic CPTu

- True Interval vs Pseudo Interval
- Traditional SCPT is Pseudo Interval
- Frequent-Interval SCPT is True Interval
- Cross-over vs Cross-Correlation

Comparison

Frequent-Interval vs Standard-Interval Seismic CPTu

- Traditional SCPT is Pseudo Interval
  - Every 1-meter rod addition
  - Δ is not between two phone locations; it is from where phones are now to where they were before
  - Different conditions – less accurate
  - Cross-over points on opposite-strike shear waves are picked – less accurate
  - Coarse shear wave velocity profile

Comparison

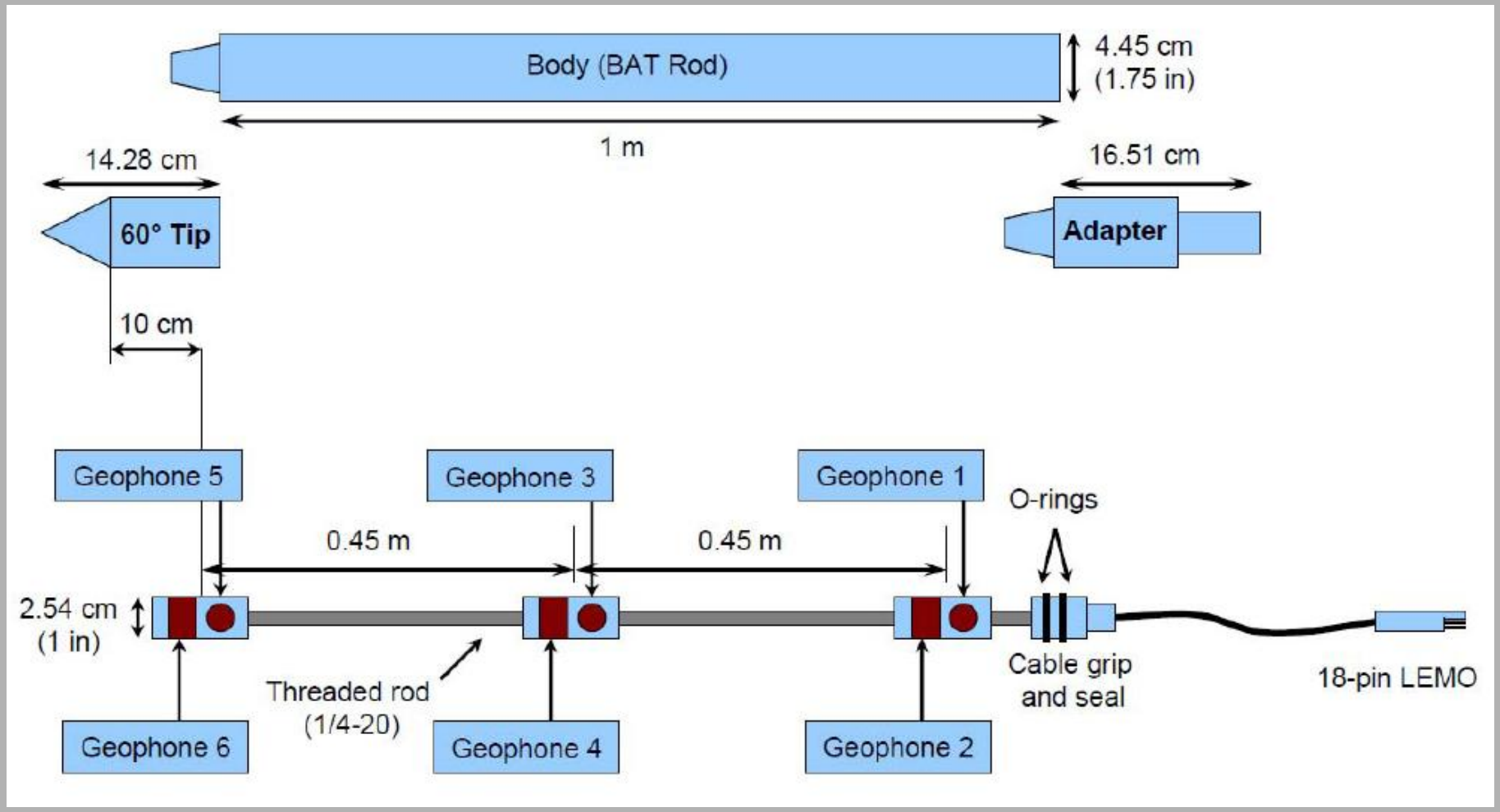
Frequent-Interval vs Standard-Interval Seismic CPTu

- Frequent-Interval SCPTu is True Interval
  - 3 sets of geophones in probe
  - Δ is between three phone locations; it is from one set of phones to next set of phones – accurate!
- Overlapping True-interval measurements
- Cross-correlation is signal processing technique that compares waves for similarity
- Finer shear wave velocity profile

The McGillivray Frequent-Interval Seismic Probe

3 orthogonal sets of geophones
spaced at 0.45 meters

Biaxial true-interval seismic probe with pairs of horizontal orthogonal geophones at three set elevations


Body (BAT Rod)
4.45 cm
(1.75 in)
1 m
14.28 cm
16.51 cm
60° Tip
Adapter
10 cm
Geophone 5
Geophone 3
Geophone 1
O-rings
0.45 m
0.45 m
2.54 cm
(1 in)
Threaded rod
(1/4-20)
Cable grip
and seal
18-pin LEMO
Geophone 6
Geophone 4
Geophone 2

Example Profiles

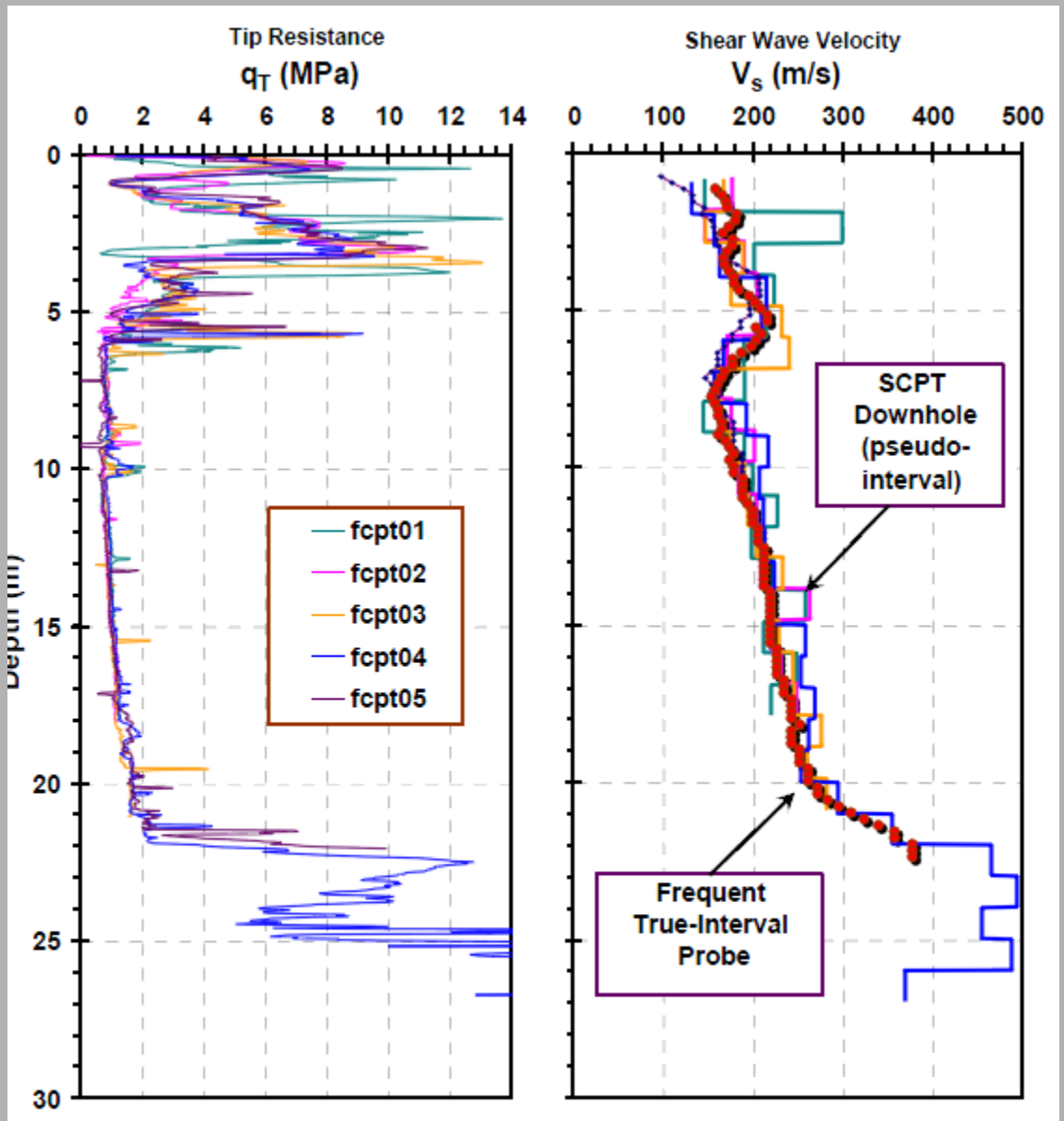


Figure 10. Comparison of frequent-interval Vs data with standard 1-m interval data from 5 SCPTu soundings at the Ford Design Center site, Illinois.

Mayne & McGillivray, 2000

Example Profiles

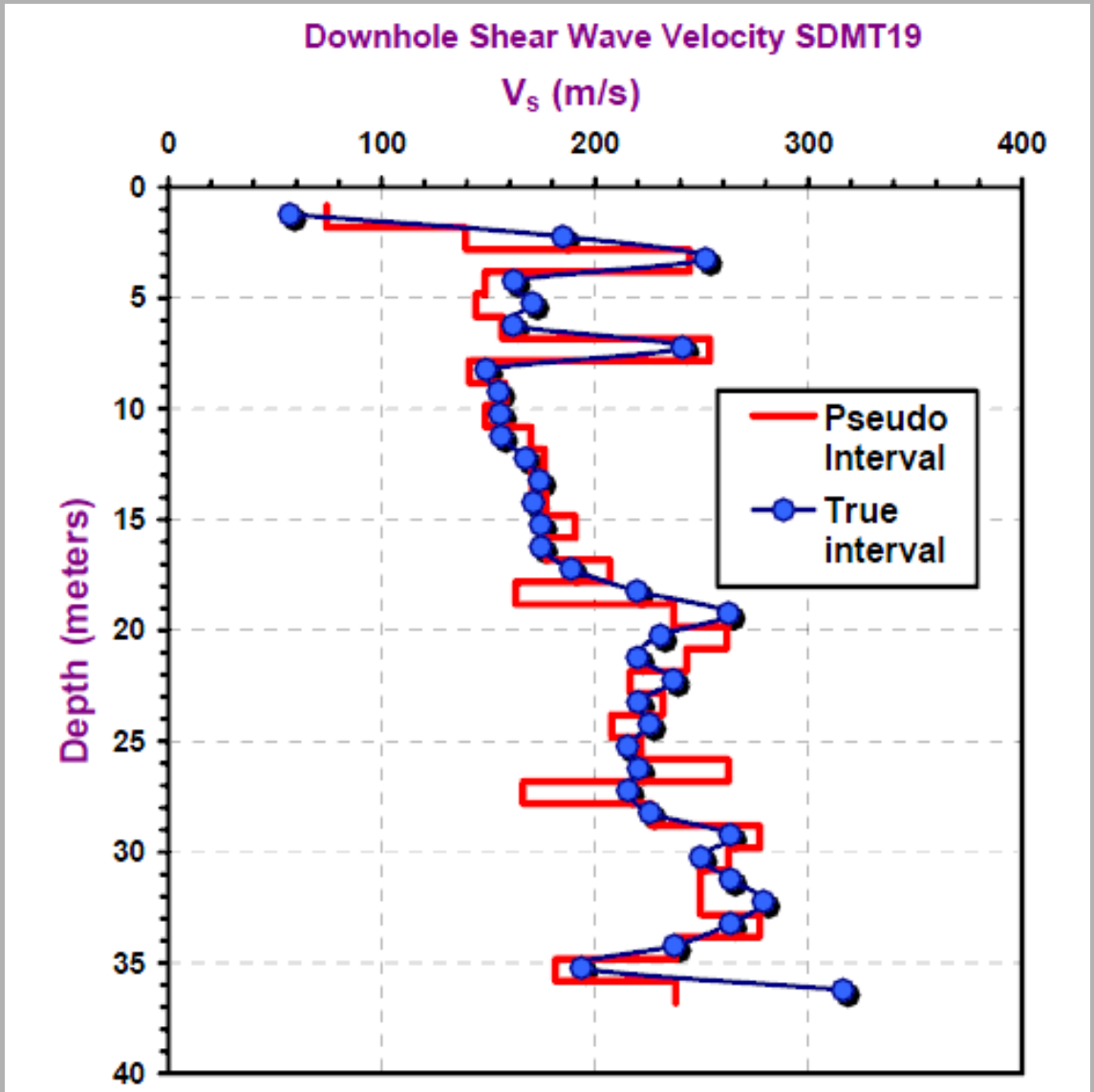


Figure 5. Comparison of true- and pseudo-interval V_s.

Mayne & McGillivray, 2004

Example Profiles

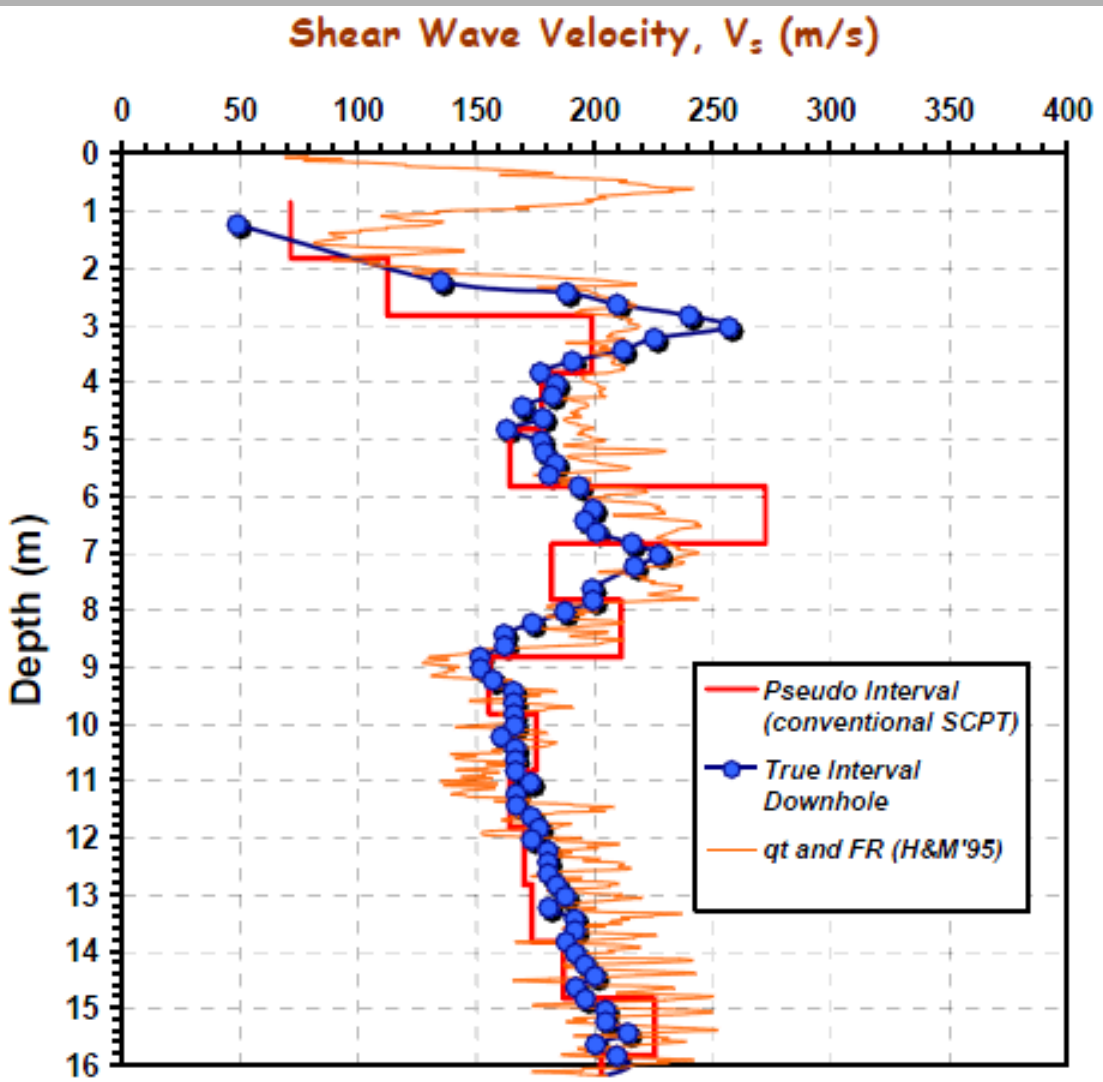
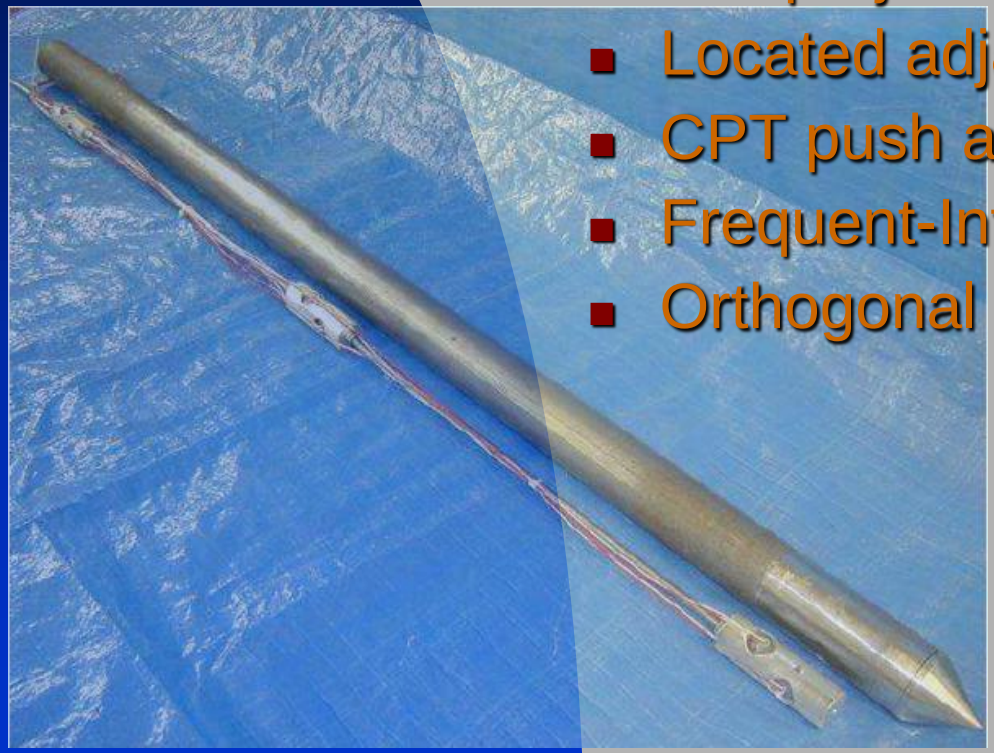


Figure 7. Frequent true-interval, coarse pseudo-interval, and empirically-estimated V_s at location 14.

Mayne & McGillivray, 2004

SRS Field Trial of Frequent Interval Probe

- Previously only tested to 30 meters
- Our project needed 50 meters
- Located adjacent to standard SCPTu
- CPT push advanced first
- Frequent-Interval Seismic Probe push
- Orthogonal seismic sources



Sledge hammer source

Auto-seis source

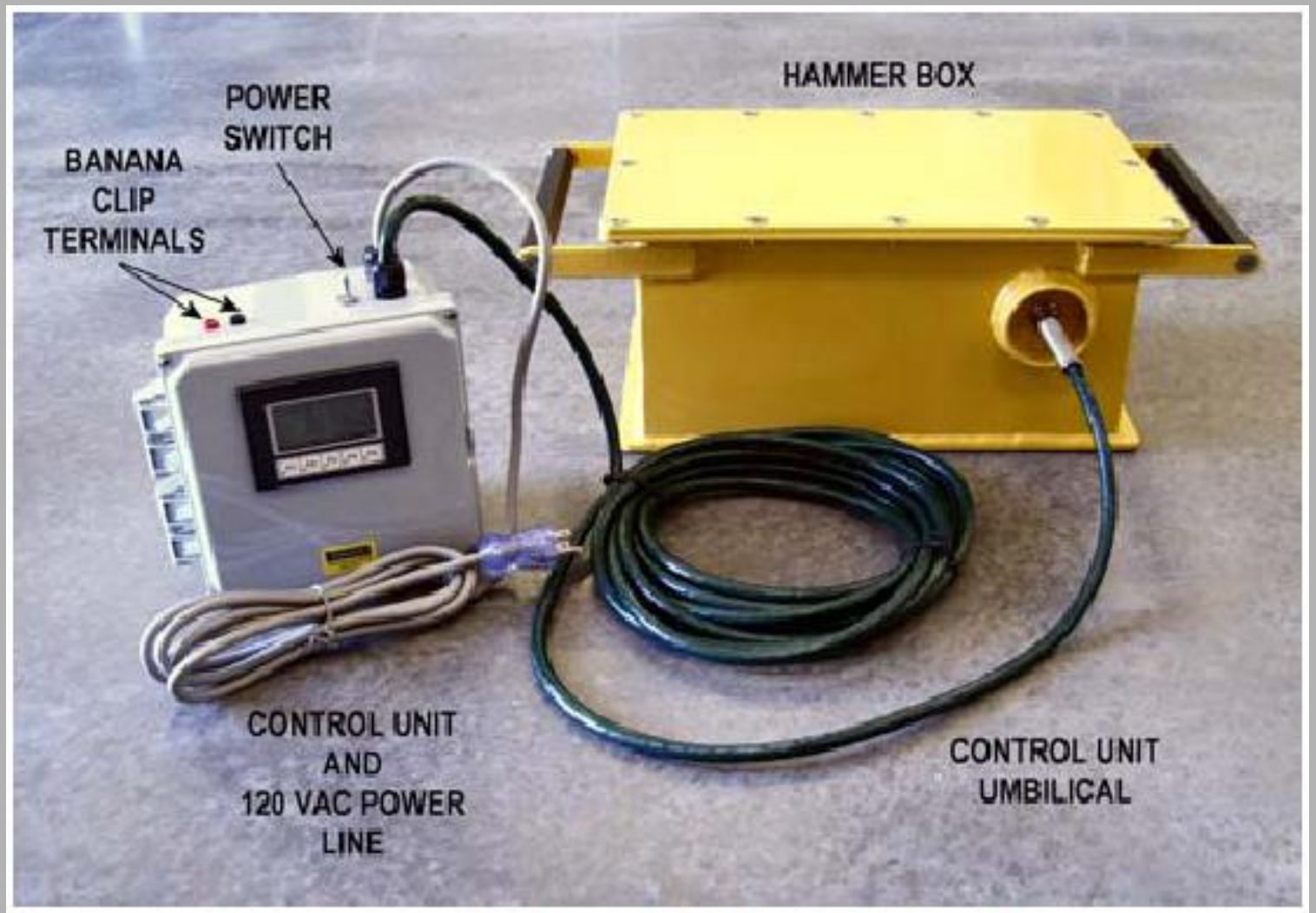
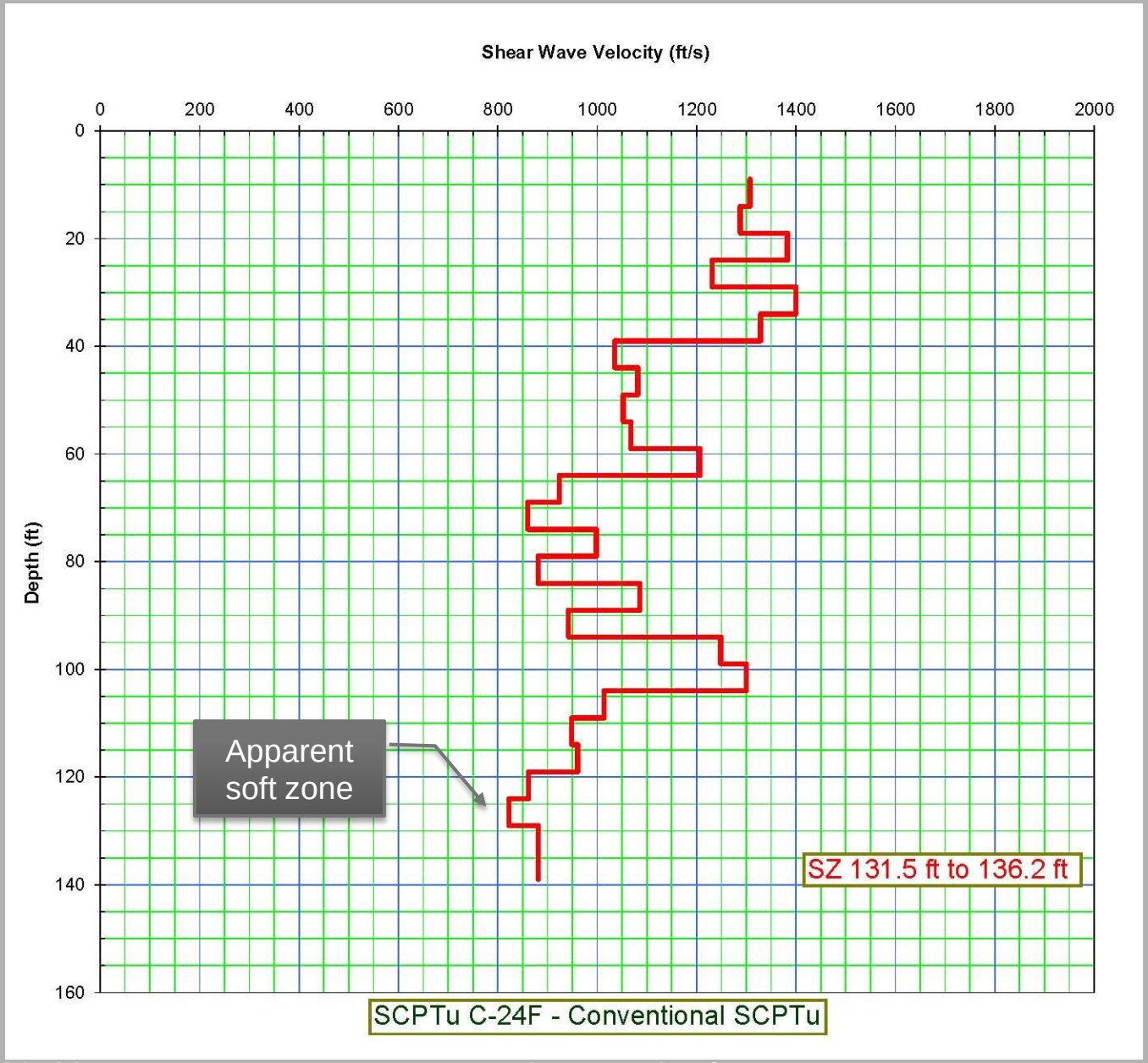
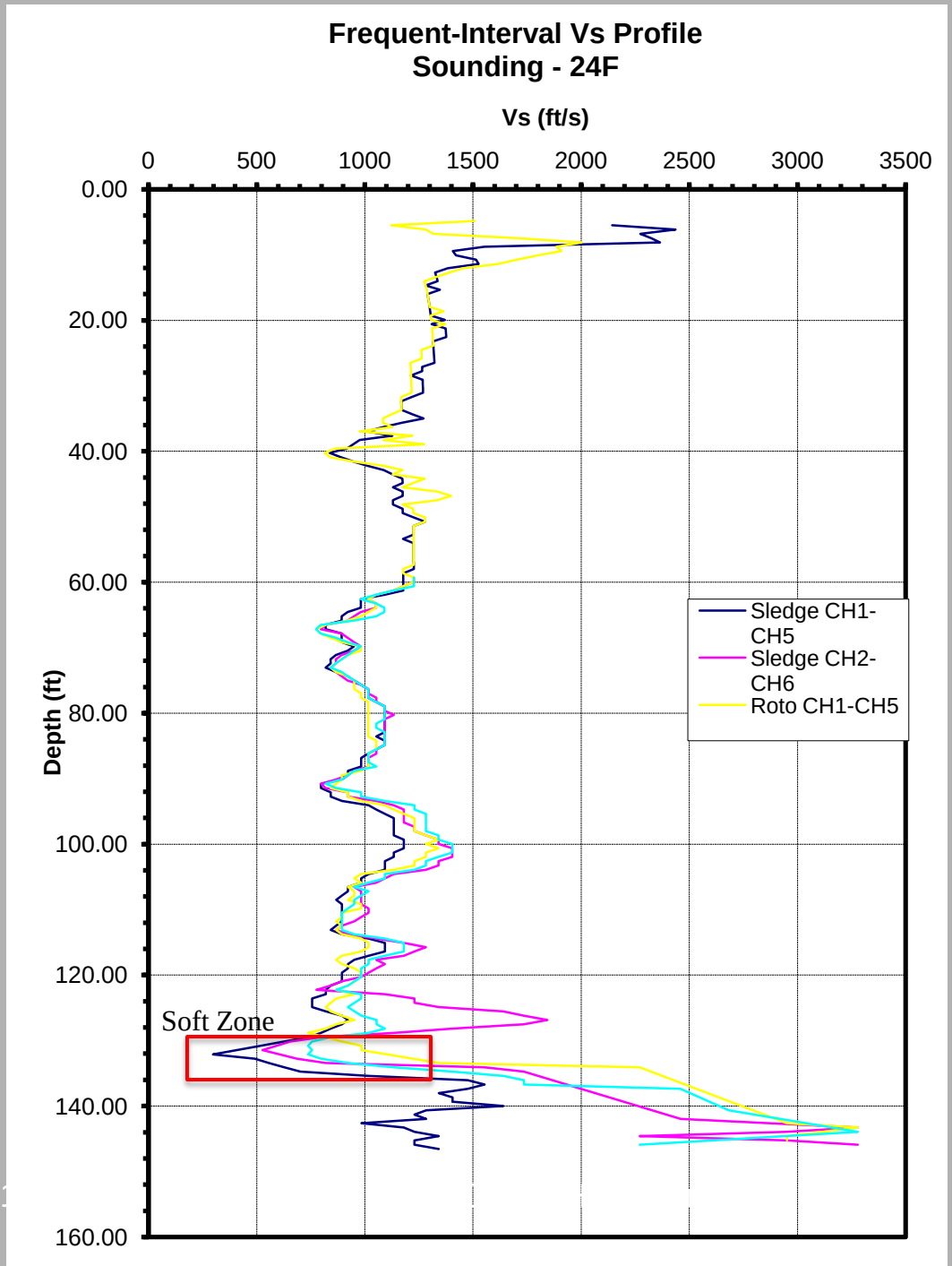
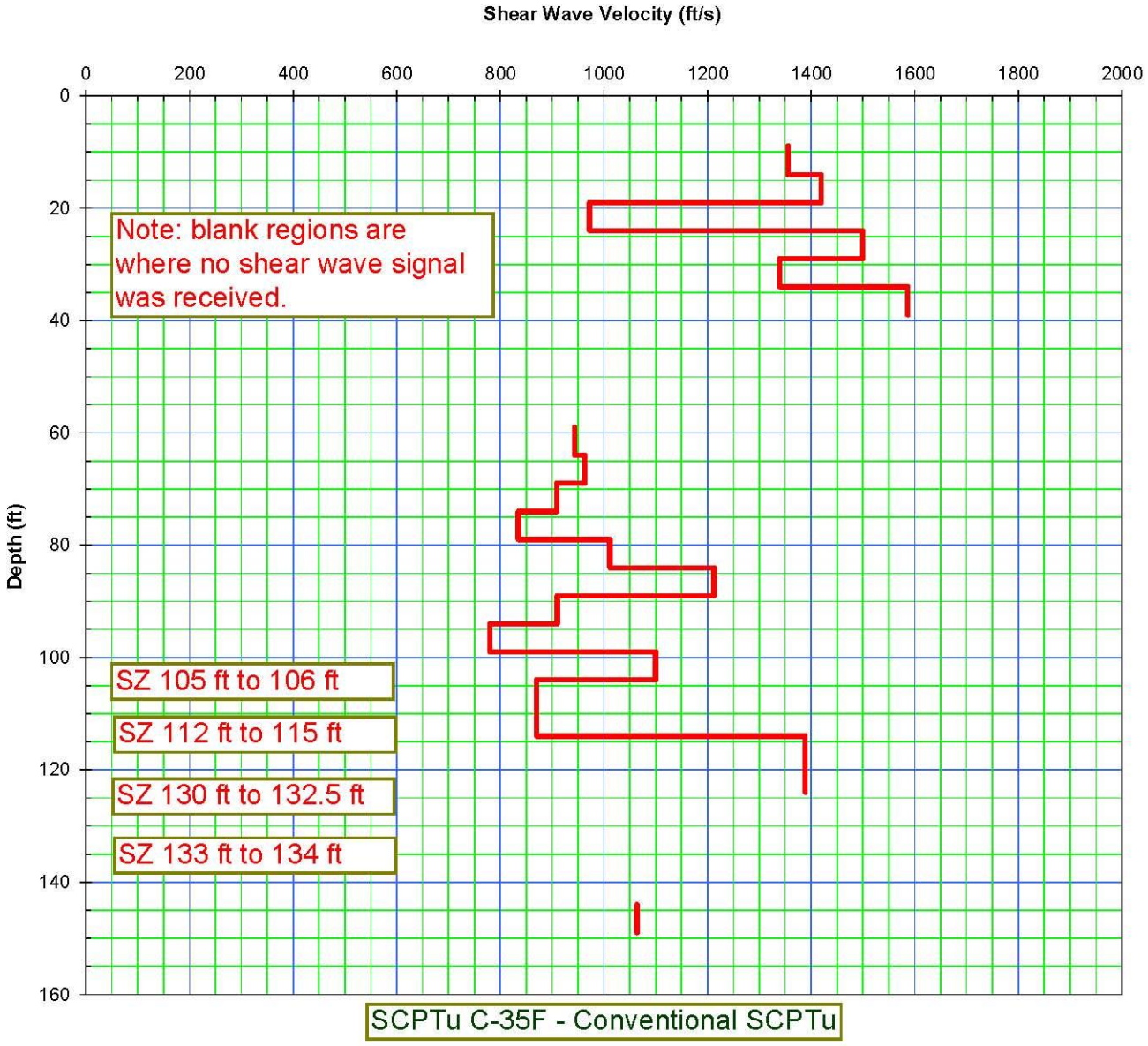


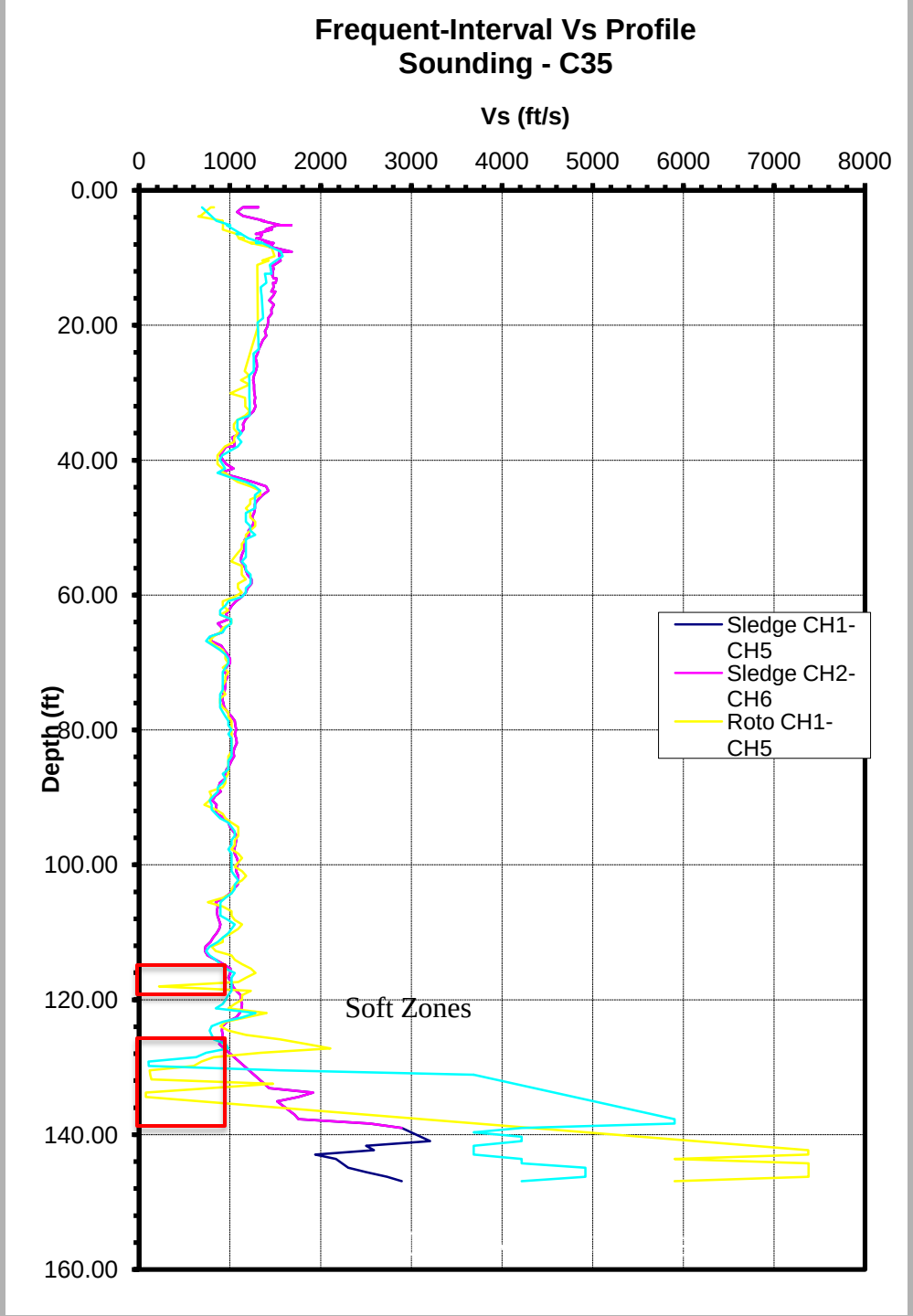
Figure 8. Commercial autoseis unit with control box.

Mayne & McGillivray, 2000


Shear Wave Velocity (ft/s)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Depth (ft)
0
20
40
60
80
100
120
140
160
Apparent soft zone
SZ 131.5 ft to 136.2 ft
SCPTu C-24F - Conventional SCPTu


Frequent-Interval Vs Profile
Sounding - 24F
Vs (ft/s)
0
500
1000
1500
2000
2500
3000
3500
Depth (ft)
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
Sledge CH1-CH5
Sledge CH2-CH6
Roto CH1-CH5
Soft Zone

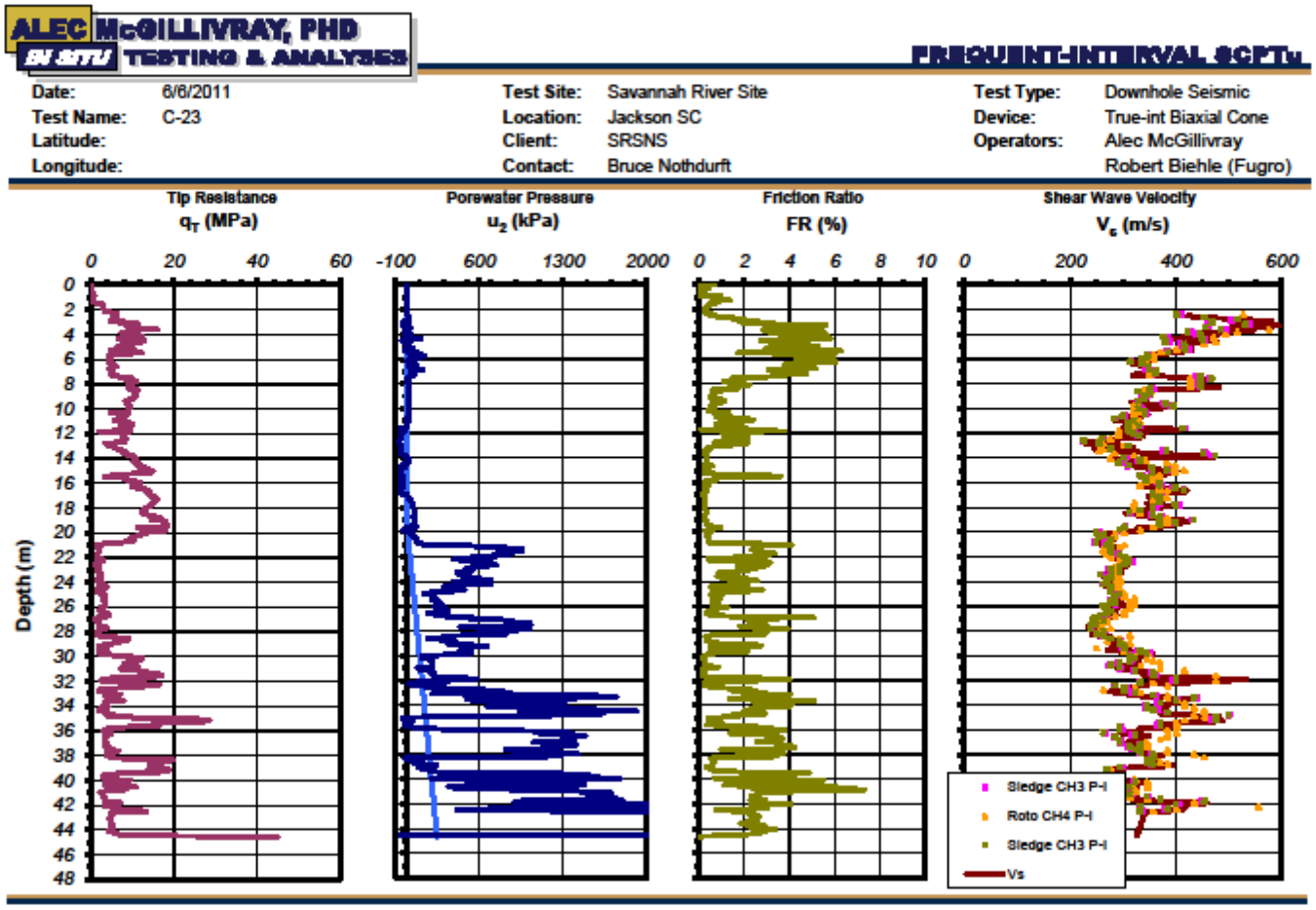

Shear Wave Velocity (ft/s)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Depth (ft)
0
20
40
60
80
100
120
140
160
Note: blank regions are where no shear wave signal was received.
SZ 105 ft to 106 ft
SZ 112 ft to 115 ft
SZ 130 ft to 132.5 ft
SZ 133 ft to 134 ft
SCPTu C-35F - Conventional SCPTu

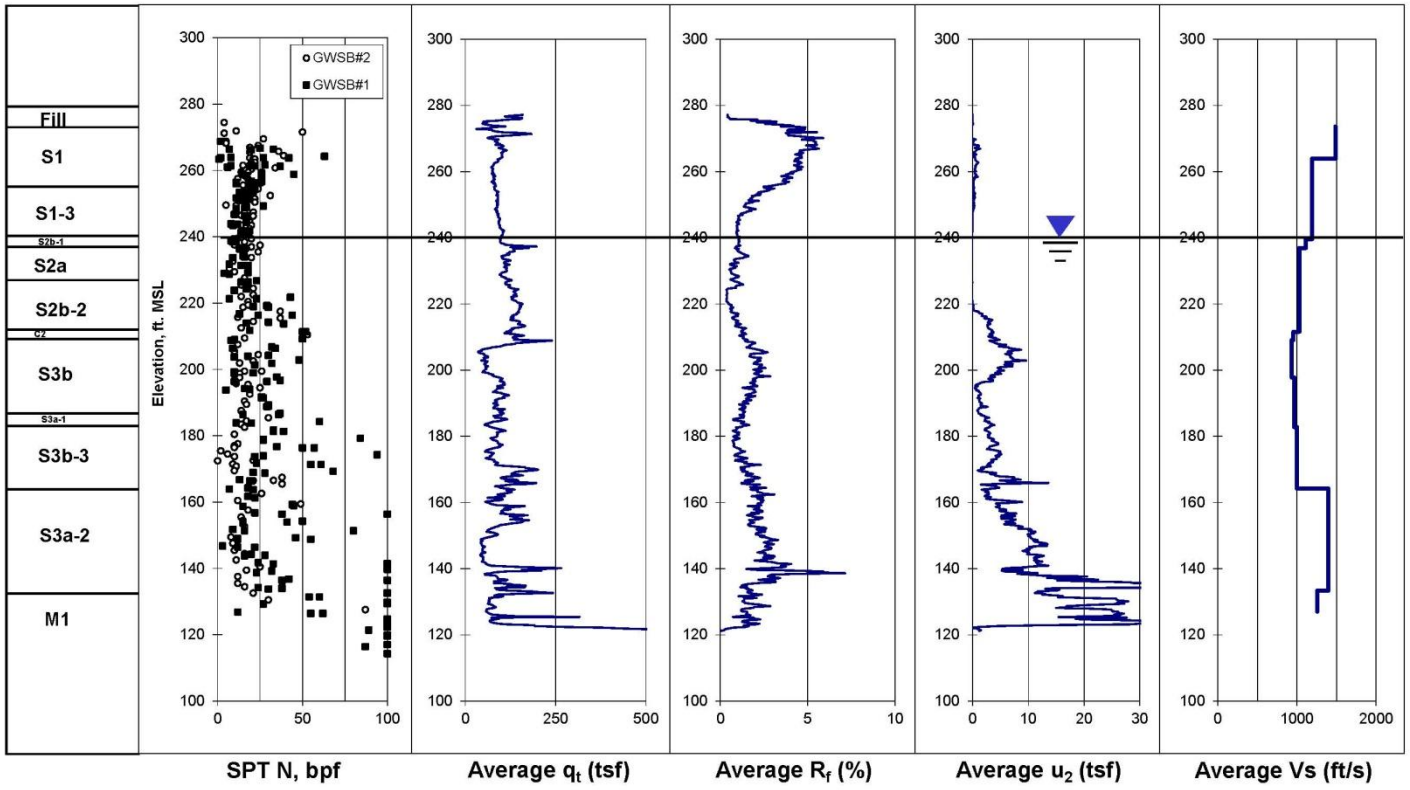

Frequent-Interval Vs Profile
Sounding - C35
Vs (ft/s)
0
1000
2000
3000
4000
5000
6000
7000
8000
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
Depth (ft)
Sledge CH1-CH5
Sledge CH2-CH6
Roto CH1-CH5
Soft Zones

Conclusions

- Frequent-Interval vs Standard-Interval Seismic CPTu
  - Pushes of 50m possible
  - Detailed Vs profile with depth
  - Frequent Interval measures lower velocities more accurately than the typical SCPT
  - This makes it better than conventional SCPT for testing low velocity soft zone materials

BU Slides


ALEC McGILLIVRAY, PHD
IN SITU TESTING & ANALYSIS
FREQUENT-INTERVAL SCPTu
Date: 6/6/2011
Test Name: C-23
Latitude:
Longitude:
Test Site: Savannah River Site
Location: Jackson SC
Client: SRSNS
Contact: Bruce Nothdurft
Test Type: Downhole Seismic
Device: True-int Biaxial Cone
Operators: Alec McGillivray
Robert Biehle (Fugro)
Tip Resistance
q_T (MPa)
Porewater Pressure
u_2 (kPa)
Friction Ratio
FR (%)
Shear Wave Velocity
V_s (m/s)
Depth (m)
Sledge CH3 P-I
Roto CH4 P-I
Sledge CH3 P-I
Vs



Summary of CPTu & SCPTu Data GWSB#2

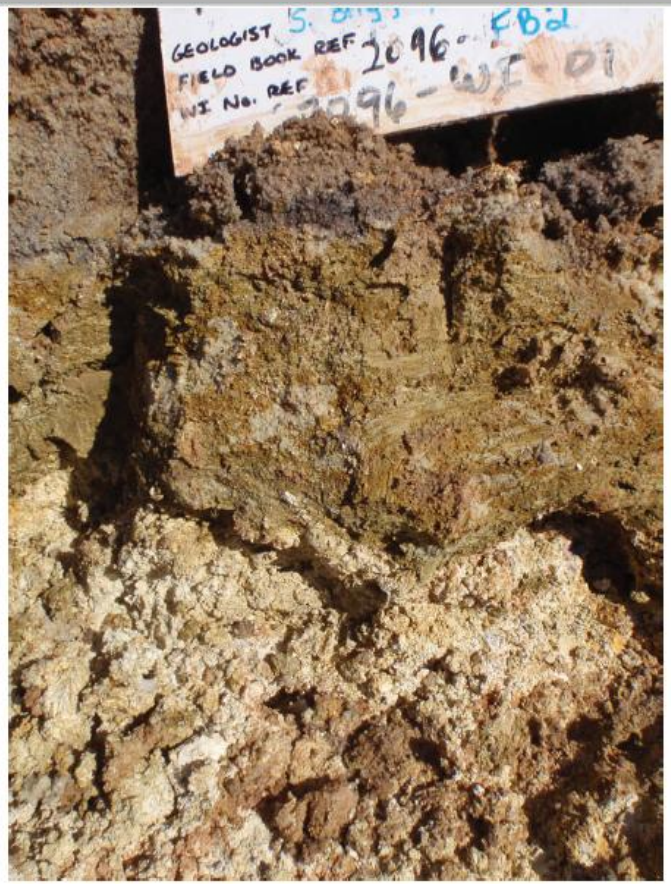
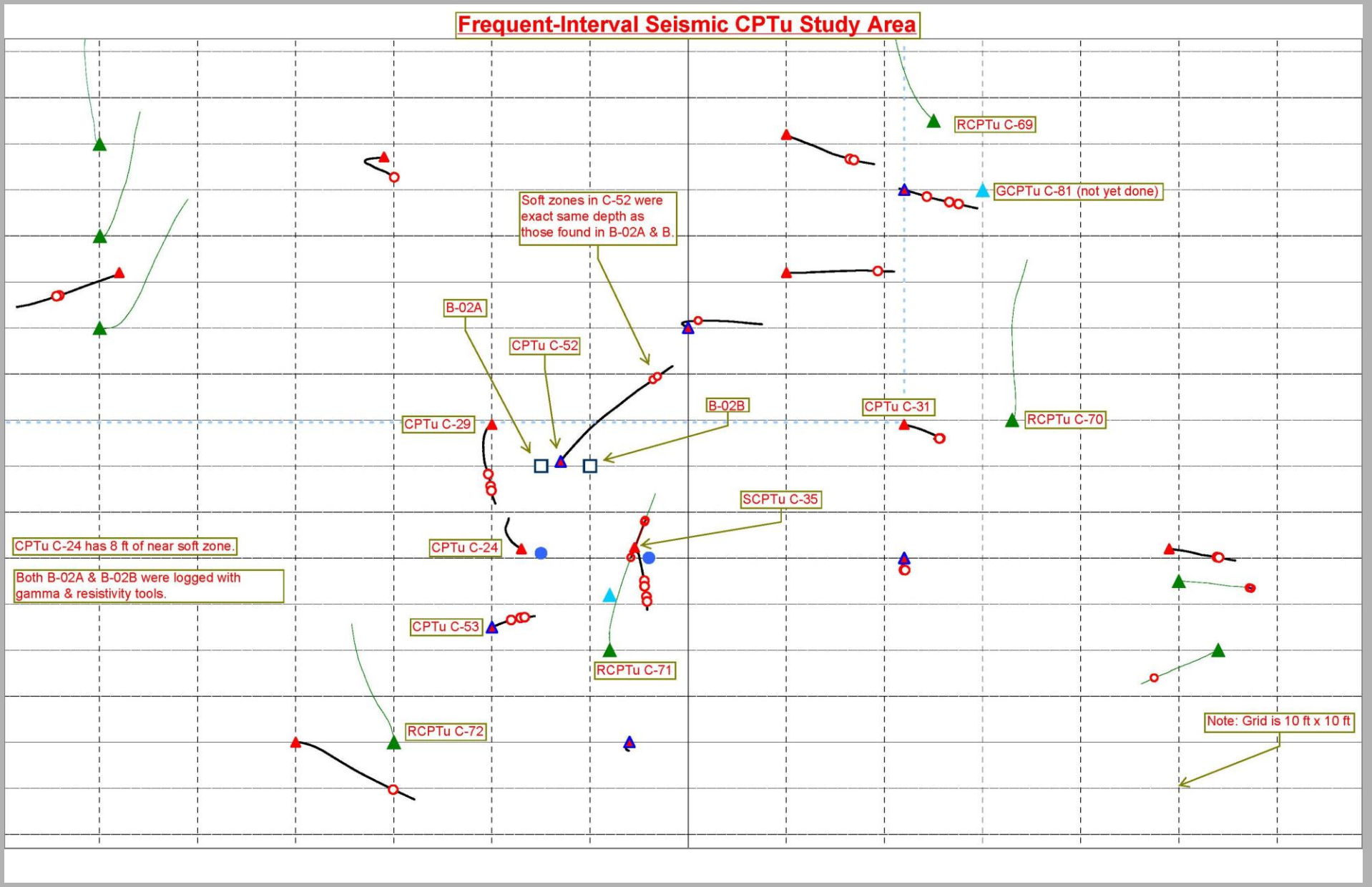
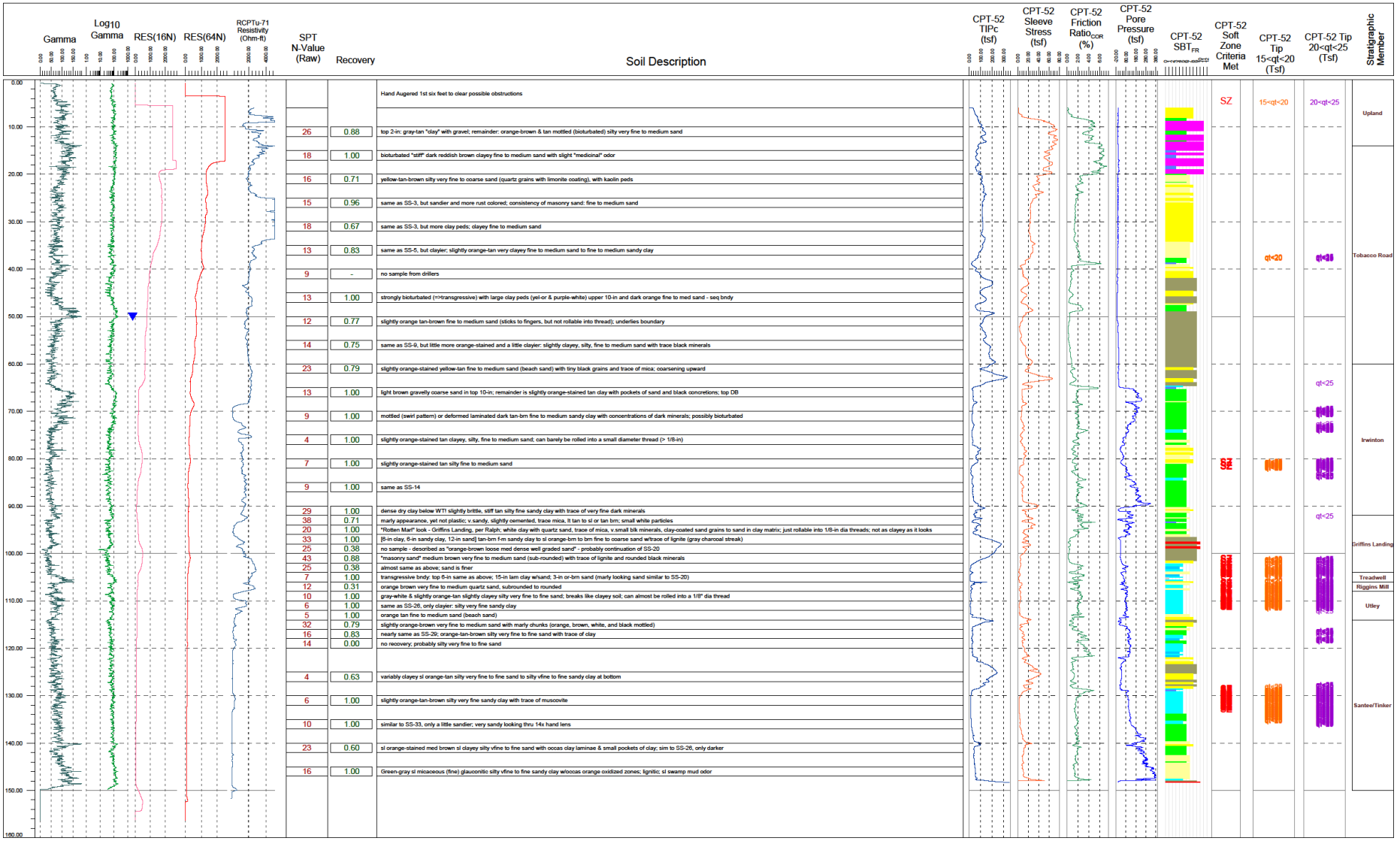
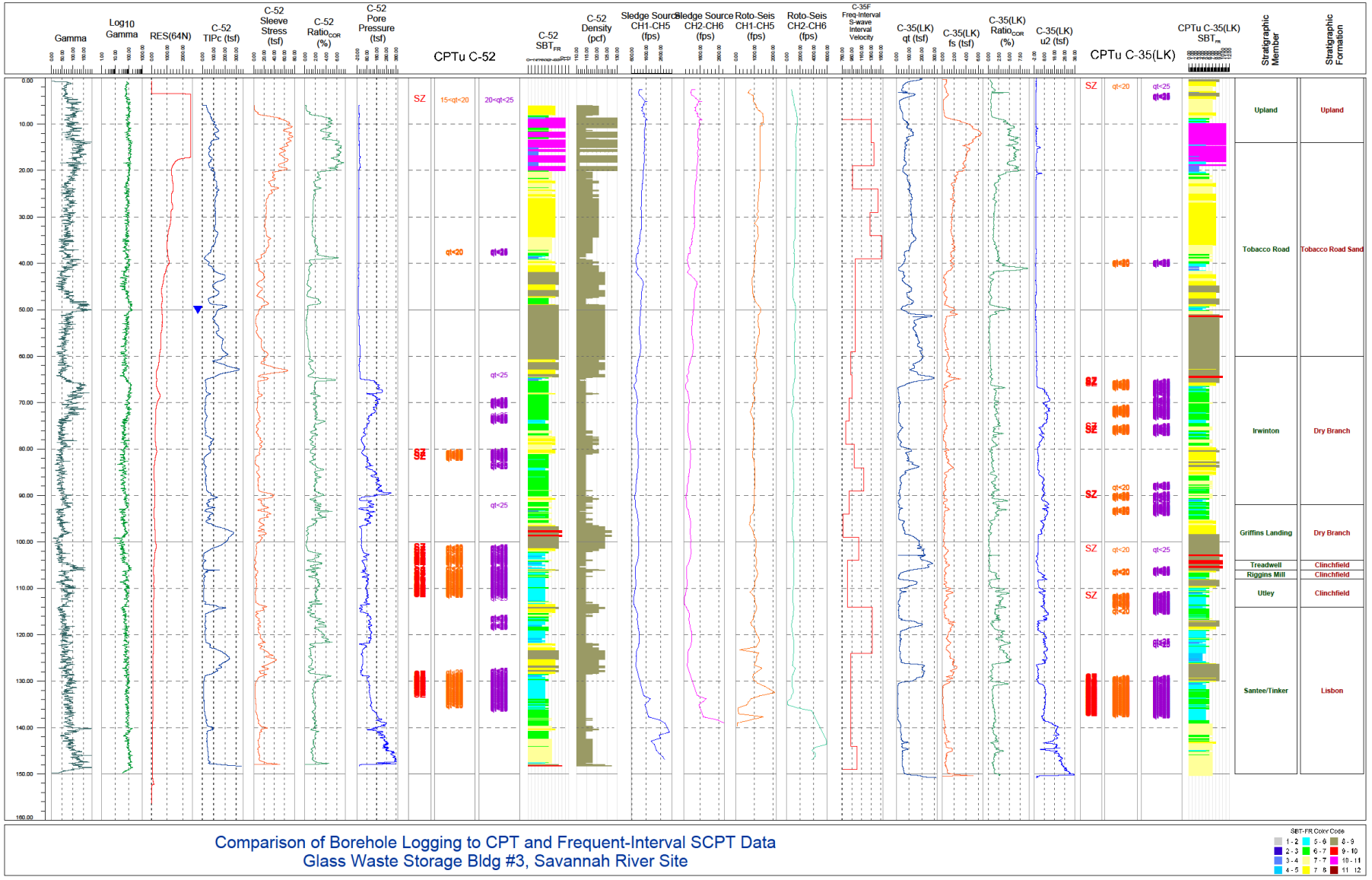


Figure 7. Facies 2 in the Utley “limestone unit”. Dominantly Uc (= “pUtley” = glauconite-rich; highly weathered facies) with suspended blocks of Ubwx and Ub. Ubwx = variably weathered, light gray to yellow, highly calcareous Utley limestone, with weathering intensity increasing relative to fossil content and apparent porosity. Ub = ledge-forming, light gray to white, richly calcareous, abundantly fossiliferous wackestone to packstone of the Utley “limestone unit”.


Frequent-Interval Seismic CPTu Study Area
RCPTu C-69
GCPTu C-81 (not yet done)
Soft zones in C-52 were exact same depth as those found in B-02A & B.
B-02A
CPTu C-52
B-02B
CPTu C-29
CPTu C-31
RCPTu C-70
SCPTu C-35
CPTu C-24 has 8 ft of near soft zone.
CPTu C-24
Both B-02A & B-02B were logged with gamma & resistivity tools.
CPTu C-53
RCPTu C-71
RCPTu C-72
Note: Grid is 10 ft x 10 ft



Comparison of Borehole B-2B Logging & CPT C-52 Data
Glass Waste Storage Bldg #3, Savannah River Site



Comparison of Borehole Logging to CPT and Frequent-Interval SCPT Data
Glass Waste Storage Bldg #3, Savannah River Site