Report on the Comparison of Shear Wave Velocity Measurements with Multispectral Analysis of Surface Waves (MASW) along with the Microtremor Array Method (MAM), Seismic Cone Penetration Tests (SCPT), and Standard Penetration Tests (SPT) for the Burlington and Colchester, Vermont USGS 7-1/2 Minute Quadrangles

June 5, 2013

By

John E. Lens[1, 2], and George E. Springston[3]
1. GeoDesign, Inc., 2. University of Vermont, 3. Norwich University

Submitted to the

Vermont Geological Survey

Background

This study and report follow from the seismic hazard mapping of the Burlington-Colchester quadrangles performed for the Vermont Geological Survey in 2010-2013 and described in the report entitled "Seismic Hazard for the Burlington and Colchester, Vermont USGS 7-1/2 Minute Quadrangles (Lens, Dewoolkar, and Springston, 2013).

The Vermont Geological Survey Open File Report VG13-3 by Lens, Dewoolkar, Springston, and Becker (2013) contains a seismic site classification map (Plate 1) which was developed using Standard Penetration Test (SPT) and shear wave velocity data for the upper 100 feet (30 meters) of subsurface profile at selected sites. The majority of the sites were classified using existing SPT data with the rest of the sites being classified using a combination of existing and study derived shear wave velocity data. Both SPT and shear wave velocity based methods are acceptable for seismic site classification according to the provisions of the International Building Code (IBC, 2012) applicable to publicly occupied buildings and associated structures.

MASW (Multispectral Analysis of Surface Waves) along with the Microtremor Array Method (MAM), and SCPT (Seismic Cone Penetration Tests) methods are widely accepted for obtaining shear wave velocity measurements and numerous publications, such as Stokoe (2008), describe the procedures and applications. Experience shows that shear wave velocity measurements provide more reliable and overall more versatile data sets for characterization of subsurface profiles for seismic site classification and seismic design than do SPT data. This is leading to increased use of shear wave velocity measurements for seismic site classification. This study and report support that trend by expanding the local experience base through comparisons of these methods at three example sites which have geologic profiles common to the area.

Objectives

The objectives of this study were to compare measurements of shear wave velocity in soil and bedrock made with MASW/MAM and Seismic SCPT, and compare those seismic site characterizations with those made with SPT methods within Burlington and Colchester, Vermont 7.5 minute United States Geological Survey (USGS) quadrangles.

Study Methodology

There were three sites within the quadrangles at which SCPT data were already available and where comparison shear wave velocity measurements could be obtained using the MASW/MAM method. These sites consisted of the Moran plant site along the waterfront in Burlington, the new State of Vermont Public Health Building site in Colchester, and a site designated as Milton Square in Milton. These are the Burlington, Colchester, and Milton sites referenced in this report.

In addition, there were two sites available within the quadrangles for shear wave velocity measurements using the MASW method on exposed bedrock. The sites were along the Winooski River and designated as the Winooski Gorge site in South Burlington and the Overlook Park site inWilliston.

George Springston of Norwich University obtained shear wave velocity measurements using the MASW/MAM methods using surface geophone sensor arrays placed nearby to SCPT probe locations at each of the three sites with SCPT data. He also obtained shear wave velocity measurements using the MASW method at the two exposed bedrock sites. Details of the measurement procedures and computed results are described in Appendix 1.

Appendix 2 contains the original SCPT data along with related site background subsurface information including SPT data.

Table 1 summarizes the site information. Figures 1, 2 and 3 provide site location sketches including the MASW/MAM array layouts.

Summary of Measurements and Comparisons – Shear Wave Velocities (Vs)

Figures 4, 5, and 6 illustrate the measurements and comparisons of SCPT and MASW/MAM shear wave velocity profiles at the Burlington, Colchester, and Milton sites, respectively.

At the Burlington and Colchester sites, the MASW/MAM derived shear wave velocities were usually within 20 percent (both above and below) of the mean SCPT shear wave velocities at the same depths. The exception is the Milton site which showed substantially more difference between MASW/MAM and SCPT derived shear wave velocities within the upper 40 feet. In that interval, the MASW/MAM velocities were between 60 and 190 percent of the mean SCPT velocities at the same depth. Below 40 feet the shear wave velocity differences were between 10 and 25 percent, essentially similar to the MASW/MAM and SCPT shear wave velocity differences in the Burlington and Colchester site profiles.

The composite shear wave velocity used in the IBC seismic site classification is computed as follows:

$$\boldsymbol{Vs} = \sum_{i=1}^{n} \boldsymbol{di} \,/\, \sum_{i=1}^{n} \boldsymbol{di/vsi}$$

where

Vs = composite shear wave velocity for 100 foot profile
di = thickness of any layer *i* between 0 and 100 feet
vsi = shear wave velocity for layer *i*

At all three of the sites with combined MASW/MAM and SCPT measurements, the composite shear wave velocity in the top 100 feet of the subsurface profiles resulted in seismic site classification of D of the IBC (2009) criteria. This corresponded to a weighted composite shear wave velocity of between 600 and 1,200 feet per second applicable for that seismic site classification category.

Depth to bedrock was over 200 feet at Burlington and Milton and precluded being able to extend the MASW/MAM arrays long enough for reliable recognition of the soil to bedrock transition depth. Bedrock in Colchester was between 65 and 90 feet deep in the soil borings and probes adjacent to the MASW/MAM array. However, a soil to bedrock transition was not evident in the MASW/MAM results within the approximately 85 foot range of the reliable shear wave velocity measurements. SCPT probes reached to refusal at the Burlington site but did not penetrate deeper as is typical of SCPT probes. SCPT probes were terminated above refusal depths at the other sites.

Shear wave velocities on the two bedrock exposures measured with MASW/MAM surface arrays ranged between approximately 1,000 and 6,600 feet per second. Table 2 summarizes the shear wave velocity measurements. There was considerable variability in measurements at the Winooski Gorge site in South Burlington with much less variability at the Overlook Park site. The source of the Winooski Gorge variability, which ranged from 2,300 to 4,800 feet per second, was not evident.

Summary of Measurements and Comparisons – SPT values

The composite SPT blow count values in the top 100 feet of the subsurface profiles are summarized as:

Site	SPT Blow Count
Burlington	Insufficient depth of borings (maximum = 47 feet < 100 feet required)
Colchester	10.5
Milton	9.8

The Colchester and Milton sites result in a seismic site classification of E according to the IBC (2012), based on the composite SPT blow count of less than 15 and a determination by the design geotechnical engineer that the soils are most likely not liquefiable. The seismic site classification of D for the Burlington site was made primarily on the basis of evaluations made by the SCPT because the borings did not extend deep enough for an SPT-based classification.

Conclusions

1. Shear wave velocity measurements made with MASW/MAM and SCPT methods in the upper portion of the soil profile at the Milton site varied by as much as a factor of 2 between the MASW/MAM measurements and the mean of the nearby SCPT measurements. However, variations between MASW/MAM and SCPT derived shear wave velocities within 20 percent were more common. Significant variations in the measured shear wave velocity values should be expected as consequence of both local variability and the measurement methods (e.g., the larger volume of soil encompassed by the MASW/MAM compared to the down-hole SCPT measurements will tend toward a smoother velocity profile).

2. MASW/MAM and SCPT methods did not detect the presence of strata changes between soil and bedrock. This was expected at the deep bedrock conditions present at the Burlington and Milton sites but was a surprising outcome at the Colchester site. This suggests that such strata changes may be difficult to detect with these methods and that special attention is warranted in planning and executing the measurement program, including use of other methods such as conventional soil borings, where detecting this transition is important for a particular project.

3. Seismic site classification made using SPT blow count data alone was more conservative than the results obtained through shear wave velocity measurements.

Recommendations

1. Evaluations for seismic site class should be performed under the direction of qualified professionals in accordance with accepted standards of practice.

2. Evaluations for seismic site classification should be expected to potentially require using more than one method of analysis in order to obtain reliable and sufficiently comprehensive data needed for proper seismic site classification. For example, soil sampling and testing is needed to evaluate soil grain size characteristics for liquefaction potential if there is evidence of submerged, loose, granular soils. Liquefiable soils will automatically result in a seismic site classification of F. Other testing may also be warranted for situations with soft and/or cohesive soils for similar reasons.

3. Shear wave velocity measurements for bedrock may require cross-hole or down-hole methods where it is important to evaluate the shear wave velocities.

4. *The information provided in this report should not be used in place of proper site-specific seismic evaluation performed under the direction of a qualified professional in accordance with accepted standards of practice.*

Acknowledgements

The site specific data used in this evaluation were obtained through cooperative effort from Laurence Becker, George Springston, David Kuhn, Todd Merchant, James Olson, Kirsten Merriman-Shapiro, Shawn Kelley, Jason Gaudette, Russ Miller-Johnson, the Vermont Department of Buildings and General Services, the City of Burlington, and other local consulting engineering firms and businesses. Field work performed to obtain shear wave velocity measurements was by George Springston of Norwich University. The study was funded by the Vermont Geological Survey through a grant provided by the Federal Emergency Management Agency.

References

International Building Code (2012), International Code Council, Country Club Hills, IL.

Springston, G.E., (2011), Shear Wave Analysis in the Colchester Quadrangle and Vicinity, Northwest Vermont, Norwich University Department of Geology and Environmental Science, Draft Internal Report.

Springston, G.E., (2013), File information on Shear Wave Velocity Measurements at the Vermont Public Health Building Site in Colchester, Overlook Park in Williston, and Winooksi Gorge in South Burlington.

Lens, J.E., Dewoolkar, M.M., Springston, G.E., and Becker, L.R., (2013) Open File Report VG13-3, Seismic Hazard for the Burlington and Colchester, Vermont USGS 7-1/2 Minute Quadrangles, Vermont Geological Survey.

Stokoe, K, (2008), The Increasing Role of Seismic Measurements in Geotechnical Engineering, The Spencer J. Buchanan Lecture presented at Texas A & M University.

VERMONT

Burlington-Moran Plant Site

Vermont Center for Geographic Information

vermont.gov

1: 2,983

June 3, 2013

LEGEND

- Airports
- Mountains and Hills
- Roads - Public (VTrans)
  - Interstate Highway
  - US Highway
  - Vermont State Highway
  - Town Highway
  - Class 4 Town Highway
  - Other
- Roads - Private (E911)
- Driveways
- Rail Lines
- County Boundaries
- Town Boundaries
- Lakes and Ponds (5K)
- Rivers (5K)
- Streams (5K)
  - Intermittent
  - Perennial
  - Unassigned

VCGI

NOTES

0.09 | 0 | 0.05 | 0.09 Miles

WGS_1984_Web_Mercator_Auxiliary_Sphere

THIS MAP IS NOT TO BE USED FOR NAVIGATION

VERMONT

Figure 2 - Colchester Site

Vermont Center for Geographic Information

vermont.gov

1: 2,686

June 4, 2013

LEGEND

- Airports
- Mountains and Hills
- Roads - Public (VTrans)
  - Interstate Highway
  - US Highway
  - Vermont State Highway
  - Town Highway
  - Class 4 Town Highway
  - Other
- Roads - Private (E911)
- Driveways
- Rail Lines
- County Boundaries
- Town Boundaries
- Lakes and Ponds (5K)
- Rivers (5K)
- Streams (5K)
  - Intermittent
  - Perennial
  - Unassigned

VCGI INC

0.08 0 0.04 0.08 Miles

WGS_1984_Web_Mercator_Auxiliary_Sphere

THIS MAP IS NOT TO BE USED FOR NAVIGATION

DISCLAIMER: This map is for general reference only. Data layers that appear on this map may or may not be accurate, current, or otherwise reliable. VCGI and the State of Vermont make no representations of any kind, including but not limited to, the warranties of merchantability, or fitness for a particular use, nor are any such warranties to be implied with respect to the data on this map.

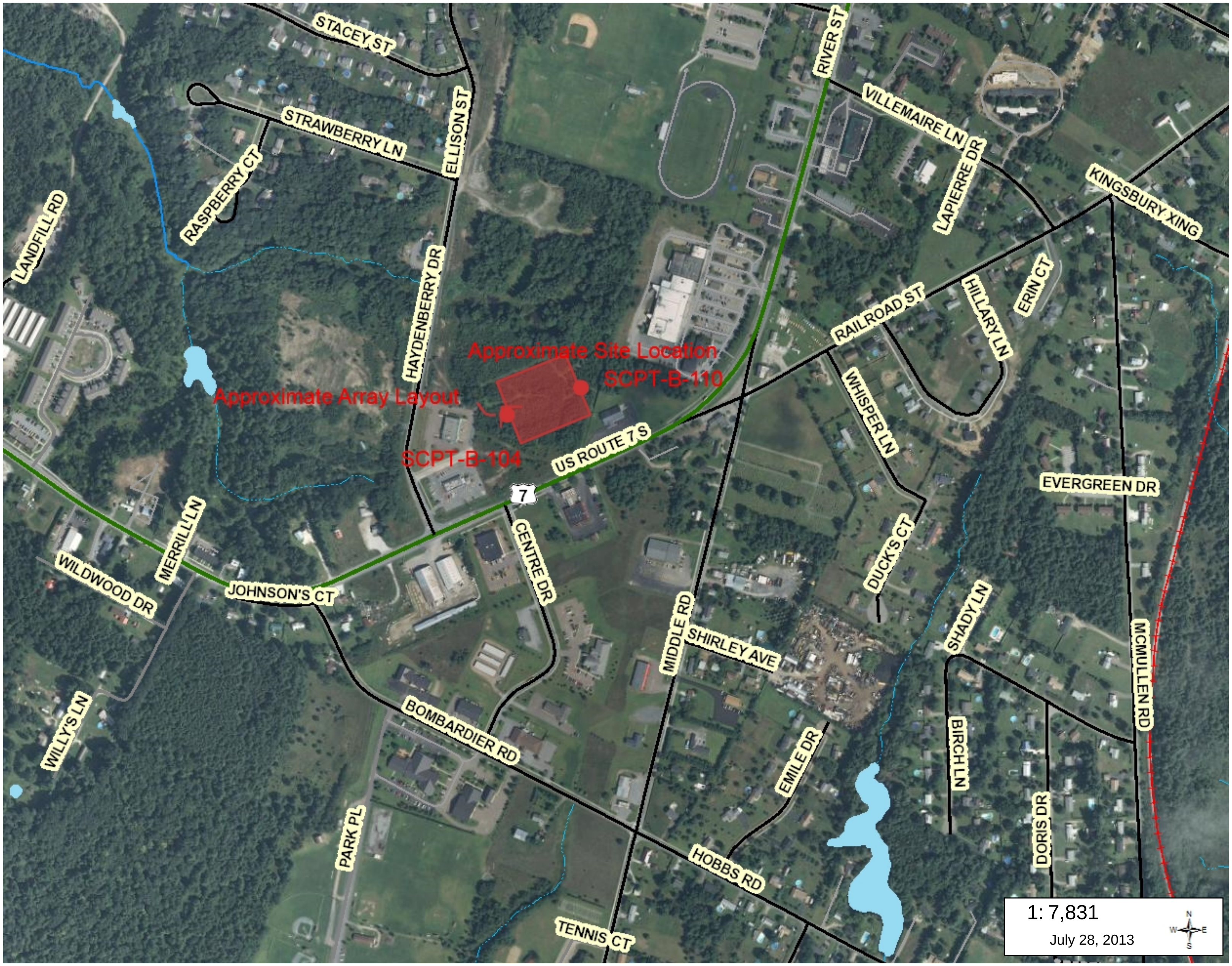
NOTES

New State of Vermont Public Health Building

Figure 3 - Milton Site

Vermont Center for Geographic Information

vermont.gov



1: 7,831

July 28, 2013

LEGEND

- Airports
- Mountains and Hills
- Roads - Public (VTrans)
  - Interstate Highway
  - US Highway
  - Vermont State Highway
  - Town Highway
  - Class 4 Town Highway
  - Other
- Roads - Private (E911)
- Driveways
- Rail Lines
- County Boundaries
- Town Boundaries
- Lakes and Ponds (5K)
- Rivers (5K)
- Streams (5K)
  - Intermittent
  - Perennial
  - Unassigned

NOTES

0.25 0 0.12 0.25 Miles

WGS_1984_Web_Mercator_Auxiliary_Sphere

THIS MAP IS NOT TO BE USED FOR NAVIGATION

Figure 4 - Burlington (Moran) - Measurement and Comparison of SCPT and MASW/MAM Shear Wave Velocity in feet/second

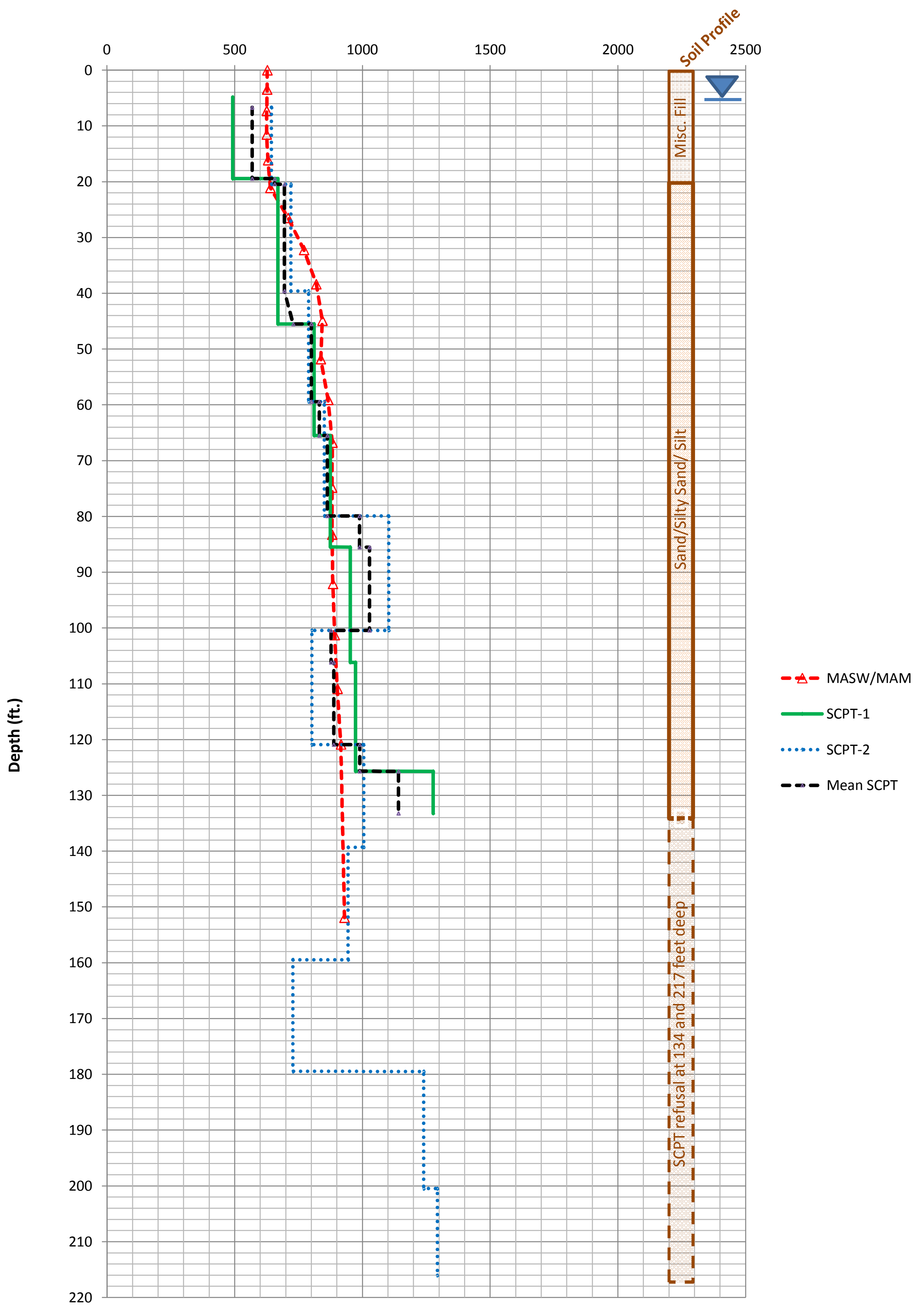


Figure 5 - Colchester - Measurement and Comparison of SCPT and MASW/MAM Shear Wave Velocity in feet/second

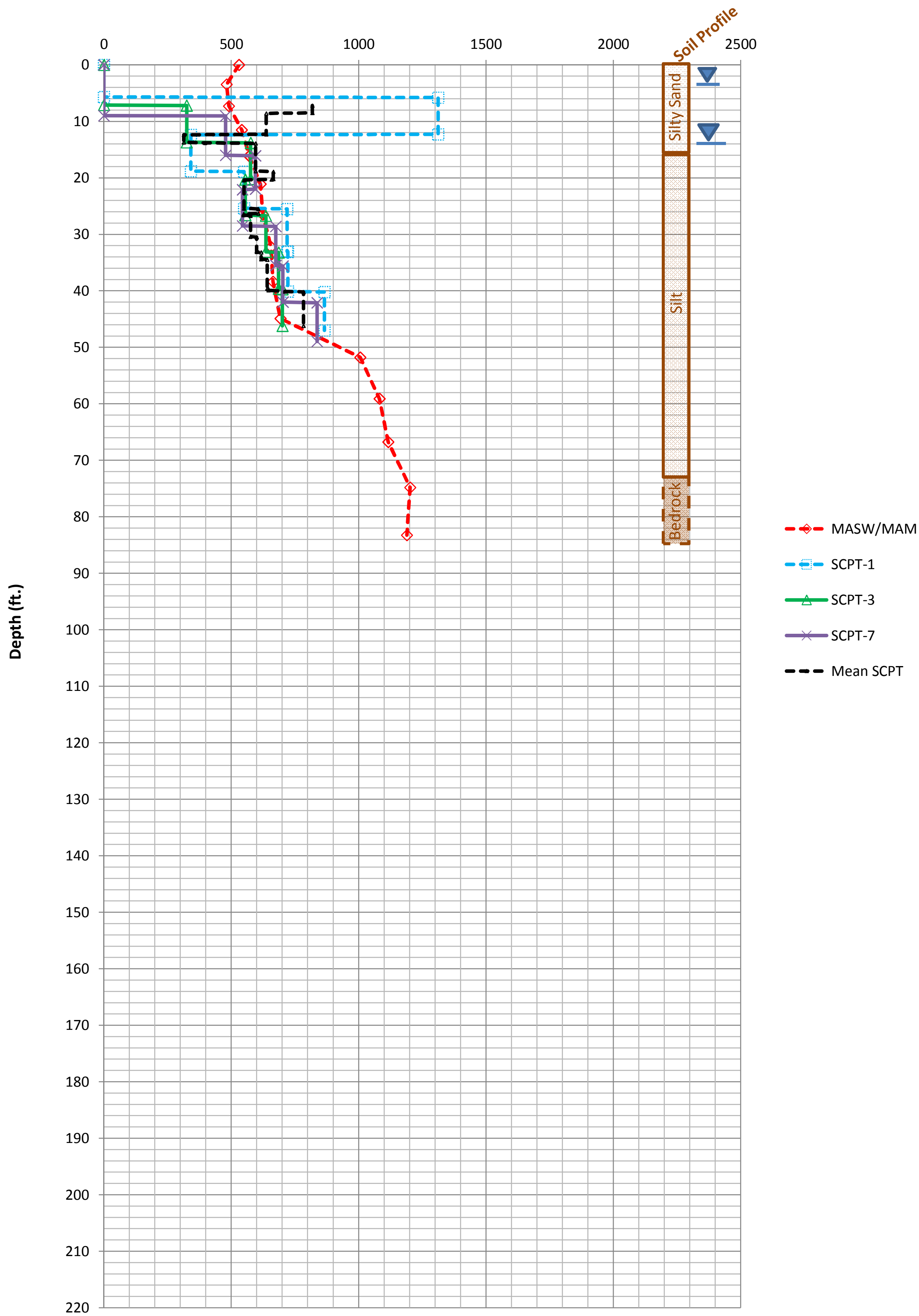


Figure 6 - Milton - Measurement and Comparison of SCPT and MASW/MAM Shear Wave Velocity in feet/second

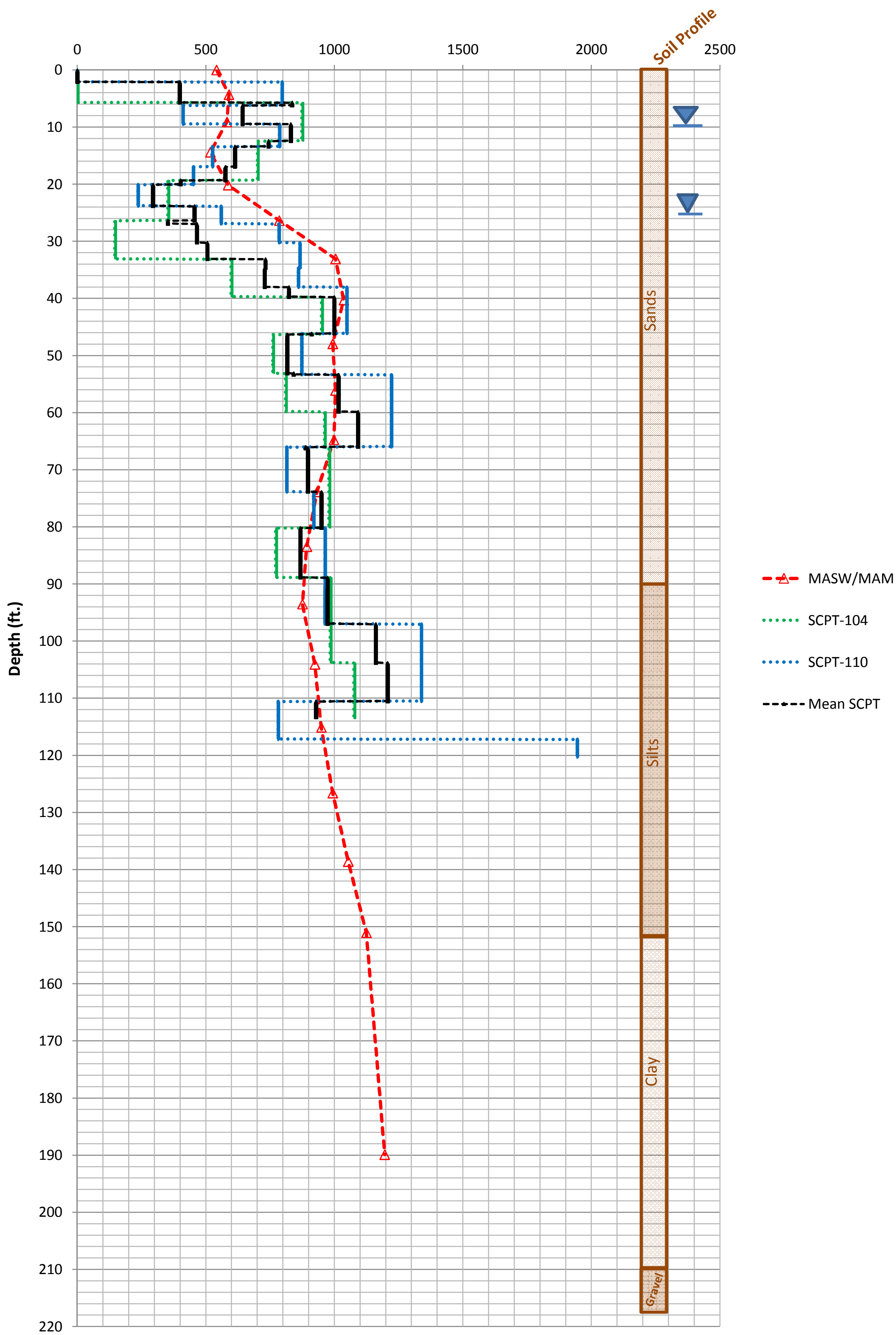


Table 1
Summary of Site Information

Site Name	Location	SCPT Data Acquisition	MASW Data Acquisition	Quantity of SCPT Probes	SCPT Probe Depths	Quantity of Borings	Boring Depths	Estimated Bedrock Depth	Soil Profile	Remarks
Burlington	Moran Plant along Waterfront	August 2010	April 2011	2	134 and 217 feet	4	32 to 47 feet	Bottom of SCPT probes	Miscellaneous fill (20-feet +/-) over stratified lacustrine sands, silt and clay	1.
Colchester	Vermont Public Health Building Site	January 2011	May 2013	8	40 to 58 feet	2 (8 bedrock probes)	56 to 59 feet (probes to 93 feet)	Varies between 65 and 90 feet across site	Fine sand (10 to 20-feet) over fluvial silt	1.
Milton	Route 5	March 2011	August 2011	2	116 and 120 feet	14	25 to 102 feet	220 feet based on water well data	Interbedded fine to medium sands with silt and coarse sand layers	1.

Remarks:

1. Refer to Appendices 1 and 2 for additional details.

Table 2
Summary of Bedrock Shear Wave Velocity Measurements

Site	Location	Shear Wave Velocity (feet/second)	Rock Type	Remarks
Winooksi Gorge	South Burlington	980 to 3300 (forward Survey 1800 to 6600 (reverse direction survey)	Shelburne Formation (Limestone)	1
Overlook Park	Williston	3900 (range is 3600 to 4400)	Clarendon Springs Formation (Limestone)	1

Remarks:

1. Refer to Appendix 1 for additional details.

Appendix 1
Shear Wave Analyses at Three Sites With Seismic Cone Penetrometer Data in the Burlington and Colchester Quadrangles, Northern Vermont

George Springston
Norwich University Department of Geology and Environmental Science
158 Harmon Drive, Northfield, VT 05663

June 5, 2013

1. Introduction

Shear wave velocity data was collected at three sites in Chittenden County where Seismic Cone Penetrometer data was also available. The site locations are described in the main report.

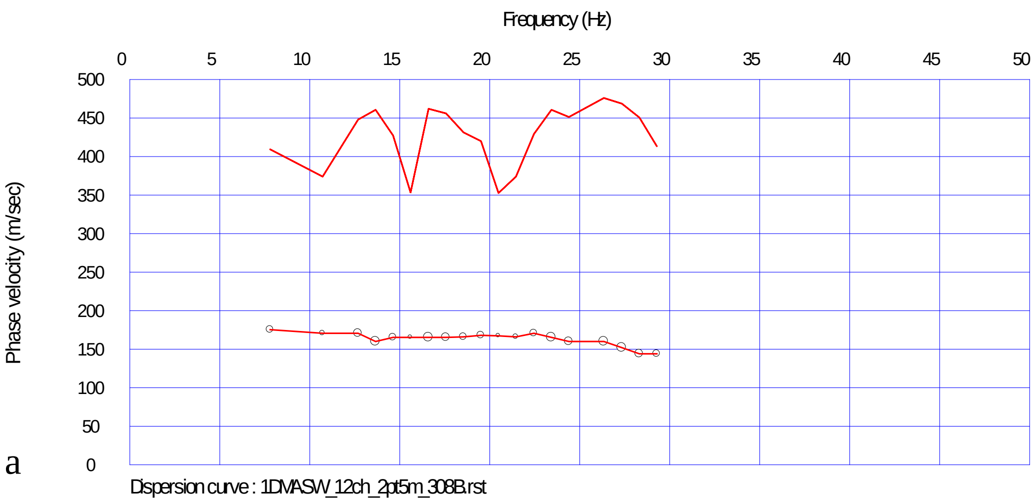
This analysis was conducted by means of the Multichannel Analysis of Surface Waves (MASW) and Microtremor Array Measurement (MAM) techniques. Both of these techniques are based on the measurement of Rayleigh waves moving across the surface of the earth. High frequency surface waves from a seismic source stress only the shallow layers of the soil while low frequency waves can stress the deeper materials. If the material properties vary with depth, this results in a dispersion of surface wave velocities. In both methods, a spectral analysis is used to identify the dominant mode at each frequency and then a curve of phase velocity versus frequency is constructed. This curve is then used to theoretically model the thickness and stiffness of soil layers. The two methods differ in that the MASW technique uses a single artificial source (commonly a hammer striking a plate) while the MAM technique makes use of ambient vibrations.

2. Methods

Data was collected using a Geometrics SmartSeis ST seismograph with three different arrangements of geophones. Data was collected for the active or MASW technique using linear arrays of 12 geophones with spacings that generally range from 1 to 2 meters (spread lengths of 11 and 22 meter, respectively). Shot locations were generally at 1 and 2 meters off of each end of both the 1- and the 2-meter arrays. The source was an 8-pound sledge hammer striking an aluminum plate. Data was collected for the passive or MAM technique using an “L” shaped array of 11 geophones. All passive surveys had 25-meter arms. The “source” in this case was ambient vibrations from a wide variety of natural and artificial sources. Data was processed using Geometrics Seisimager/SW software.

The field procedures and use of the software are described detail in Geometrics (2009). The general principles of these surface wave techniques are explained in Park and others (1999) and Park and others (2007). Park and Miller (2005) provide a very useful discussion of optimum parameters for MASW surveys. Long and Donohue (2007) use the MASW technique to characterize shear wave velocities in Norwegian clay, silt and sand deposits and compare the results with cone penetrometer and other geotechnical data. Their article provides useful analyses of the optimum equipment parameters to use for fairly shallow analyses of surficial geologic materials. Lin and others (2004) discuss field configurations, give a useful description of the principles of dispersion analysis, and show how the MASW technique can be used to evaluate liquefaction potential. Miller and others (no date) show the utility of these techniques for mapping depth to bedrock. Detailed analyses of shear wave velocity profiles produced using a related two-receiver method are given in Stokoe and others, 2005). This last report gives a useful overview of the general methodology used in these surface wave analysis methods.

3. Results from Moran Plant, Burlington
3A. Active Survey.



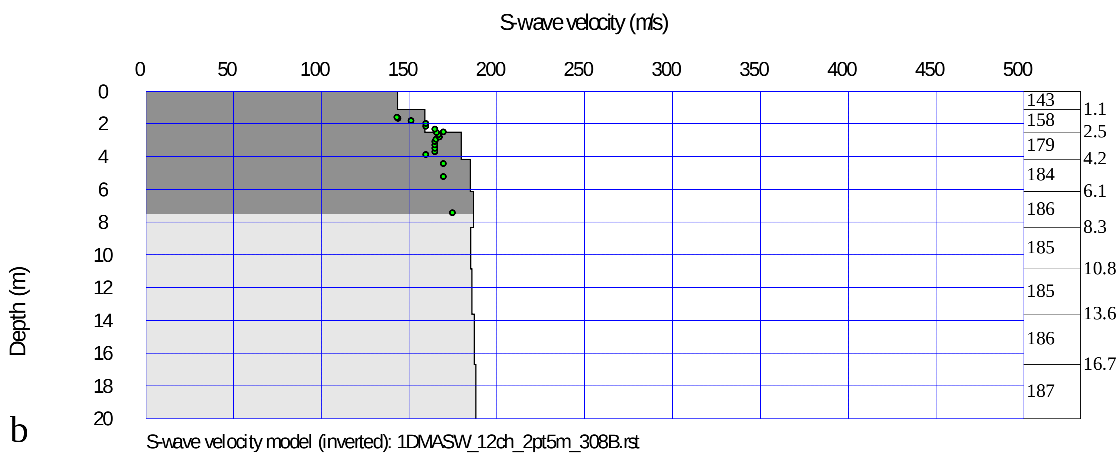
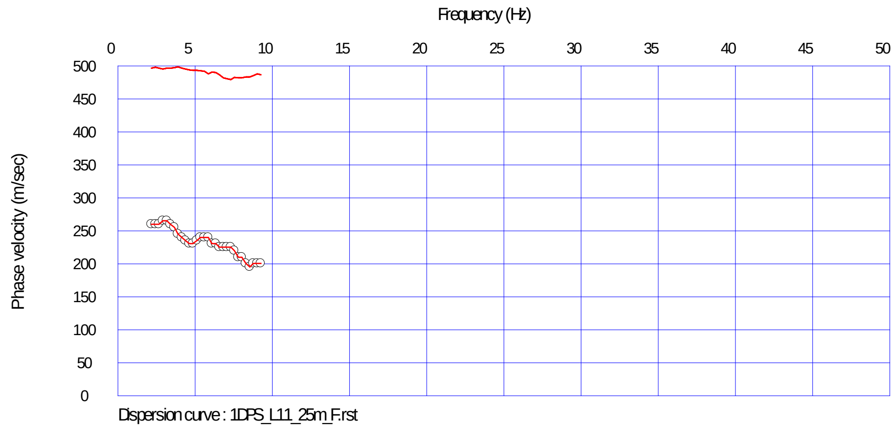
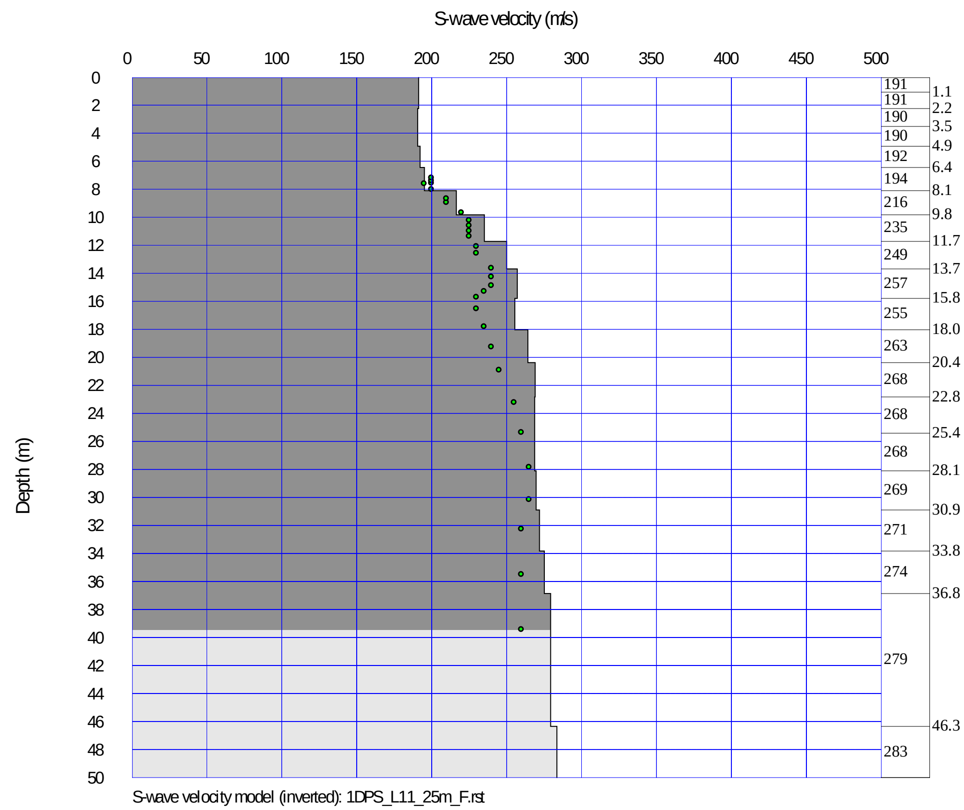


Figure 1. Results from active MASW analysis using 27.5 m spread with 2.5m spacing and 2.5 m end offset from west end. RMS error after inversion = 6.0 m/Sec. 1a. Dispersion curve. 1b. Results of shear wave velocity model after inversion.

3B. Passive Survey.

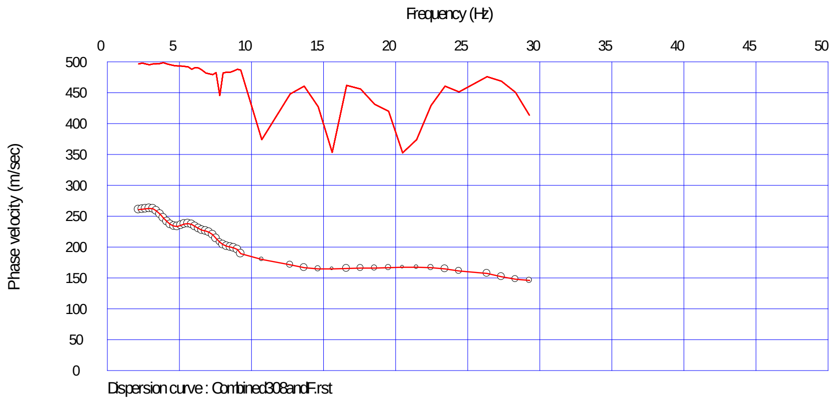




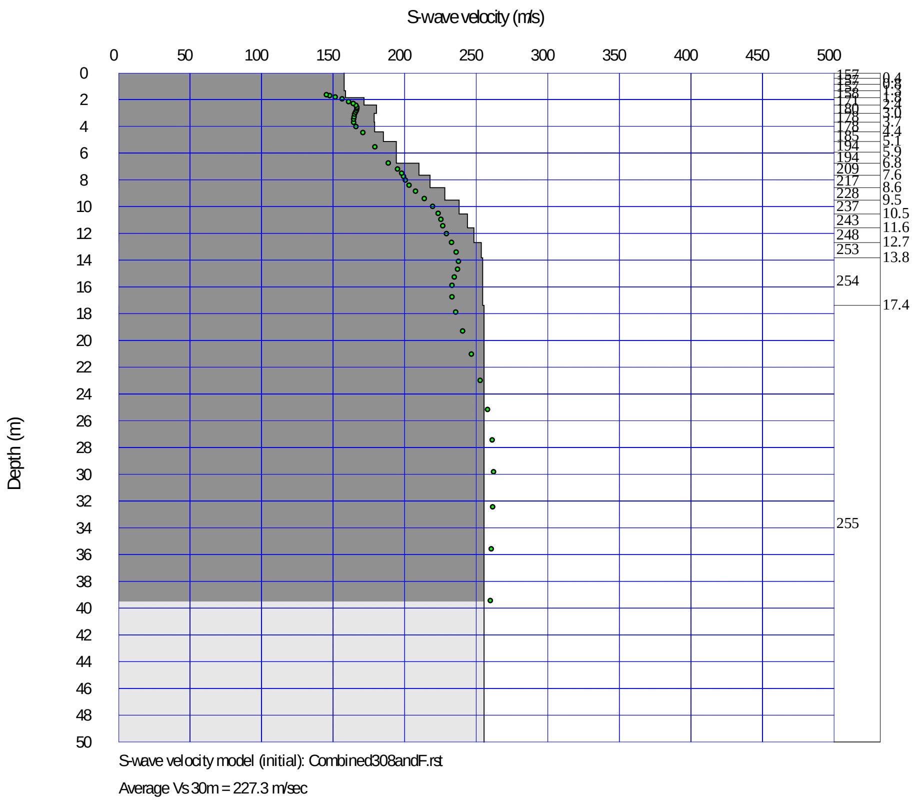
b

Figure 2. Results from L-shaped passive seismic array with 25 m arms. Data from a set of 100 8-second files. RMS error = 8.3 m/sec. a. Dispersion curve. b. Results of shear wave velocity model after inversion.

3C. Combined Survey.

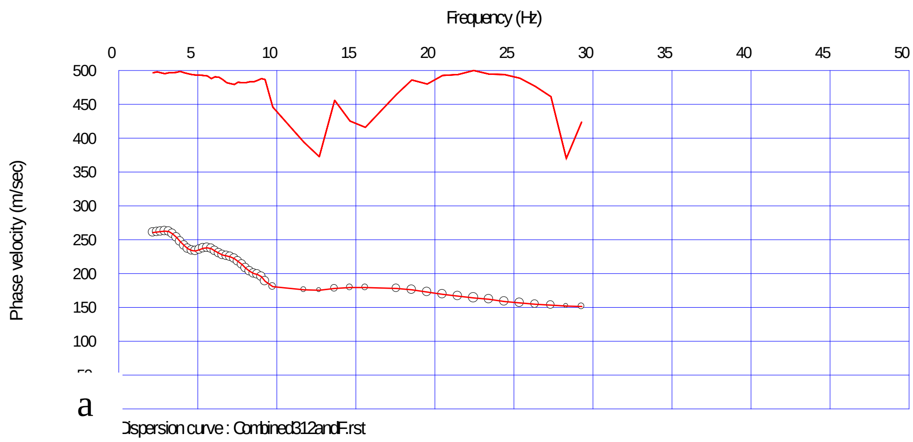


a



b

Figure 3. Results of combination of MASW File 1DMASW_12ch_2pt5m_308.rst and passive seismic file 1DPS_l11_25M_ F.rst. The passive seismic record consists of set of 100 8-second files. RMS error after inversion = 7.0 m/sec. V_S30m = 227.3 m/sec = 745.7 ft/sec. a. Dispersion curve. b. Results of shear wave velocity model after inversion.



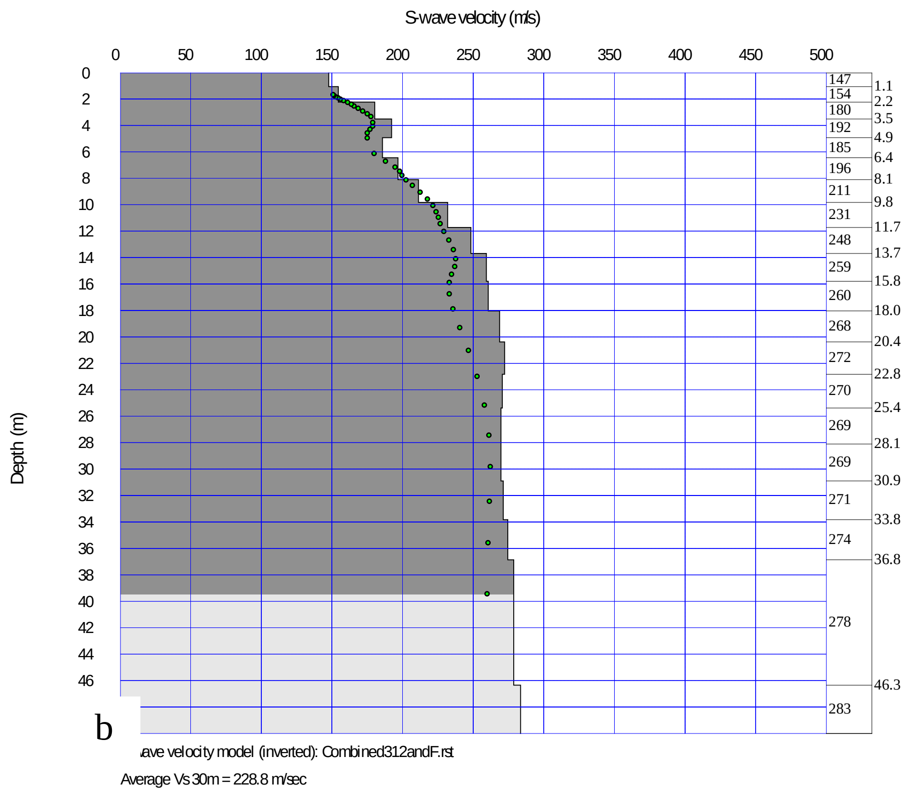
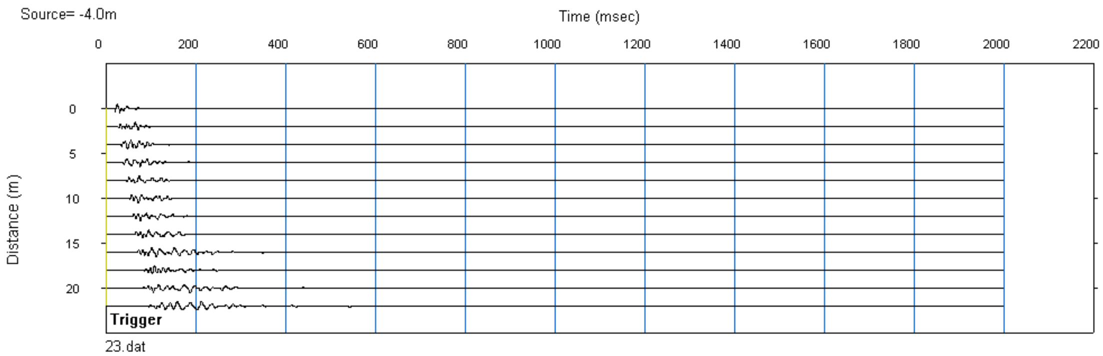


Figure 4. Combination of MASW File 1DMASW_12ch_2pt5m_312.rst and passive seismic file 1DPS_l11_25M_ F.rst. The passive seismic record is the same 100 file set used in the previous figure. Note that results are nearly identical to the previous figures. RMS error after inversion = 7.0 m/sec. V_S30m = 228.8 m/sec = 750.6 ft/sec. a. Dispersion curve. b. Results of shear wave velocity model after inversion.

4. Results from Milton Square Site in Milton

4A. Results from active survey using file 23.dat, 22 meter survey length with 4 meter shot offset.



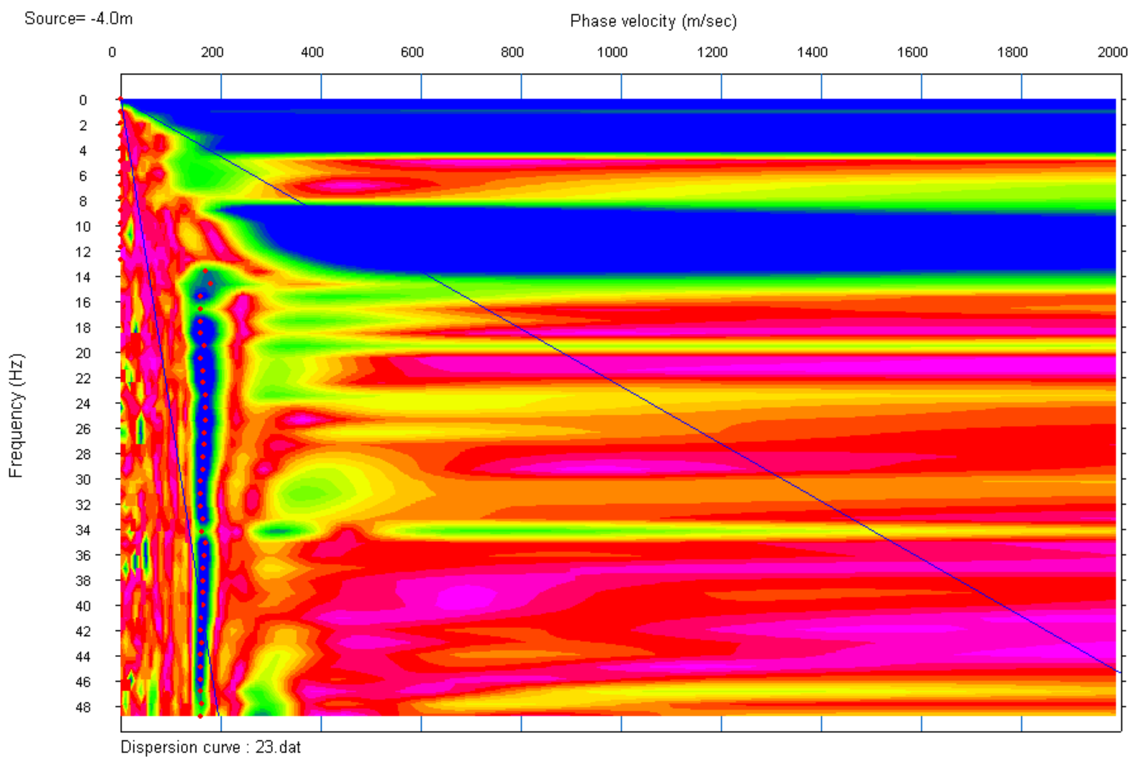
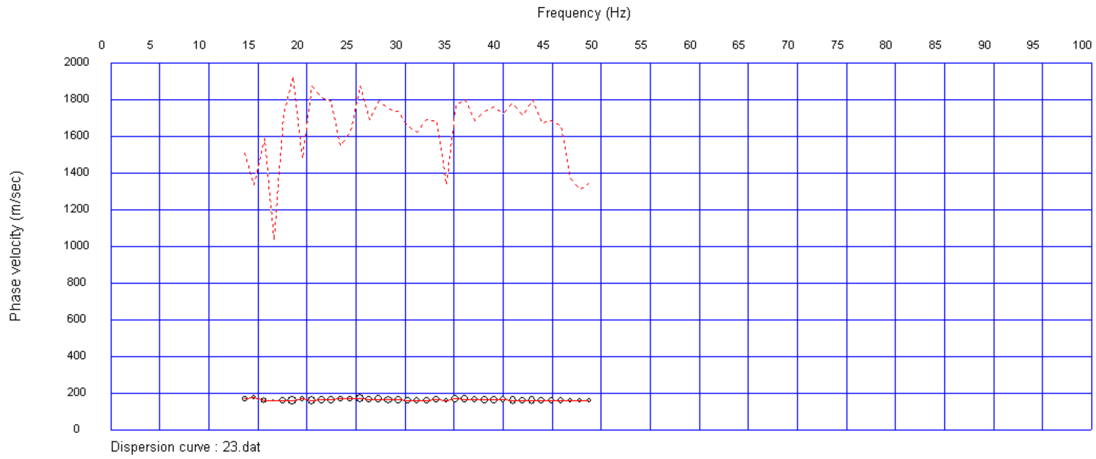


Figure 5. Time-distance plot and phase velocity versus frequency plot for active survey at Milton Square site.



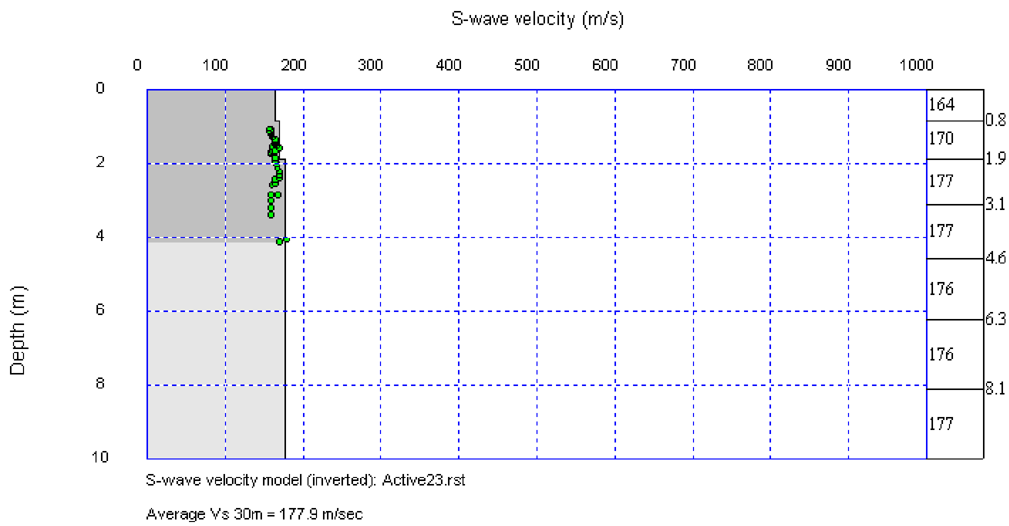
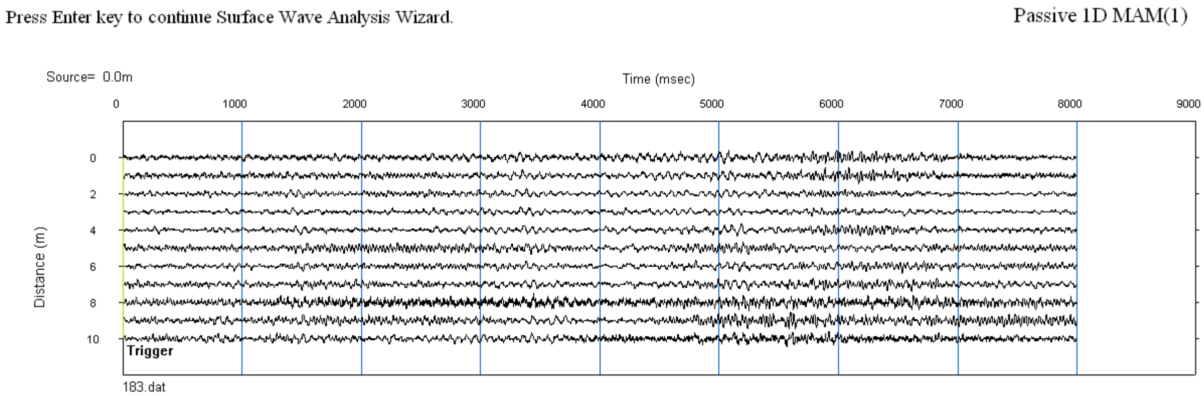


Figure 6. Dispersion curve and velocity model for active survey at Milton Square site.

4B. Passive Survey at Milton Square



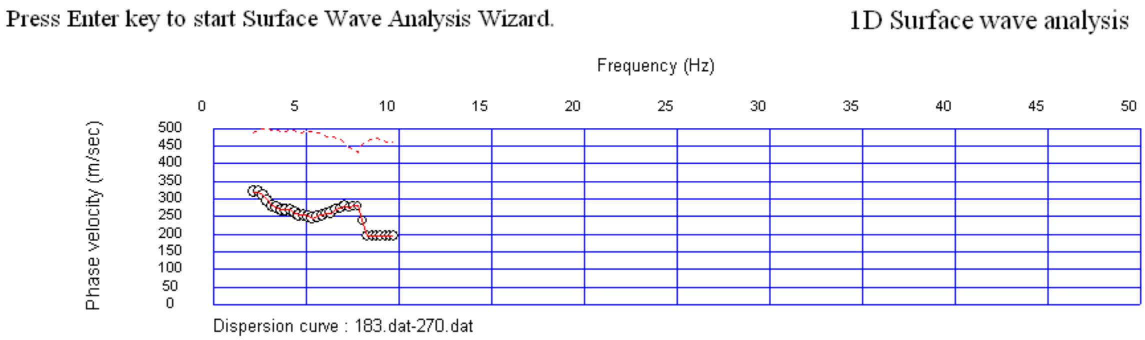


Figure 7. Example of an 8 second file of passive seismic data from files 183 to 270. Data collected using all low gains (24 dB) and the associated dispersion curve.

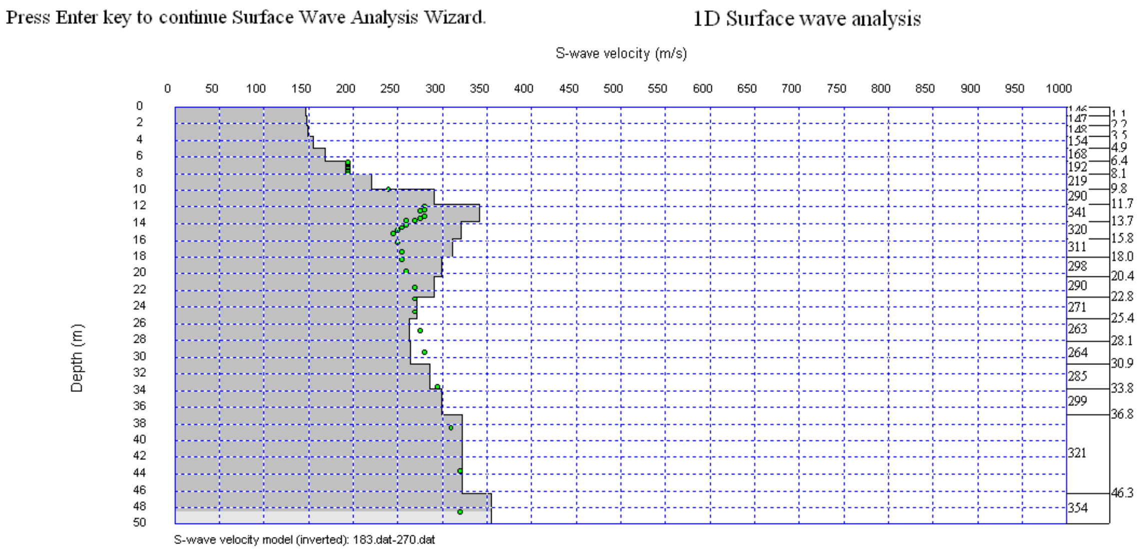
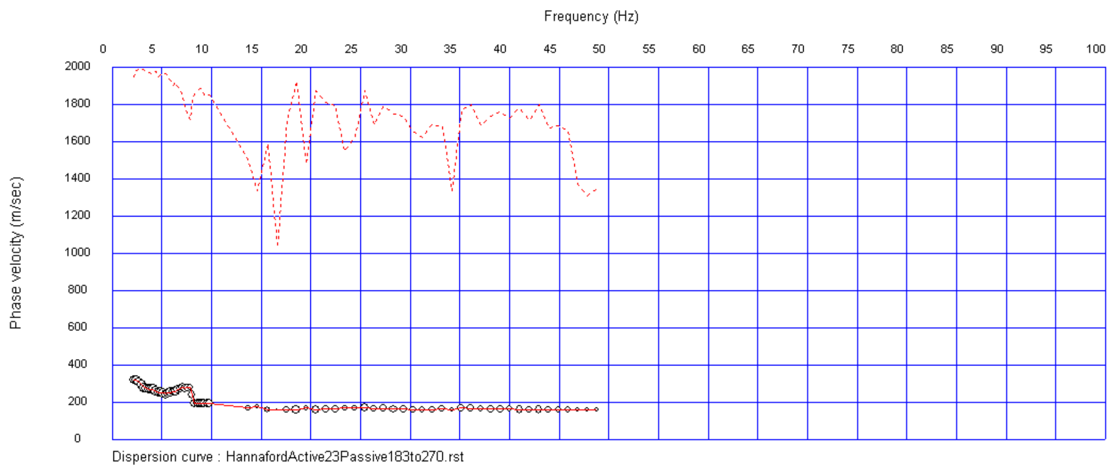


Figure 8. Modeled velocity profile for passive seismic data. Solution converged with 5 iterations to an RMS error of 18.0 m/s. There is a good general correspondence with velocities in hole B-104.

4C. Combined Active and Passive Surveys at Milton Square.



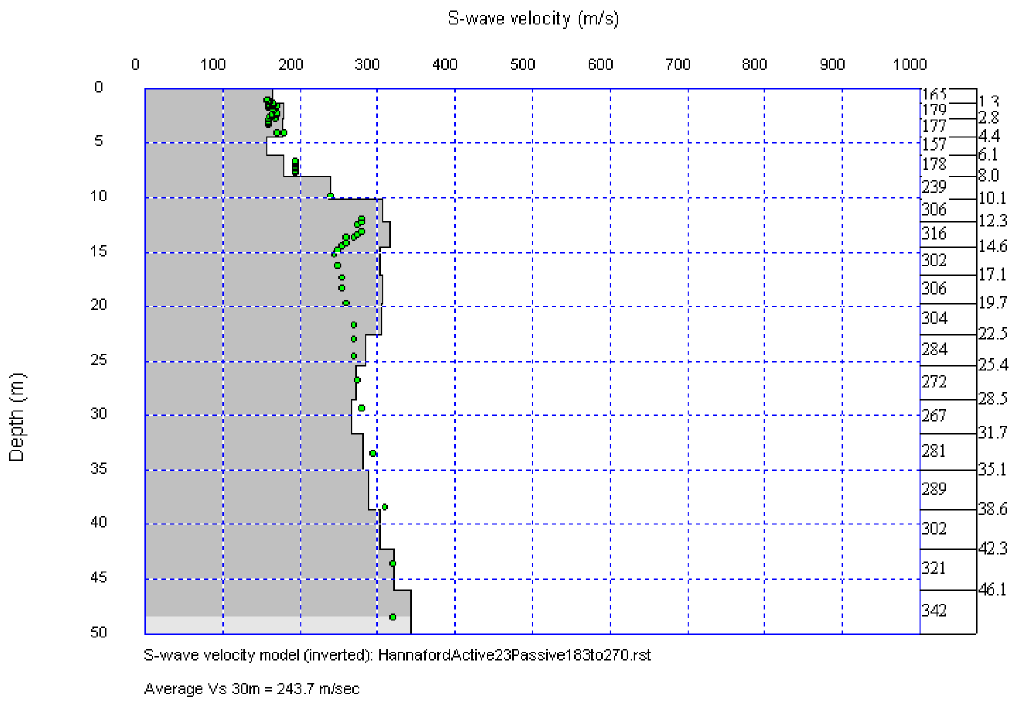
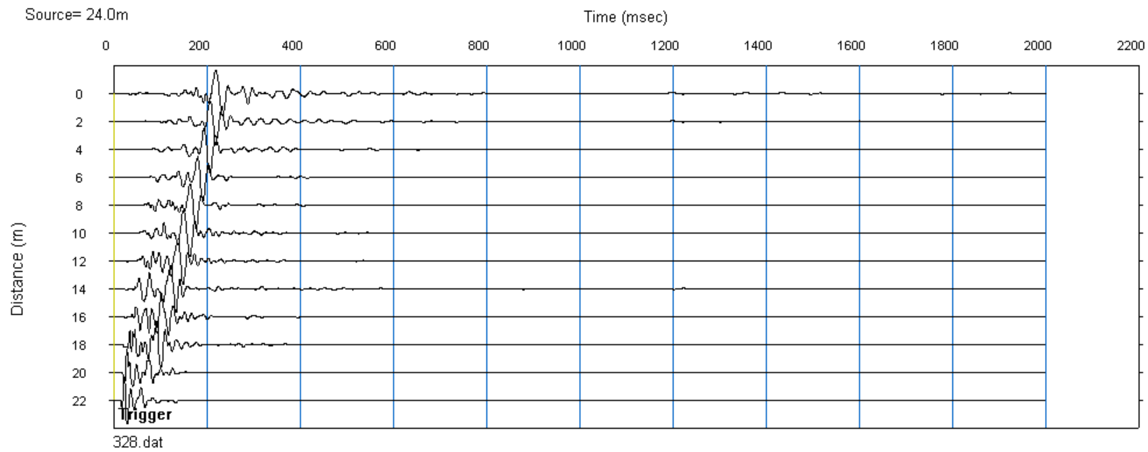


Figure 9. Dispersion curve and velocity model based on combined active and passive surveys for the Milton Square site.

5. Public Health Lab, UVM, Colchester
Data collected 05/03/2013
Data Processed 05/22/2013 by George Springston

5A. Active survey, File 328.dat. 22 meter spread length, hammer offset 2 meters.



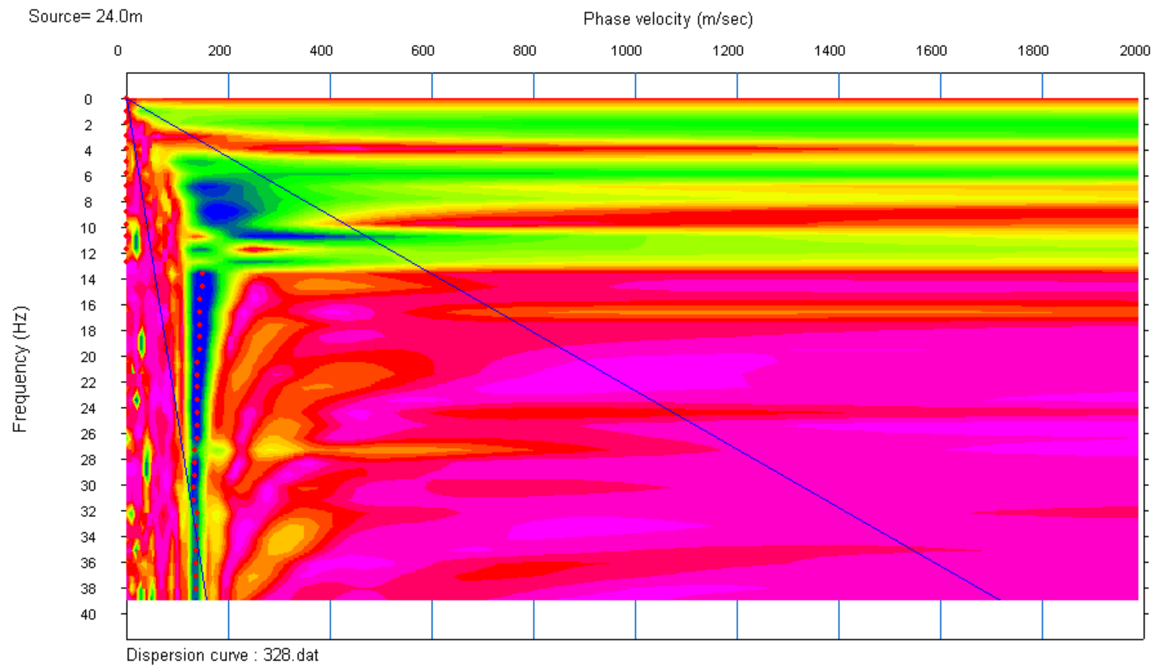


Figure 10. Dispersion curve and phase velocity versus frequency plot for active survey at Public Health Lab.

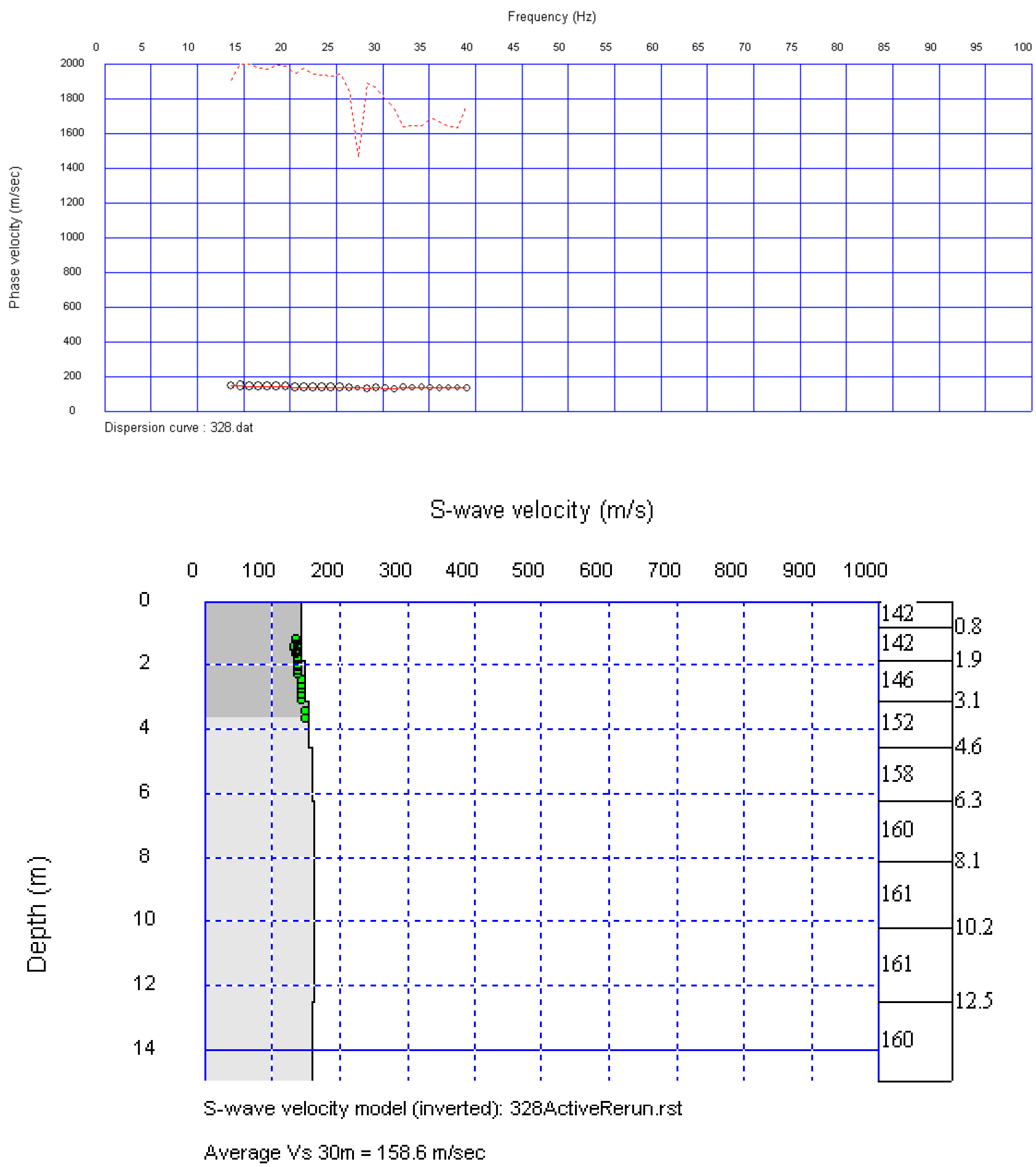
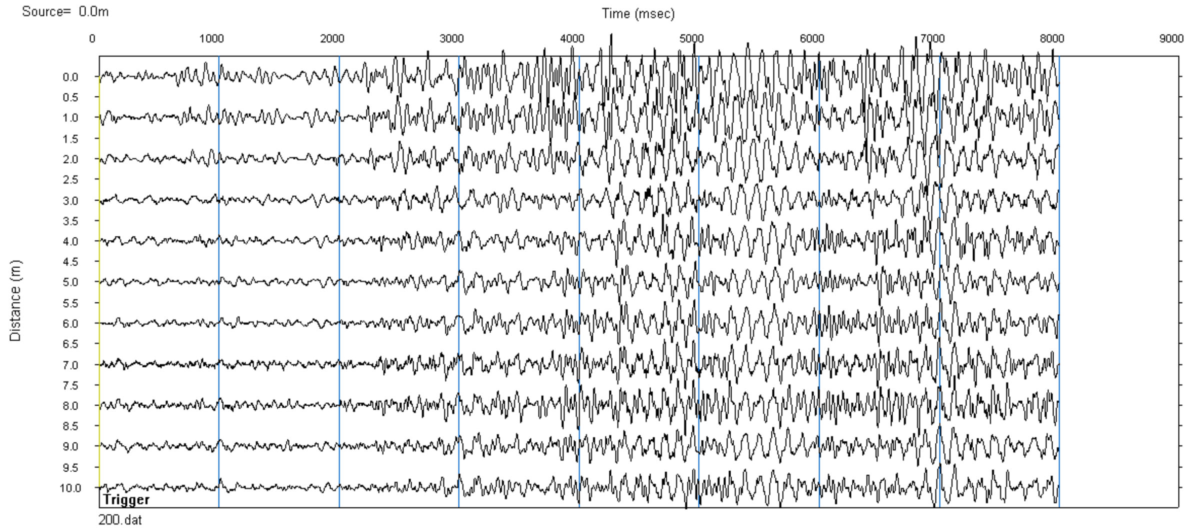


Figure 11. Dispersion curve and velocity model for active survey at Public Health Lab.

5B. Passive survey at Public Health Lab. Files 200-300.dat. L-shaped array with 25 meter arms, 11 geophones.



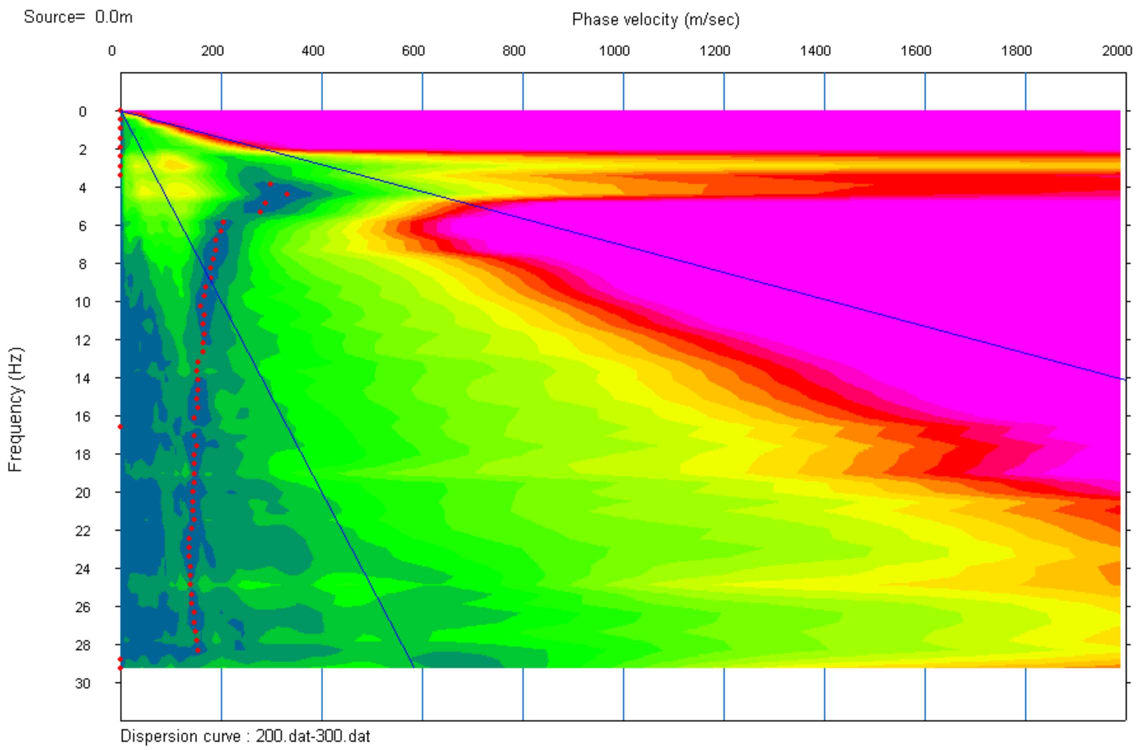
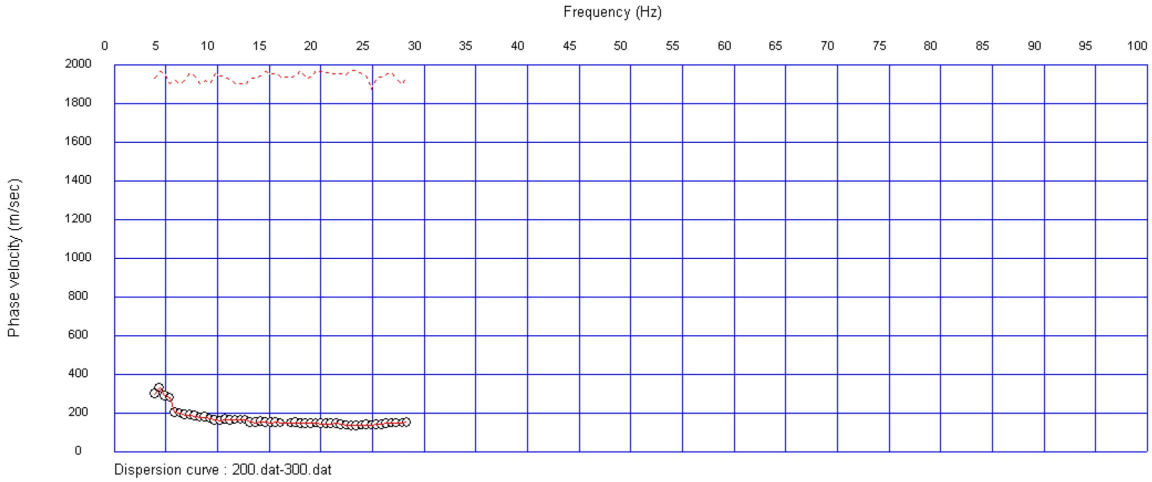


Figure 12. Example data file and phase velocity versus frequency plot for passive survey at Public Health Lab.



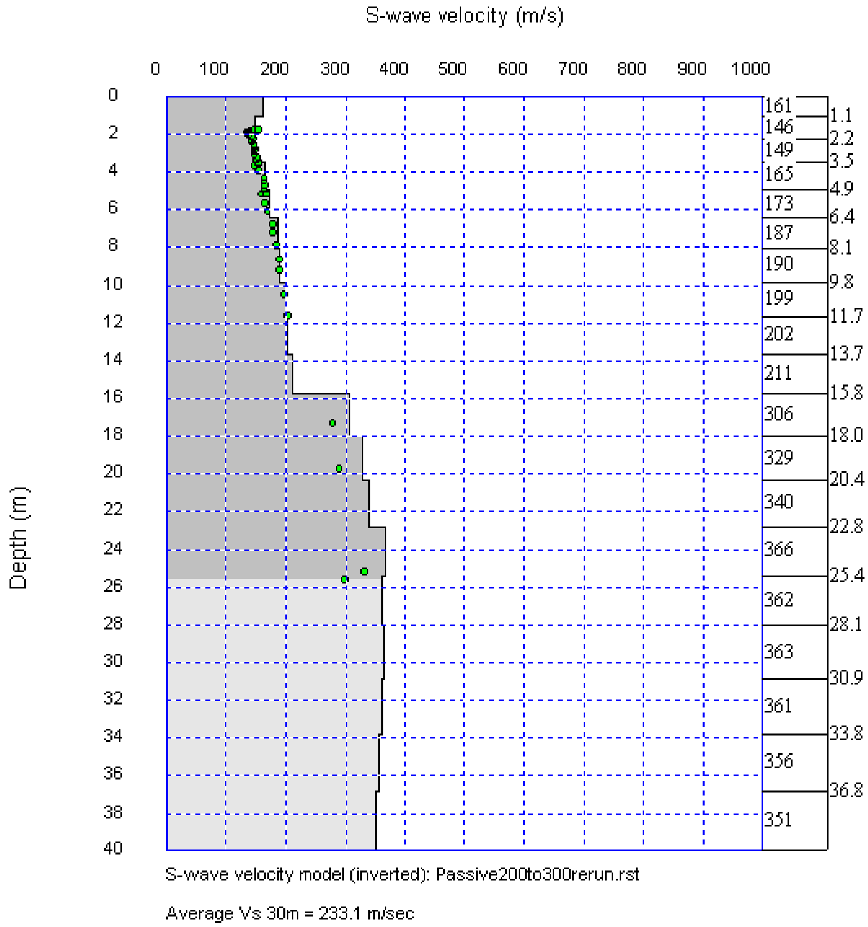
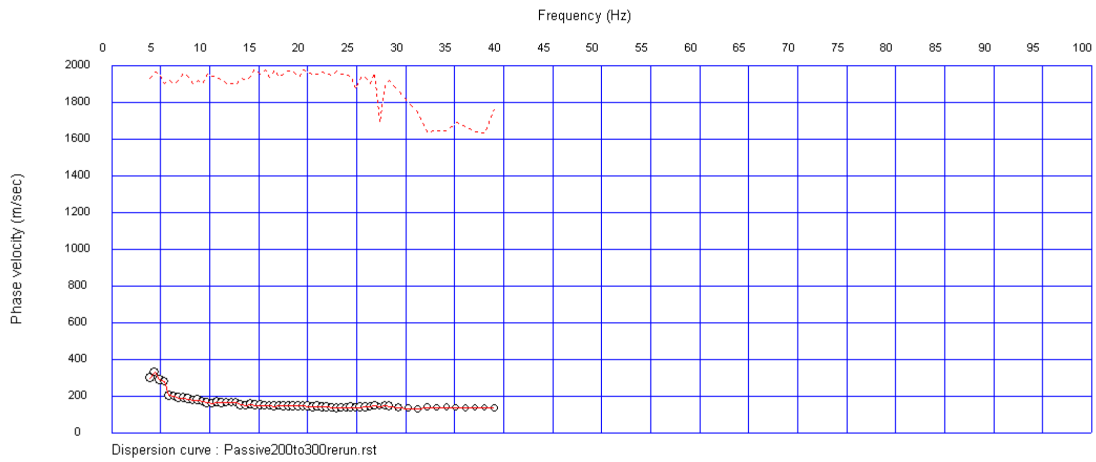


Figure 13. Dispersion curve and velocity model for passive survey at Public Health Lab.

5C. Combined Active and Passive surveys at Public Health Lab.



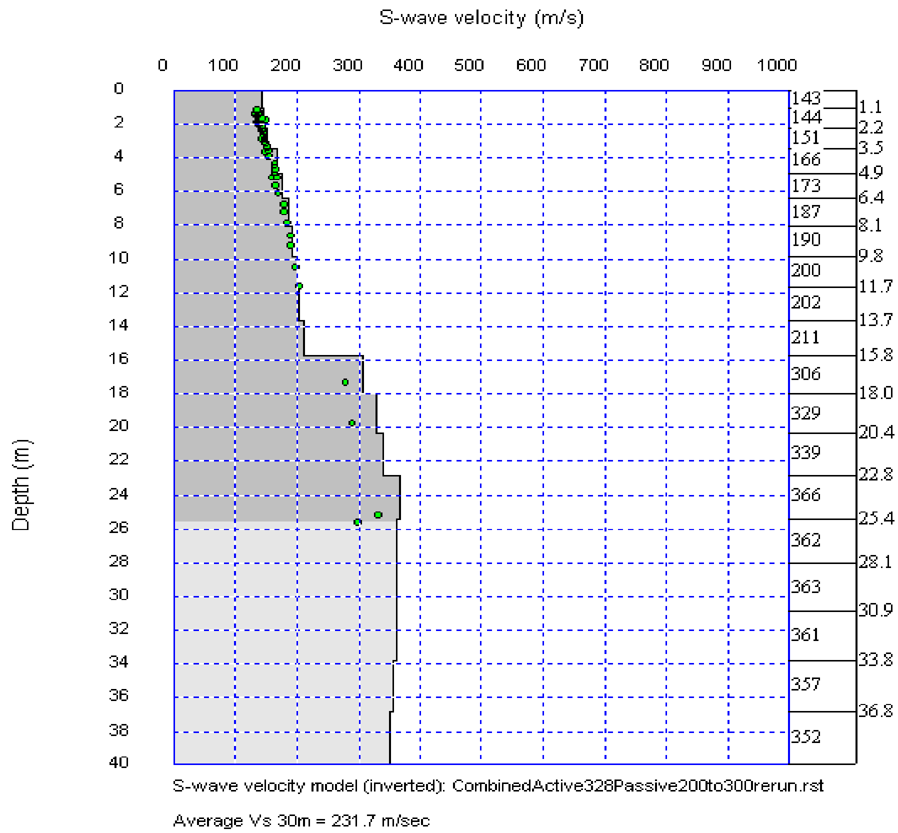


Figure 14. Dispersion curve and velocity model for combined active and passive surveys at Public Health Lab. The combined active and passive surveys shown above show a consistent picture of low, but increasing velocity down to about 16 meters, with an abrupt increase below there.

6. Acknowledgements

Thanks to John Lens and Bradford Berry for their hard work and enthusiastic assistance in gathering the field data.

7. References

Geometrics, 2009, SeisImager/SW Manual: Windows software for analysis of surface waves: Manual version 3.0, Geometrics Inc., 314p.

Lin, Chih-Ping, Cheng-Chou Chang, and Tzong-Sheng Chang, 2004, The use of MASW method in the assessment of soil liquefaction: Soil dynamics and Earthquake Engineering, v. 24, p 689-698.

Long, Michael, and Donahue, Shane, 2007, In situ shear wave velocity from multichannel analysis of surface waves (MASW) tests at eight Norwegian research sites: Canadian Geotechnical Journal, v. 44, p. 533-544.

Miller, R.D., Xia, Jianghai, Park, C.B and Ivanov, Julian, no date, Multichannel analysis of surface waves to map bedrock, 6 p., downloaded from ftp://geom.geometrics.com/pub/seismic/Literature/SurfaceWaves/KGS/LEv18n12.pdf

Park, C.B., and Miller, R.D., 2005, Seismic characterization of wind turbine sites in Kansas by the MASW method: Kansas Geological Survey Open File Report 2005-23, 30 p.

Park, C.B., Miller, R.D., and Xia, Jianghai, 1999, Multichannel analysis of surface waves: Geophysics, v. 64, no. 3, p. 800-808.

Park, C.B., Miller, R.D., Xia, Jianghai, and Ivanov, Julian, 2007, Multichannel analysis of surface waves (MASW)—active and passive methods: The Leading Edge, January, 6 p.

Stokoe, K.H., II, Lin, Yin-Cheng, Menq, Farn-Yuh, and Rosenblad, Brent, 2005, SASW measurements in Taiwan at 26 strong motion recordings sites: Summary report of the shear wave velocity profiles: Geotechnical Engineering Report GR05-2, Geotechnical Engineering Center, University of Texas at Austin,

Appendix 2

Subsurface Data for:

Burlington (Moran) Site
State of Vermont-Colchester Public Health Building Site
Milton Square Site

Burlington (Moran) Site
SCPT and Soil Boring Data

PRESENTATION OF IN SITU TESTING PROGRAM RESULTS

Community Sailing Center
Burlington, Vermont

August 25th, 2009

Prepared for:

GeoDesign, Inc.
Windsor, Vermont

786-33

Prepared by:

ConeTec Inc.
West Berlin, NJ

August 31st, 2009

1.0 INTRODUCTION

This report presents the results of a piezocone penetrometer testing (CPTU; also CPT) program carried out at the Community Sailing Center Site located in Burlington, Vermont. The work was performed under subcontract to GeoDesign, Inc. of Windsor, Vermont. The CPT program took place on August 25th, 2009.

A total of two soundings were completed at two different sounding locations. The CPT program was performed to evaluate in situ geotechnical criteria relative to the soils.

In addition to the CPT soundings, shear wave velocity tests were performed at both of the locations with testing at various depth intervals.

CPT sounding locations were selected and numbered under the direction and supervision of GeoDesign personnel.

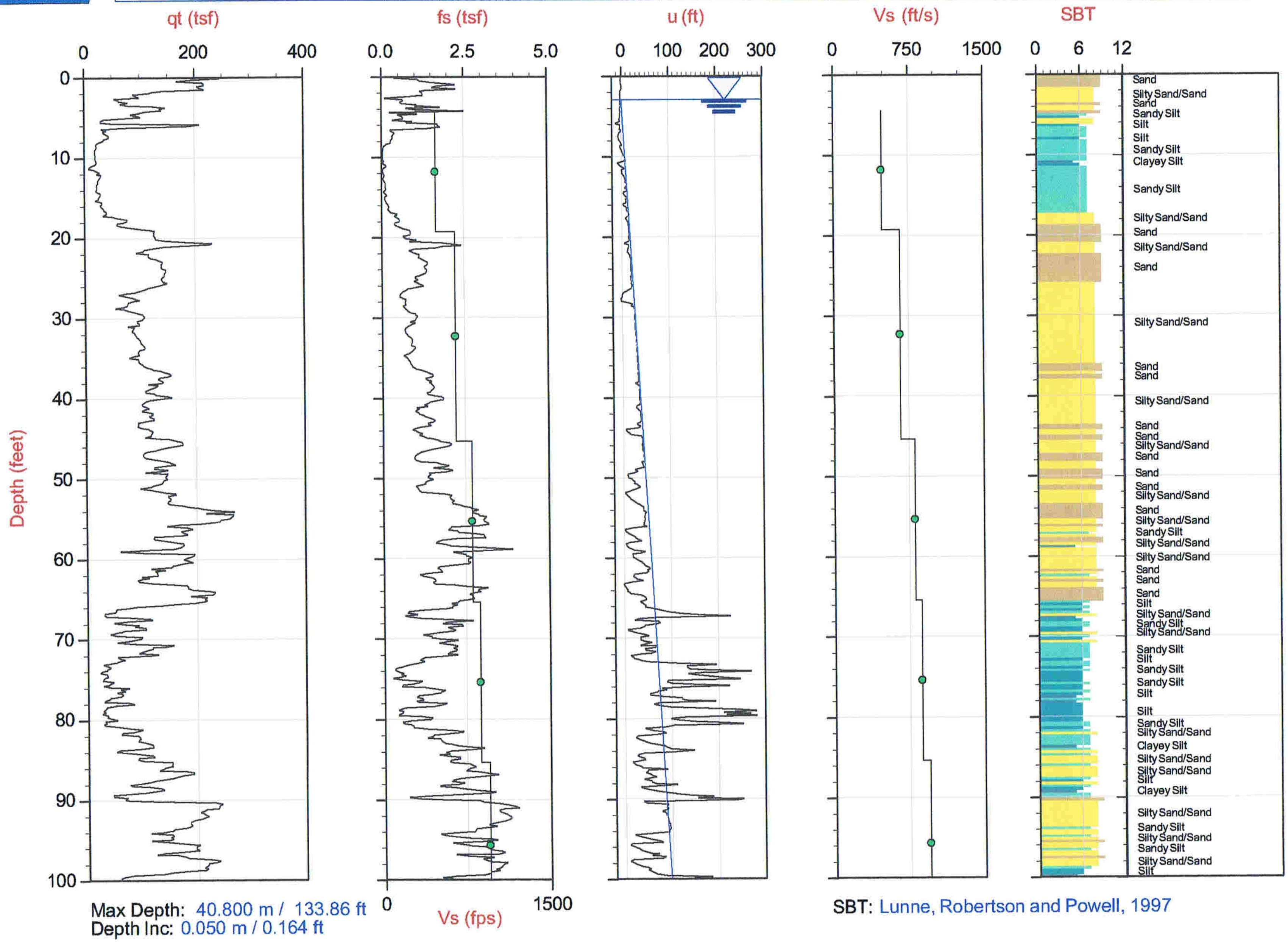
Shear Wave Velocity CPT Plots

ConeTec

GeoDesign

Job No: 09-756
Date: 08:25:09 08:18
Site: Burlington, VT

Sounding: CPT-1
Cone: 230:T1500F15U500



Max Depth: 40.800 m / 133.86 ft
Depth Inc: 0.050 m / 0.164 ft

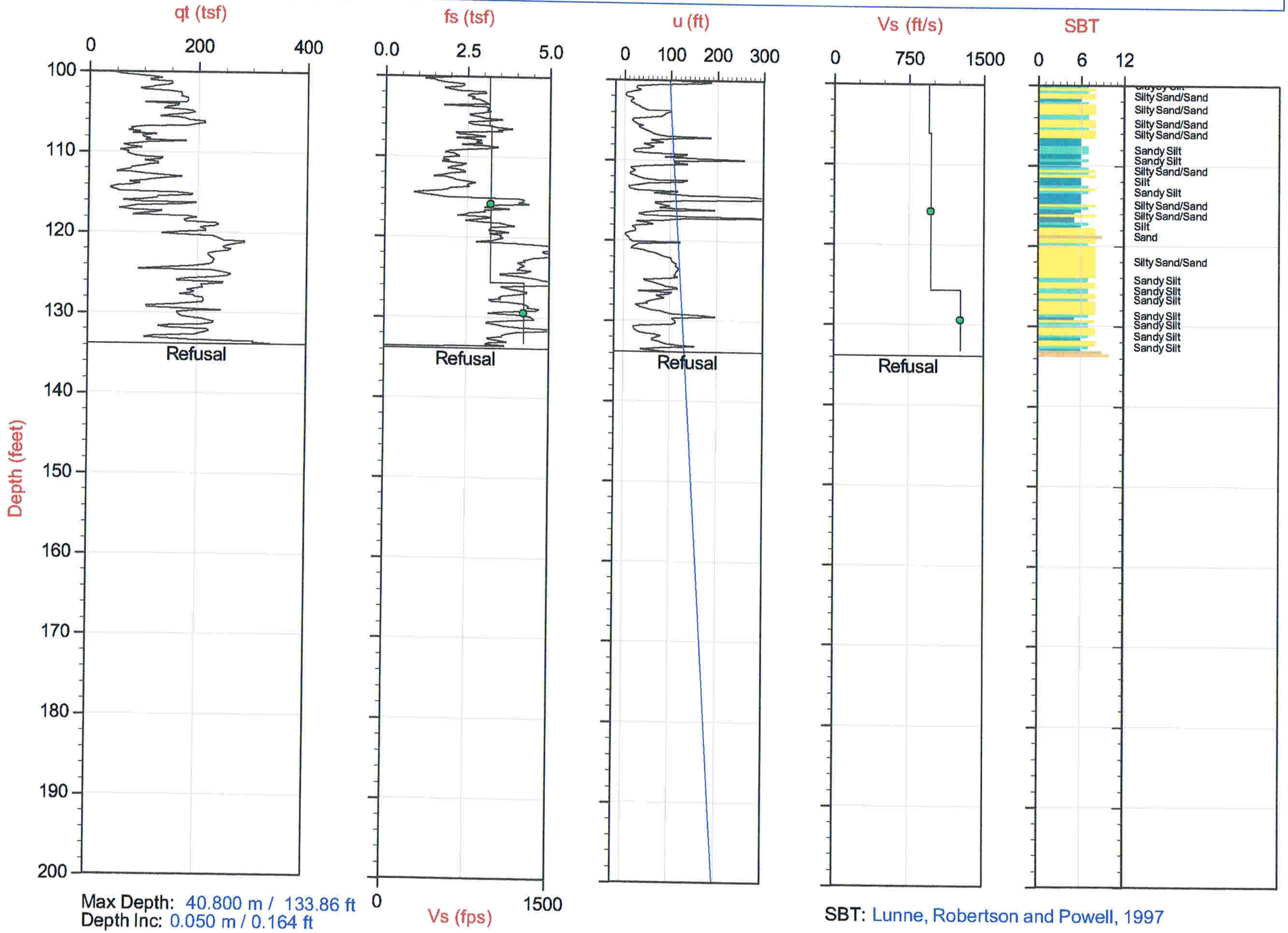
SBT: Lunne, Robertson and Powell, 1997

CONETEC

GeoDesign

Job No: 09-756
Date: 08:25:09 08:18
Site: Burlington, VT

Sounding: CPT-1
Cone: 230:T1500F15U500



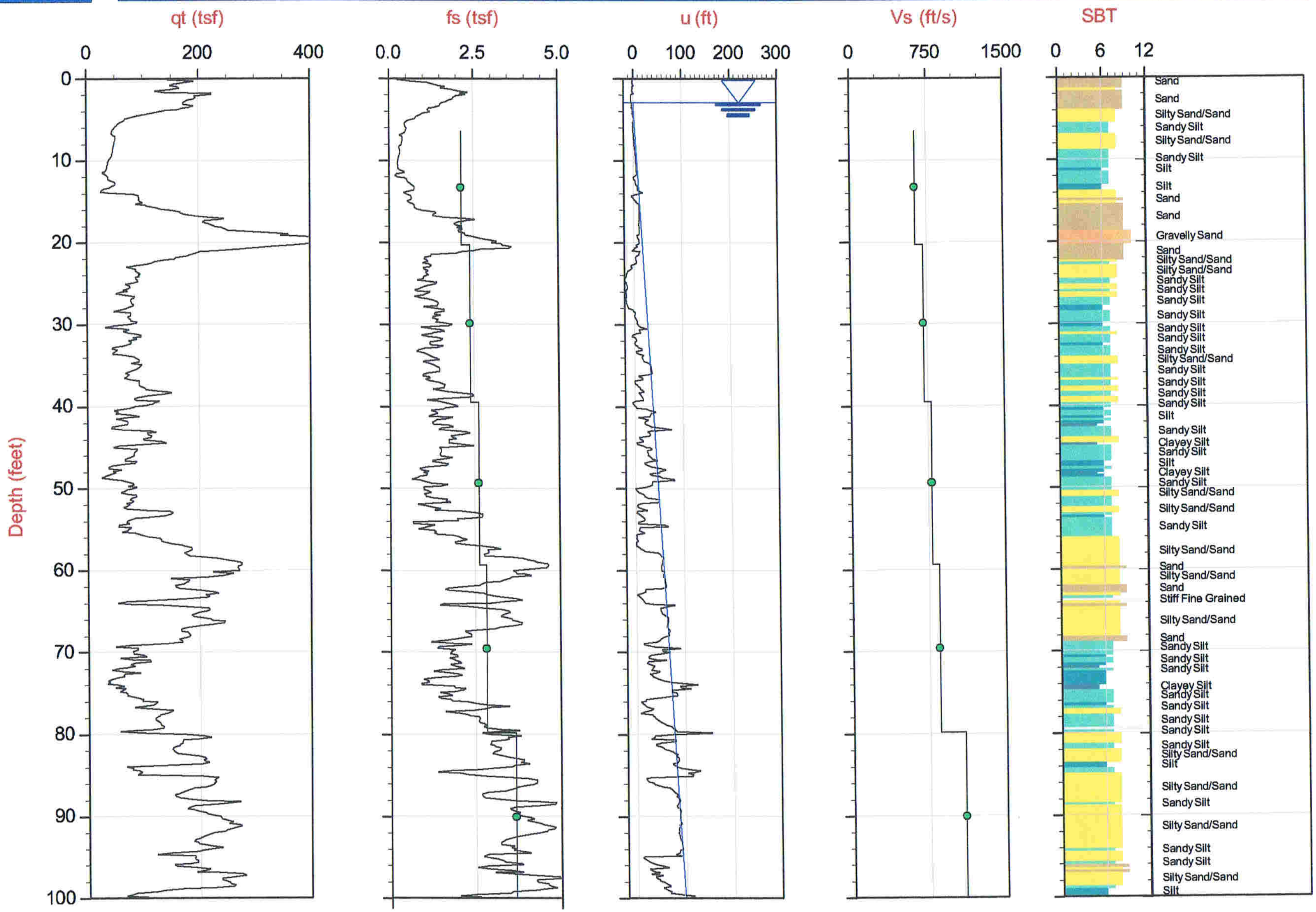
Max Depth: 40.800 m / 133.86 ft
Depth Inc: 0.050 m / 0.164 ft

SBT: Lunne, Robertson and Powell, 1997

CONETEC | *GeoDesign*

Job No: 09-756
Date: 08:25:09 09:55
Site: Burlington, VT

Sounding: CPT-2
Cone: 230:T1500F15U500



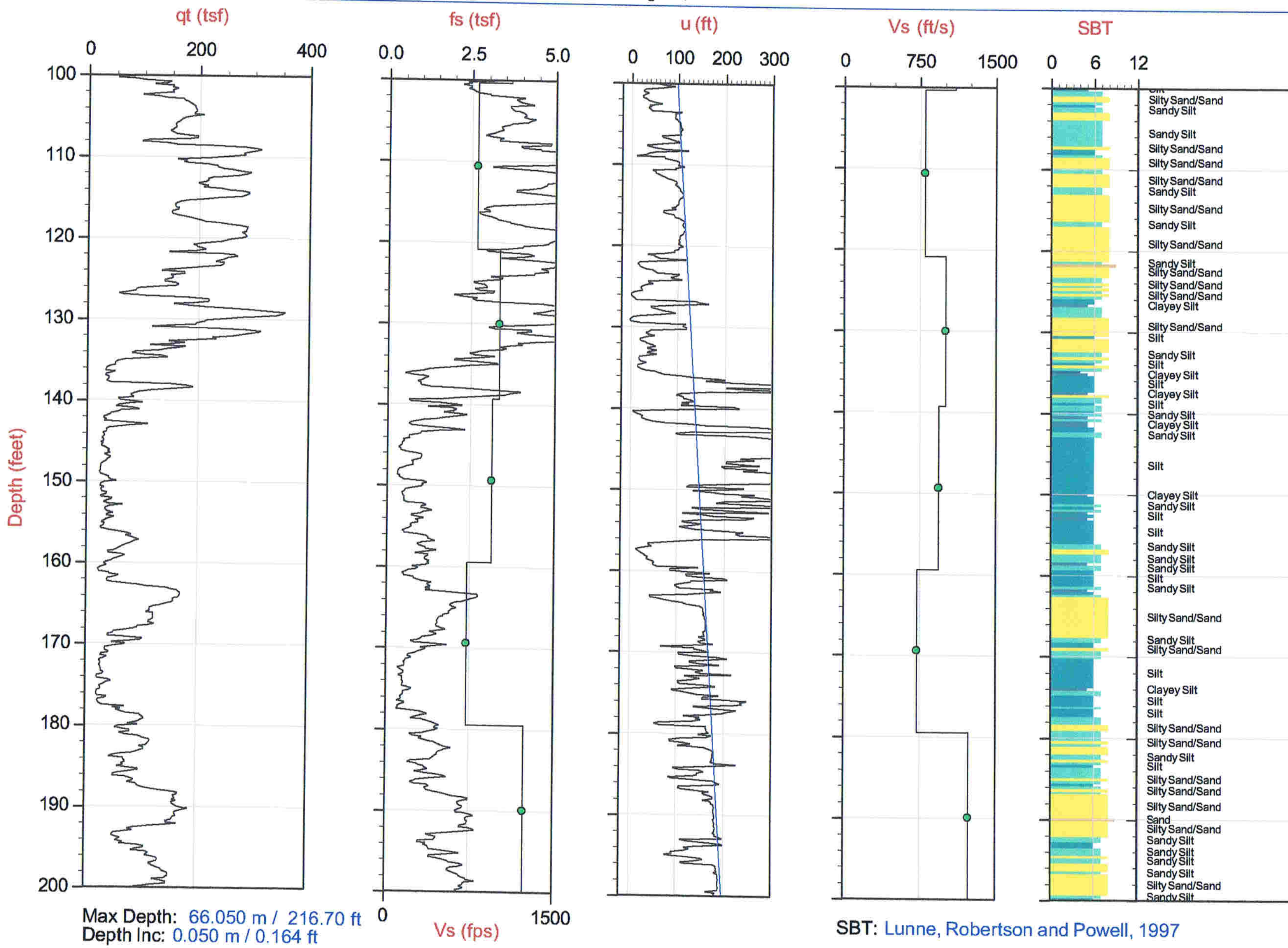
Max Depth: 66.050 m / 216.70 ft
Depth Inc: 0.050 m / 0.164 ft

SBT: Lunne, Robertson and Powell, 1997

CONETEC | GeoDesign

Job No: 09-756
Date: 08:25:09 09:55
Site: Burlington, VT

Sounding: CPT-2
Cone: 230:T1500F15U500



Max Depth: 66.050 m / 216.70 ft
Depth Inc: 0.050 m / 0.164 ft

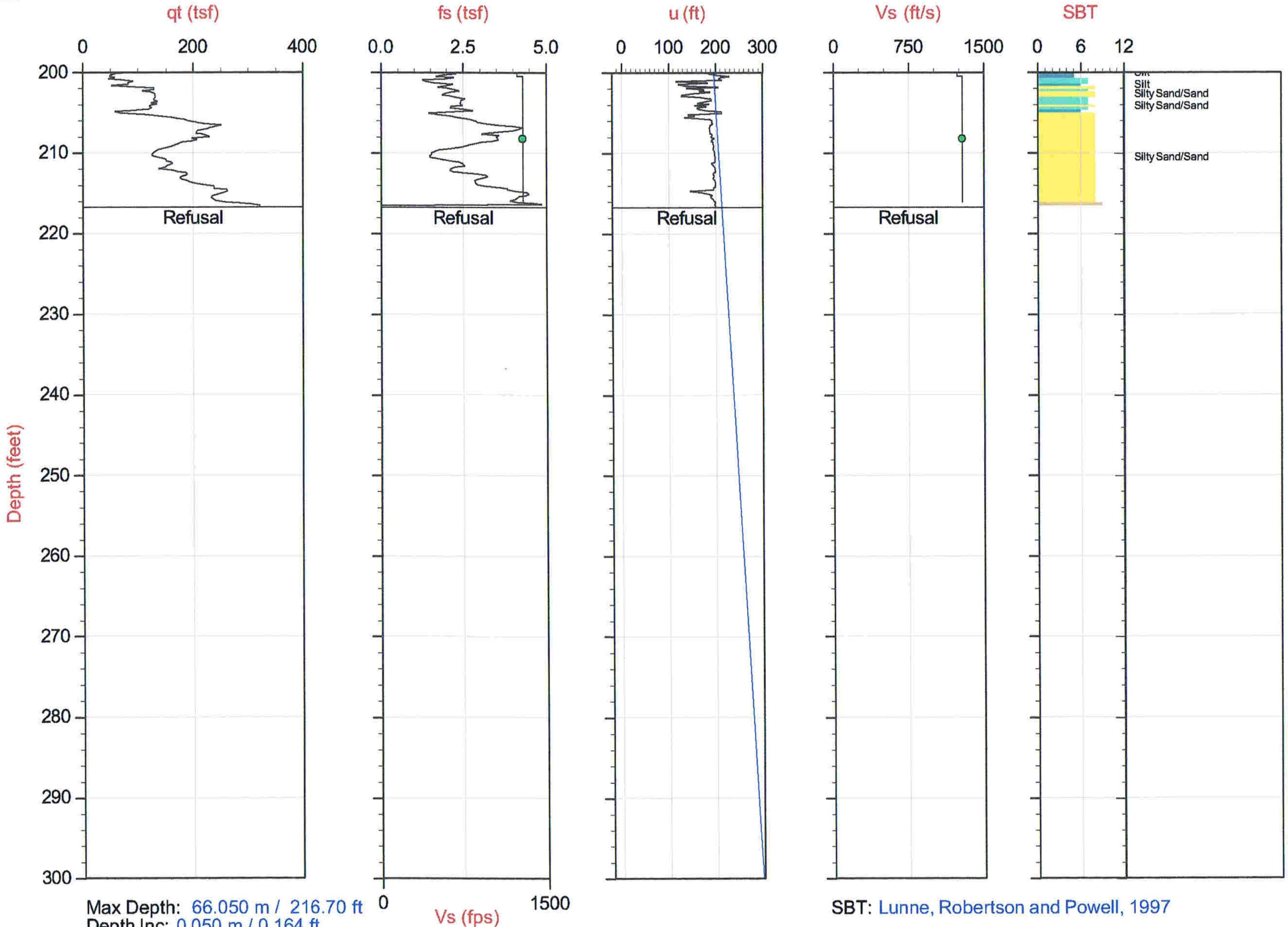
SBT: Lunne, Robertson and Powell, 1997

CONETEC

GeoDesign

Job No: 09-756
Date: 08:25:09 09:55
Site: Burlington, VT

Sounding: CPT-2
Cone: 230:T1500F15U500



Max Depth: 66.050 m / 216.70 ft
Depth Inc: 0.050 m / 0.164 ft

SBT: Lunne, Robertson and Powell, 1997

Job No	09-756
Client	GeoDesign
Project Title	Community Sailing Center
Hole	CPT-1
Site	Burlington, Vermont
Date	8/25/2009

Seismic Source:	Beam	
Source Offset:	1.97	(ft)
Source Depth:	0.00	(ft)
Geophone Offset:	0.66	(ft)

SEISMIC TEST RESULTS - Vs

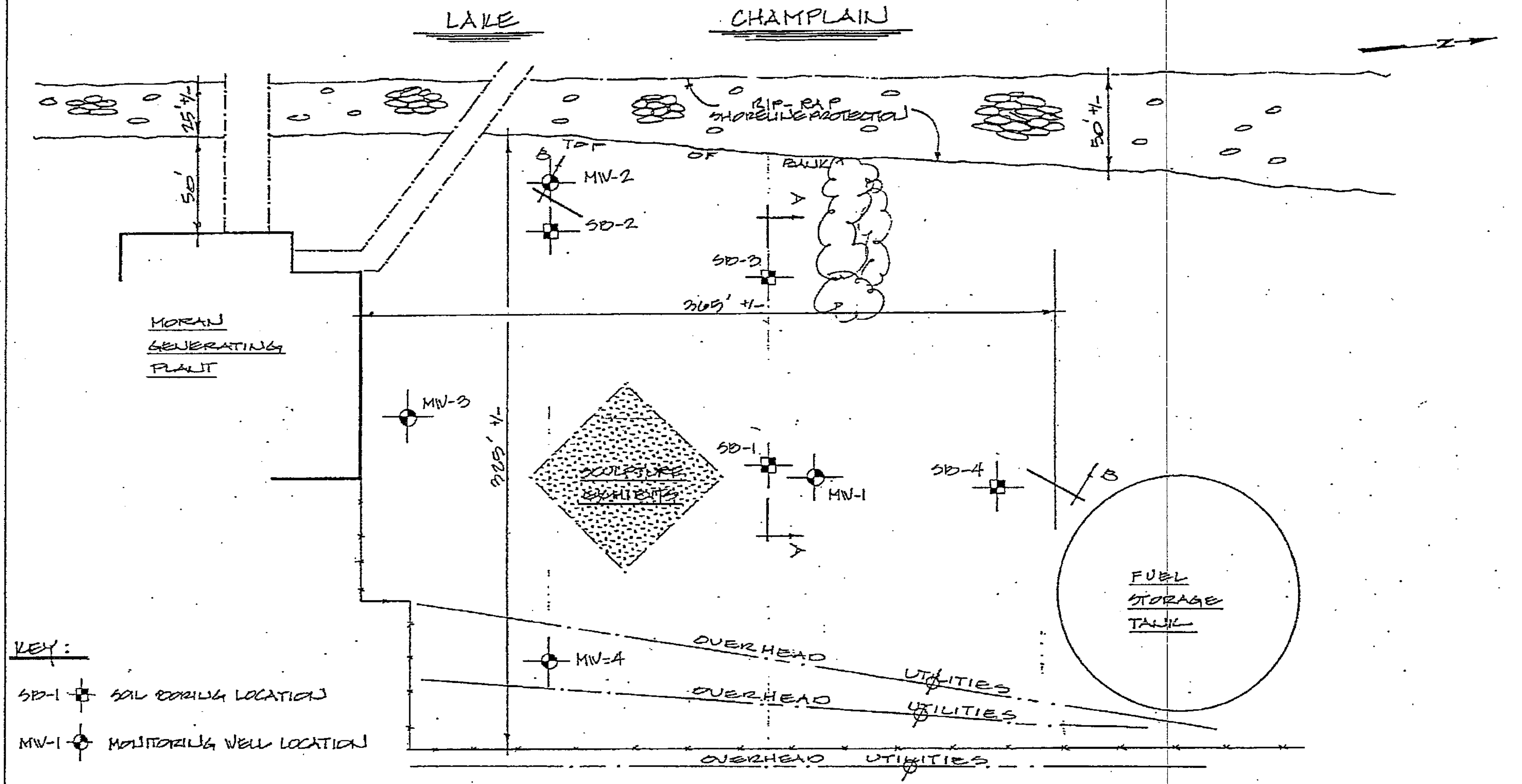
Tip Depth (ft)	Geophone Depth (ft)	Ray Path (ft)	Depth Interval (ft)	Time Interval (ms)	Mid-layer Depth (ft)	Vs Interval Velocity (ft/s)
5.08	4.42	4.84				
20.01	19.35	19.45	14.61	29.70	11.89	492
46.10	45.44	45.49	26.03	38.89	32.40	669
66.11	65.45	65.48	20.00	24.66	55.45	811
86.12	85.46	85.49	20.00	22.88	75.46	874
106.79	106.13	106.15	20.67	21.70	95.80	952
126.31	125.65	125.67	19.52	20.05	115.89	973
133.86	133.20	133.22	7.55	5.91	129.43	1277

Job No	09-756
Client	GeoDesign
Project Title	Community Sailing Center
Hole	CPT-2
Site	Burlington, Vermont
Date	8/25/2009

Seismic Source:	Beam	
Source Offset:	1.97	(ft)
Source Depth:	0.00	(ft)
Geophone Offset:	0.66	(ft)

SEISMIC TEST RESULTS - Vs

Tip Depth (ft)	Geophone Depth (ft)	Ray Path (ft)	Depth Interval (ft)	Time Interval (ms)	Mid-layer Depth (ft)	Vs Interval Velocity (ft/s)
7.05	6.39	6.69				
21.00	20.34	20.44	13.75	21.36	13.37	644
40.19	39.53	39.58	19.14	26.58	29.94	720
60.04	59.38	59.42	19.83	25.14	49.46	789
80.54	79.88	79.91	20.49	24.08	69.63	851
101.05	100.39	100.41	20.51	18.59	90.14	1103
121.55	120.89	120.91	20.50	25.55	110.64	802
139.93	139.27	139.29	18.38	18.29	130.08	1005
160.10	159.44	159.46	20.17	21.37	149.36	944
180.12	179.46	179.47	20.02	27.50	169.45	728
201.12	200.46	200.47	21.00	16.94	189.96	1240
216.70	216.04	216.05	15.58	12.05	208.25	1293



SK-1 SOIL BORING LOCATION PLAN

1" = 50'

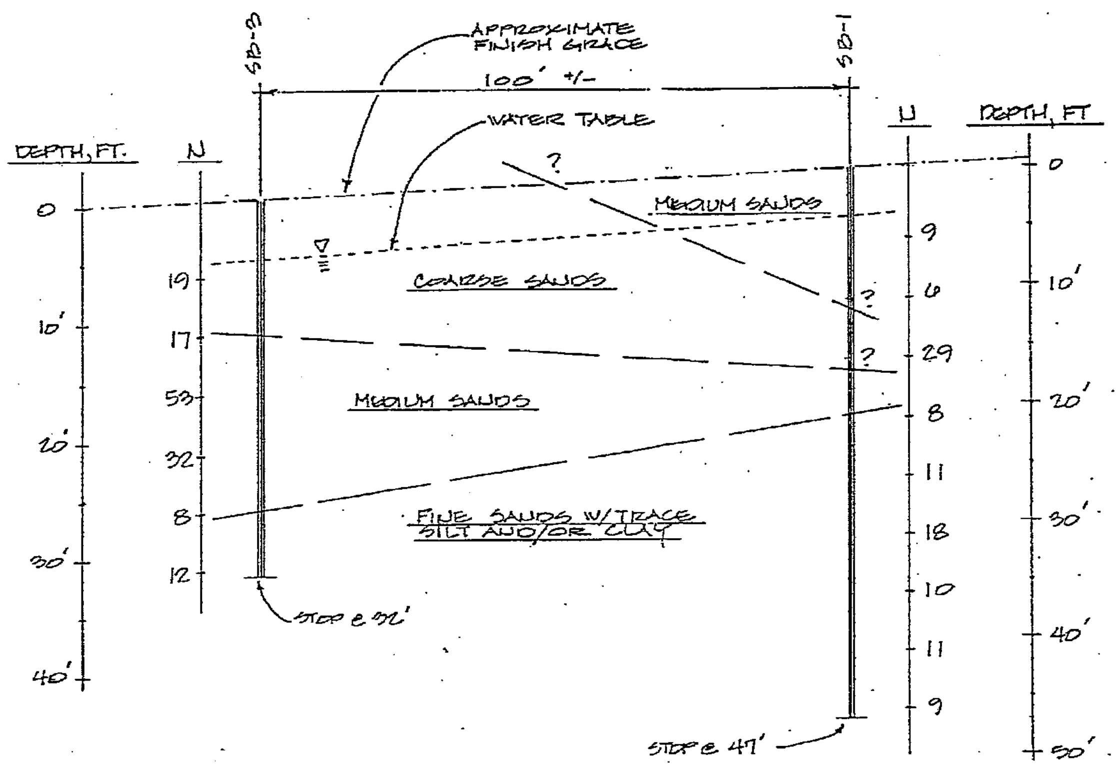
NOTE: DIMENSIONS SHOWN ARE APPROXIMATE AND SHOULD BE FIELD VERIFIED.

CITY OF BURLINGTON, VT.

JOB COMMUNITY RECREATION CENTER

SHEET NO. 1 OF 4

SCALE NOTED

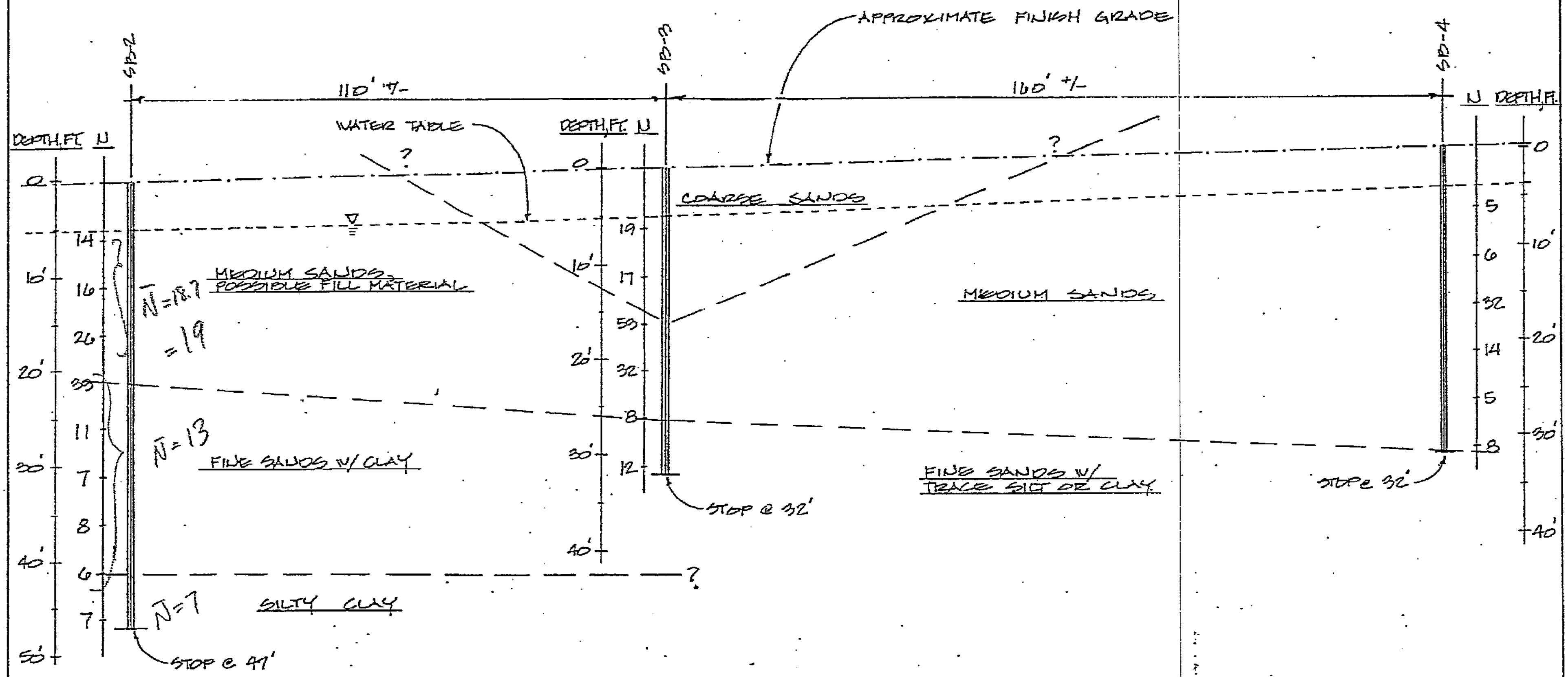


SK-2 SITE SECTION A-A

HORIZONTAL : 1" = 20'
VERTICAL : 1" = 10'

NOTE: DIMENSIONS SHOWN ARE APPROXIMATE AND SHOULD BE FIELD VERIFIED.

CITY OF BURLINGTON, VT.
JOB COMMUNITY RECREATION CENTER
SHEET NO. 2 OF 4
SCALE NOTED



SK-3 SITE SECTION B-B

HORIZONTAL: 1" = 20'
VERTICAL: 1" = 10'

NOTE: DIMENSIONS SHOWN ARE APPROXIMATE AND SHOULD BE FIELD VERIFIED.

CITY OF BURLINGTON, VT.
JOB COMMUNITY RECREATION CENTER
SHEET NO. 3 OF 4
SCALE NOTED

Green Mountain Boring Co., Inc.

R. D. 2 — BARRE, VERMONT 05641

SHEET 1 OF
DATE 9/26/91
HOLE NO. SB-1
LINE & STA.
OFFSET None

GROUND WATER OBSERVATIONS		CASING	SAMPLER	CORE BAR.	
At 3' at 0 Hours	Type	AUGERS	SPLIT SPOON		SURFACE ELEV.
	Size I. D.	2.5"	1 3/8"		DATE STARTED 9/26/91
	Hammer Wt.		140#		DATE COMPL. 9/26/91
At at Hours	Hammer Fall		30"		BORING FOREMAN
					INSPECTOR
					SOILS ENGR.

LOCATION OF BORING: As staked

DEPTH	Casing Blows per foot	Sample Depths From — To	Type of Sample	Blows per 6" on Sampler From 0-6	6-12	To 12-18	Moisture Density or Consist.	Strata Change Elev.	SOIL IDENTIFICATION Remarks include color, gradation, Type of soil etc. Rock-color, type, condition, hardness, Drilling time, seams and etc.	SAMPLE No.	Pen	
		5' - 7'	Dry	3 / 9	6	7	Wet		Brown medium sand with trace of stone	1	24"	2
		10'-12'	Dry	8 / 5	3	3	Wet		Brown medium sand some pebbles	2	24"	2
		15'-17'	Dry	13 / 35	16	23	Wet	16'	Coarse sand into medium sand	3	24"	2
		20'-22'	Dry	3 / 12	5	10	Wet		Fine sand and silt	4	24"	2
		25'-27'	Dry	3 / 18	8	12	Wet		Fine sand with trace of silt	5	24"	2
		30'-32'	Dry	8 / 17	10	14	Wet		Fine sand with trace of silt	6	24"	2
		35'-37'	Dry	4 / 14	6	10	Wet		Fine sand	7	24"	2
		40'-42'	Dry	5 / 9	6	8	Wet		Fine sand, silt, clay	8	24"	2
		45'-47'	Dry	4 / 7	5	5	Wet		Fine sand and silt	9	24"	2

GROUND SURFACE TO 45' USED 2.50" AUGERS: THEN Split spoon to 47'

140 lb. Wt. x 30" fall on 2" O. D. Sampler

Sample Type
D = Dry C = Cored W = Washed
UP = Undisturbed Piston
TP = Test Pit A = Auger V = Vane Test

Proportions Used	
trace	0 to 10%
little	10 to 20%
some	20 to 35%

Cohesionless Density	
0-10	Loose
10-30	Med. Dense
30-50	Dense

Cohesive Consistency	
0-4	Soft
4-8	M/Stiff
8-15	Stiff
30 +	Hard

SUMMARY
Earth Boring 47
Rock Coring
Samples 9

Green Mountain Boring Co., Inc.

R. D. 2 — BARRE, VERMONT 05641

SHEET 2 OF

DATE 9/26/91

HOLE NO. MW-1

LINE & STA.

OFFSET None

GROUND WATER OBSERVATIONS		CASING	SAMPLER	CORE BAR.
At 3' at 0 Hours	Type	AUGERS	SPLIT SPOON	
	Size I. D.	3.25"	1 3/8"	
At at Hours	Hammer Wt.		140#	
	Hammer Fall		30"	

SURFACE ELEV.

DATE STARTED 9/26/91

DATE COMPL. 9/26/91

BORING FOREMAN

INSPECTOR

SOILS ENGR.

~~LOCATION OF BORING:~~ As mapped

DEPTH	Casing Blows per foot	Sample Depths From — To	Type of Sample	Blows per 6" on Sampler From 0-6	6-12	To 12-18	Moisture Density or Consist.	Strata Change Elev.	SOIL IDENTIFICATION Remarks include color, gradation, Type of soil etc. Rock-color, type, condition, hardness, Drilling time, seams and etc.	SAMPLE No.	Pen
									Augered to 12' and installed well		
									Materials Used:		
									10' .020 Screen		
									4' 2" riser		
									1 top wing cap		
									1 bottom slip cap		
									1½ bags of sand		
									¼ bag of bentonite		

GROUND SURFACE TO 12' USED 3.25" AUGERS: THEN Installed well

Sample Type
D=Dry C=Cored W=Washed
UP=Undisturbed Piston
TP=Test Pit A=Auger V=Vane Test

Proportions Used
trace 0 to 10%
little 10 to 20%
some 20 to 35%

140 lb. Wt. x 30" fall on 2" O. D. Sampler

Cohesionless Density		Cohesive Consistency			
0-10	Loose	0-4	Soft	30 +	Hard
10-30	Med. Dense	4-8	M/Stiff		
30-50	Dense	8-15	Stiff		

SUMMARY:
Earth Boring 1
Rock Coring
Samples 0

Green Mountain Boring Co., Inc.

R. D. 2 — BARRE, VERMONT 05641

SHEET 3 OF ....
DATE 9/26/91
HOLE NO. MW-2
LINE & STA.
OFFSET None

GROUND WATER OBSERVATIONS		CASING	SAMPLER	CORE BAR.	
At 5' at 0 Hours	Type	AUGERS	SPLIT SPOON		SURFACE ELEV:
	Size I. D.	3.25"	1 3/8"		DATE STARTED 9/26/91
At ..... at ..... Hours	Hammer Wt.		140#		DATE COMPL. 9/26/91
	Hammer Fall		30"		BORING FOREMAN
					INSPECTOR
					SOILS ENGR.

LOCATION OF BORING: As mapped

DEPTH	Casing Blows per foot	Sample Depths From — To	Type of Sample	Blows per 6" on Sampler From 0-6	6-12	To 12-18	Moisture Density or Consist.	Strata Change Elev.	SOIL IDENTIFICATION Remarks include color, gradation, Type of soil etc. Rock-color, type, condition, hardness, Drilling time, seams and etc.	SAMPLE No.	Pen
									Augered to 14' and installed well Materials Used: 10' .020 screen 6' 2" riser 1 top wing cap 1 bottom slip cap 1½ bags of sand ¼ bag of bentonite		

GROUND SURFACE TO 14' USED 3.25" AUGERS: THEN Installed well.

Sample Type	Proportions Used	140 lb. Wt. x 30" fall on 2" O. D. Sampler		SUMMARY
D=Dry C=Cored W=Washed	trace 0 to 10%	Cohesionless Density	Cohesive Consistency	Earth Boring
UP=Undisturbed Piston	little 10 to 20%	0-10 Loose	0-4 Soft 30 + Hard	Rock Coring
TP=Test Pit A=Auger V=Vane Test	some 20 to 35%	10-30 Med. Dense	4-8 M/Stiff	Samples
UT=Undisturbed Thinwall	and 35 to 50%	30-50 Dense	8-15 Stiff	
		50 + Very Dense	15-30 V-Stiff	HOLE NO. MW-

Green Mountain Boring Co., Inc.

R. D. 2 — BARRE, VERMONT 05641

SHEET 4 OF
DATE 9/26/91
HOLE NO. MW-3
LINE & STA.
OFFSET None

GROUND WATER OBSERVATIONS		CASING	SAMPLER	CORE BAR.
At 6' at 0 Hours	Type	AUGERS	SPLIT SPOON	
	Size I. D.	3.25"	1 3/8"	
At at Hours	Hammer Wt.		140#	
	Hammer Fall		30"	

SURFACE ELEV.
DATE STARTED 9/26/91
DATE COMPL. 9/26/91
BORING FOREMAN
INSPECTOR
SOILS ENGR.

~~LOCATION OF BORING:~~ As mapped

DEPTH	Casing Blows per foot	Sample Depths From — To	Type of Sample	Blows per 6" on Sampler From 0-6	6-12	To 12-18	Moisture Density or Consist.	Strata Change Elev.	SOIL IDENTIFICATION Remarks include color, gradation, Type of soil etc. Rock-color, type, condition, hardness, Drilling time, seams and etc.	SAMPLE No.	Pen
									Augered to 14' and installed well Materials Used" 10' .020 screen 6' 2" riser 1 top wing cap 1 bottom slip cap 1¼ bags of sand ¼ bag bentonite		

GROUND SURFACE TO 14' USED 3.25" AUGERS: THEN Installed Well

140 lb. Wt. x 30" fall on 2" O. D. Sampler

Sample Type
D = Dry C = Cored W = Washed
UP = Undisturbed Piston
TP = Test Pit A = Auger V = Vane Test

Proportions Used	
trace	0 to 10%
little	10 to 20%
some	20 to 35%

Cohesionless Density		Cohesive Consistency	
0-10	Loose	0-4	Soft
10-30	Med. Dense	4-8	M/Stiff
30-50	Dense	8-15	Stiff
		30 +	Hard

SUMMARY
Earth Boring 1
Rock Coring ..
Samples ()

Green Mountain Boring Co., Inc.

R. D. 2 — BARRE, VERMONT 05641

SHEET 5 OF
DATE 9/27/91
HOLE NO. MW-4
LINE & STA.
OFFSET None

GROUND WATER OBSERVATIONS

At 4' at 0 Hours

At at Hours

	CASING	SAMPLER	CORE BAR.
Type	AUGERS	SPLIT SPOON	
Size I. D.	3.25"	1 3/8"	
Hammer Wt.		140#	
Hammer Fall		30"	

SURFACE ELEV.
DATE STARTED 9/27/91
DATE COMPL. 9/27/91
BORING FOREMAN
INSPECTOR
SOILS ENGR.

LOCATION OF BORING: As mapped

DEPTH	Casing Blows per foot	Sample Depths From — To	Type of Sample	Blows per 6" on Sampler From To 0-6	6-12	12-18	Moisture Density or Consist.	Strata Change Elev.	SOIL IDENTIFICATION Remarks include color, gradation, Type of soil etc. Rock-color, type, condition, hardness, Drilling time, seams and etc.	SAMPLE No.	Pen
									Augered to 14' and installed well Materials Used: 10' .020 screen 6' 2" riser 1 top wing cap 1 bottom slip cap 1½ bags of sand ¼ bag of bentonite		

GROUND SURFACE TO 14' USED 3.25" AUGERS: THEN Installed well

Sample Type
D = Dry C = Cored W = Washed
UP = Undisturbed Piston
TP = Test Pit A = Auger V = Vane Test

Proportions Used
trace 0 to 10%
little 10 to 20%
some 20 to 35%

140 lb. Wt. x 30" fall on 2" O. D. Sampler

Cohesionless Density		Cohesive Consistency			
0-10	Loose	0-4	Soft	30 +	Hard
10-30	Med. Dense	4-8	M/Stiff		
30-50	Dense	8-15	Stiff		

SUMMARY
Earth Boring
Rock Coring
Samples 0

Green Mountain Boring Co., Inc.

R. D. 2 — BARRE, VERMONT 05641

SHEET 6 OF
DATE 9/27/91
HOLE NO. SB-2
LINE & STA.
OFFSET None

GROUND WATER OBSERVATIONS		CASING	SAMPLER	CORE BAR.	
At 5' at 0 Hours	Type	AUGERS	SPLIT SPOON		SURFACE ELEV.
	Size I. D.	2.50"	1 3/8"		DATE STARTED 9/27/91
At at Hours	Hammer Wt.		140#		DATE COMPL. 9/27/91
	Hammer Fall		30"		BORING FOREMAN
					INSPECTOR
					SOILS ENGR.

LOCATION OF BORING: As mapped (SB-4)

DEPTH	Casing Blows per foot	Sample Depths From — To	Type of Sample	Blows per 6" on Sampler From 0-6	6-12	To 12-18	Moisture Density or Consist.	Strata Change Elev.	SOIL IDENTIFICATION Remarks include color, gradation, Type of soil etc. Rock-color, type, condition, hardness, Drilling time, seams and etc.	SAMPLE No.	Pen
		5' - 7'	Dry	6	8	72	Dry		Fine sand fractures of brick	1	24"
				23							
									Auger refusal on stone at 7' Offset 5' West		
		10'-12'	Dry	8	8	10	Wet		Medium sand some stone	2	24"
				12							
		15'-17'	Dry	12	14	24	Wet		Coarse sand into medium sand with pebbles	3	24"
				33							
		20'-22'	Dry	8	25	26	Wet		Medium sand into fine sand	3	24"
				26							
		25'-27'	Dry	5	6	6	Wet		Fine sand, little clay	4	24"
				8							
		30'-32'	Dry	3	4	5	Wet		Fine sand with a little clay	5	24"
				7							
		35'-37'	Dry	3	5	8	Wet		Fine sand, some clay	6	24"
				13							
		40'-42'	Dry	3	3	4	Wet		Silty grey clay	7	24"
				4							
		45'-47'	Dry	3	4	6	Wet		Silty grey clay	8	24"
				9							

GROUND SURFACE TO 45' USED 2.50" AUGERS: THEN Split spoon to 47'

140 lb. Wt. x 30" fall on 2" O. D. Sampler

Sample Type
D=Dry C=Cored W=Washed
UP=Undisturbed Piston
TP=Test Pit A=Auger V=Vane Test

Proportions Used	
trace	0 to 10%
little	10 to 20%
some	20 to 35%

Cohesionless Density	
0-10	Loose
10-30	Med. Dense
30-50	Dense

Cohesive Consistency		
0-4	Soft	30 + Hard
4-8	M/Stiff	
8-15	Stiff	

SUMMARY
Earth Boring 4
Rock Coring
Samples 9

Green Mountain Boring Co., Inc.

R. D. 2 — BARRE, VERMONT 05641

SHEET 1 OF ....
DATE 9/27/91
HOLE NO. SB-3
LINE & STA. ....
OFFSET None

GROUND WATER OBSERVATIONS		CASING	SAMPLER	CORE BAR.	
At 5' at 0 Hours	Type	AUGERS	SPLIT SPOON		SURFACE ELEV.
	Size I. D.	2.50"	1 3/8"		DATE STARTED 9/27/91
At .... at .... Hours	Hammer Wt.		140#		DATE COMPL.
	Hammer Fall		30"		BORING FOREMAN
					INSPECTOR
					SOILS ENGR.

LOCATION OF BORING: As mapped (SB-6)

DEPTH	Casing Blows per foot	Sample Depths From — To	Type of Sample	Blows per 6" on Sampler From 0-6	6-12	To 12-18	Moisture Density or Consist.	Strata Change Elev.	SOIL IDENTIFICATION Remarks include color, gradation, Type of soil etc. Rock-color, type, condition, hardness, Drilling time, seams and etc.	SAMPLE No.	Pen
		5' - 7'	Dry	8	11	10	Wet		Coarse sand and stone into fine sand	1	24"
				10							
		10'-12'	Dry	6	11	13	Wet		Coarse sand into fine sand with pebbles	2	24"
				16							
		15'-17'	Dry	20	33	35	Wet		Medium sand with coarse sand lenses	3	24"
				33							
		20'-22'	Dry	15	24	17	Wet		Medium sand	4	24"
				15							
		25'-27'	Dry	4	4	5	Wet		Medium sand into fine sand	5	24"
				7							
		30'-32'	Dry	4	8	11	Wet		Fine sand trace of silt	6	24"
				13							

GROUND SURFACE TO 30' USED 2.50" AUGERS: THEN SPLIT SPOON

140 lb. Wt. x 30" fall on 2" O. D. Sampler

Sample Type	Proportions Used	Cohesionless Density	Cohesive Consistency	SUMMARY
D = Dry C = Cored W = Washed	trace 0 to 10%	0-10 Loose	0-4 Soft 30 + Hard	Earth Boring 3[illegible]
UP = Undisturbed Piston	little 10 to 20%	10-30 Med. Dense	4-8 M/Stiff	Rock Coring
TP = Test Pit A = Auger V = Vane Test	some 20 to 35%	30-50 Dense	8-15 Stiff	Samples 6
UT = Undisturbed Th...	and 35 to 50%	50 + Very Dense	15-30 V. Stiff	HOLE NO. SB[illegible]

Green Mountain Boring Co., Inc.

R. D. 2 — BARRE, VERMONT 05641

SHEET 8 OF
DATE 9/30/91
HOLE NO. SB-4
LINE & STA.
OFFSET None

GROUND WATER OBSERVATIONS			CASING	SAMPLER	CORE BAR.	
At 4' at 0 Hours		Type	AUGERS	SPLIT SPOON		SURFACE ELEV.
		Size I. D.	2.50"	1⅜"		DATE STARTED 9/30/91
At at Hours		Hammer Wt.		140#		DATE COMPL.
		Hammer Fall		30"		BORING FOREMAN
						INSPECTOR
						SOILS ENGR.

LOCATION OF BORING: As mapped

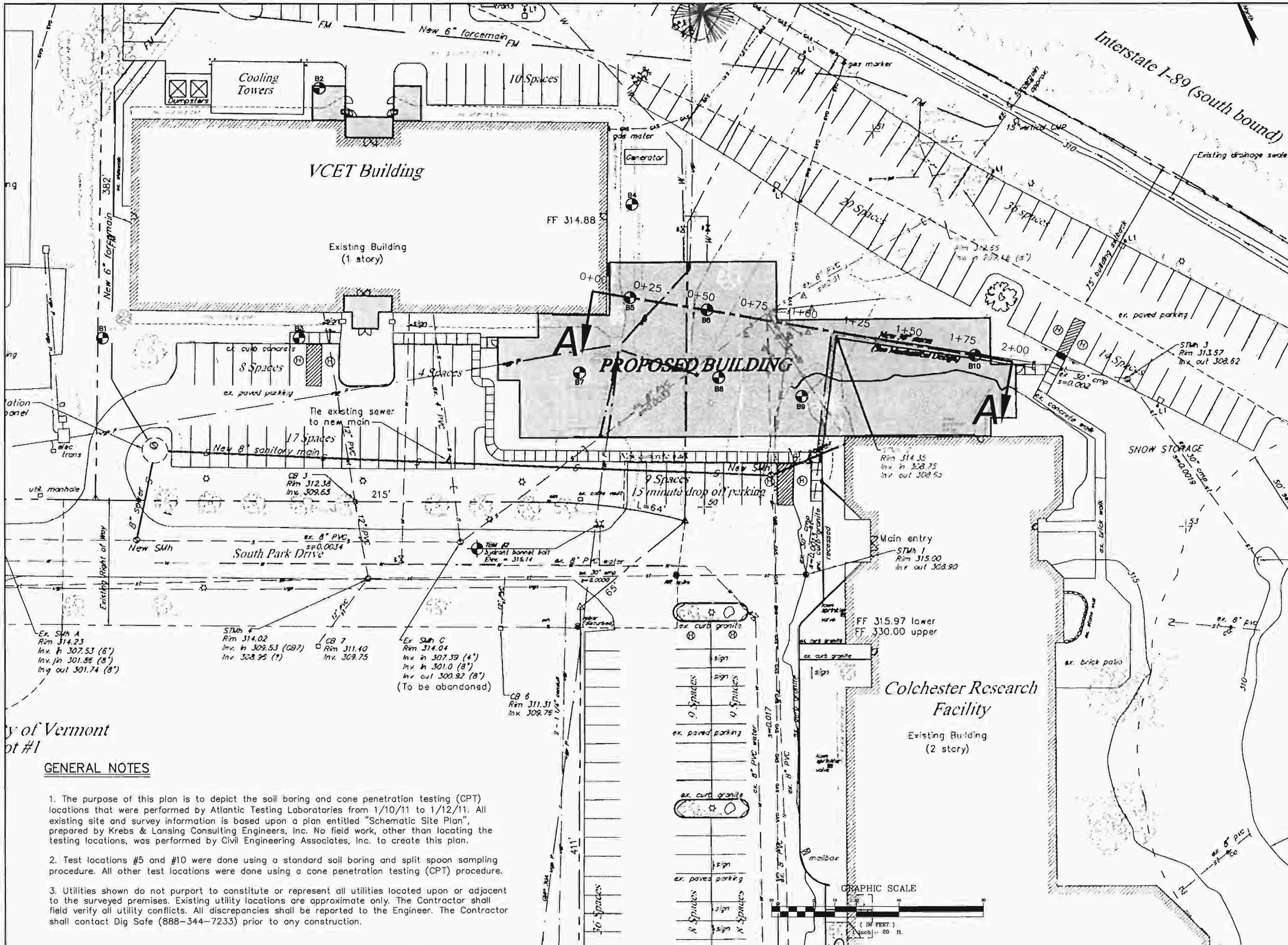
DEPTH	Casing Blows per foot	Sample Depths From — To	Type of Sample	Blows per 6" on Sampler From To 0-6	6-12	12-18	Moisture Density or Consist.	Strata Change Elev.	SOIL IDENTIFICATION Remarks include color, gradation, Type of soil etc. Rock-color, type, condition, hardness, Drilling time, seams and etc.	SAMPLE No.	Pen
		5' - 7'	Dry	3 3	3	2	Wet		Medium sand	1	24"
		10'-12'	Dry	2 5	4	3	Wet		Medium sand	2	24"
		15'-17'	Dry	10 55	22	35	Wet		Medium sand	3	24"
		20'-22'	Dry	7 11	7	12	Wet		Medium sand	4	24"
		25'-27'	Dry	2 8	3	5	Wet		Medium sand	5	24"
		30'-32'	Dry	4 11	4	6	Wet		Medium sand	6	24"

GROUND SURFACE TO 30' USED 2.50" AUGERS: THEN Split spoon to 32'

140 lb. Wt. x 30" fall on 2" O. D. Sampler

Sample Type	Proportions Used	Cohesionless Density	Cohesive Consistency	SUMMARY
D — Dry C — Cored W — Washed	trace 0 to 10%	0-10 Loose	0-4 Soft 30 + Hard	Earth Boring 3
UP — Undisturbed Piston	little 10 to 20%	10-30 Med. Dense	4-8 M/Stiff	Rock Coring
				Samples 6

Colchester Site
SCPT and Soil Boring Data



GENERAL NOTES

1. The purpose of this plan is to depict the soil boring and cone penetration testing (CPT) locations that were performed by Atlantic Testing Laboratories from 1/10/11 to 1/12/11. All existing site and survey information is based upon a plan entitled "Schematic Site Plan", prepared by Krebs & Lansing Consulting Engineers, Inc. No field work, other than locating the testing locations, was performed by Civil Engineering Associates, Inc. to create this plan.

2. Test locations #5 and #10 were done using a standard soil boring and split spoon sampling procedure. All other test locations were done using a cone penetration testing (CPT) procedure.

3. Utilities shown do not purport to constitute or represent all utilities located upon or adjacent to the surveyed premises. Existing utility locations are approximate only. The Contractor shall field verify all utility conflicts. All discrepancies shall be reported to the Engineer. The Contractor shall contact Dig Safe (888-344-7233) prior to any construction.

SITE ENGINEER:

CIVIL ENGINEERING ASSOCIATES, INC.
10 MANSFIELD VIEW LANE, SOUTH BURLINGTON, VT 05403
802-864-2323 FAX: 802-864-2271 web: www.cea-vt.com

DRAWN: JSO
CHECKED: JPO
APPROVED: JPO

OWNER:
VERMONT DEPARTMENT OF HEALTH
208-245 SOUTH PARK DRIVE
COLCHESTER
VERMONT 05446

PROJECT:
VERMONT PUBLIC HEALTH LABORATORY PROJECT
208-245 SOUTH PARK DRIVE
COLCHESTER
VERMONT 05446

LOCATION MAP
1" = 2000'

DATE	CHECKED	REVISION

OVERALL SOIL BORING SITE PLAN

DATE: JAN., 2011
SCALE: 1" = 20'
PROJ. NO. 10261
DRAWING NUMBER: C1.0

ATLANTIC TESTING LABORATORIES, Limited

Subsurface Investigation

Report No.: CD7159-01-01-11

Client: Civil Engineering Associates, Inc.
Project: Subsurface Investigation
Proposed Building
Colchester, Vermont

Boring Location: As Staked

Start Date: 1/12/2011 Finish Date: 1/12/2011

Boring No.: B-5 Sheet 1 of 2

Coordinates
Northing ______
Easting ______

Sampler Hammer
Weight: 140 lbs.
Fall: 30 in.
Hammer Type: Automatic

Groundwater Observations

Date	Time	Depth	Casing
1/12/2011	AM	DRY	10.0'
1/12/2011	AM	2.9'	35.0'
1/12/2011	AM	DRY	OUT

Ground Elev.: ______

Boring Advance By: 4 1/4" Auger

Borehole caved at 9.0 feet.

DEPTH	METHOD OF ADVANCE	SAMPLE NO.	DEPTH OF SAMPLE From	DEPTH OF SAMPLE To	SAMPLE TYPE	BLOWS ON SAMPLER PER 6" 2" O.D. SAMPLER	DEPTH OF CHANGE	CLASSIFICATION OF MATERIAL (f - fine, m - medium, c - coarse; and - 35-50%, some - 20-35%, little - 10-20%, trace - 0-10%)	Recovery (Inches)
0	AUGER	1	0.0	2.0	SS	2 5 7 8	0.5	6" TOPSOIL & ORGANIC MATERIAL Brown cmf SAND; little SILT; trace f GRAVEL (wet, non-plastic)	9
3							3.0		
5		2	5.0	7.0	SS	1 1 1 1		Grey mf SAND; some SILT (saturated, non-plastic)	6
8							8.0		
10		3	10.0	12.0	SS	WOH 1 1 1		Grey SILT; little f SAND (saturated, non-plastic)	12
15		4	15.0	17.0	SS	1 2 3 5		Similar Soil (saturated, non-plastic)	15
20		5	20.0	22.0	SS	1 WOH 1 1		Similar Soil; trace CLAY (saturated, very slightly plastic)	18
25									

SS Split Spoon Sample
NX Rock Core
SH Undisturbed Sample (Shelby Tube)
Estimated Groundwater

Drillers: Tony Mallory; Cory Farmer

Inspector: ______

ATL-LOG1 CD7159 CIVIL ENGINEERING ASSOCIATES.GPJ LOG-WELL.GDT 1/20/11

ATLANTIC TESTING LABORATORIES, Limited

Subsurface Investigation

Boring No.: B-5 Report No.: CD7159-01-01-11 Sheet 2 of 2

f - fine, m - medium, c - course; and - 35-50%, some - 20-35%, little - 10-20%, trace - 0-10%

DEPTH	METHOD OF ADVANCE	SAMPLE NO.	DEPTH OF SAMPLE From	DEPTH OF SAMPLE To	SAMPLE TYPE	BLOWS ON SAMPLER PER 6" 2" O.D. SAMPLER	DEPTH OF CHANGE	CLASSIFICATION OF MATERIAL	RECOVERY (inches)
25		6	25.0	27.0	SS	1 2 1 2		Similar Soil (saturated, very slightly plastic)	16
30		7	30.0	32.0	SS	WOH/12" 1 2		Similar Soil (saturated, very slightly plastic)	18
35		8	35.0	37.0	SS	WOH/12" 7 5		Similar Soil; no CLAY (saturated, non-plastic)	18
40		9	40.0	42.0	SS	WOH 1 1 2		Similar Soil; trace f SAND; trace CLAY (saturated, very slightly plastic)	24
42			42.0	44.0	SH			Shelby tube sample- No Recovery	
44		10	44.0	46.0	SS	WOR WOH 3 3		Grey SILT; little f SAND (saturated, non-plastic)	24
50		11	50.0	52.0	SS	WOH 2 1 2		Similar Soil; trace f SAND; trace CLAY (saturated, very slightly plastic)	18
55		12	55.0	57.0	SS	WOR/18" WOH		Similar Soil; little CLAY (saturated, slightly plastic)	24
57		13	57.0	59.0	SS	1 2 4 4		Similar Soil; some CLAY (saturated, moderately plastic)	20
59							59.0	Boring terminated at 59.0 feet.	

Notes:
1. Borehole backfilled with on-site soil.

ATL-LOG1 CD7159 CIVIL ENGINEERING ASSOCIATES.GPJ LOG-WELL.GDT 1/20/11

ATLANTIC TESTING LABORATORIES, Limited

Subsurface Investigation

Report No.: CD7159-01-01-11

Client: Civil Engineering Associates, Inc.

Boring Location: As Staked

Project: Subsurface Investigation
Proposed Building
Colchester, Vermont

Start Date: 1/10/2011 Finish Date: 1/11/2011

Boring No.: B-10 Sheet 1 of 2

Coordinates
Northing ______
Easting ______

Sampler Hammer
Weight: 140 lbs.
Fall: 30 in.
Hammer Type: Automatic

Ground Elev.: ______

Boring Advance By: 4 1/4" Auger

Groundwater Observations

Date	Time	Depth	Casing
1/10/2011	PM	SURFACE	10.0'
1/10/2011	PM	19.6'	56.5'
1/11/2011	AM	14.1'	OUT

DEPTH	METHOD OF ADVANCE	SAMPLE NO.	DEPTH OF SAMPLE From	DEPTH OF SAMPLE To	SAMPLE TYPE	BLOWS ON SAMPLER PER 6" 2" O.D. SAMPLER	DEPTH OF CHANGE	CLASSIFICATION OF MATERIAL (f - fine, m - medium, c - coarse; and - 35-50%, some - 20-35%, little - 10-20%, trace - 0-10%)	Recovery (Inches)
0	AUGER	1	0.0	2.0	SS	10 11 20 13	0.5	6" TOPSOIL & ORGANIC MATERIAL	10
								Brown cmf SAND; and SILT; trace f GRAVEL (wet, non-plastic)	
5		2	5.0	7.0	SS	8 9 3 4		Similar Soil; trace ORGANIC MATERIAL (root hairs)	11
8							8.0		
10		3	10.0	12.0	SS	6 5 5 3		Grey f SAND; and SILT (wet, non-plastic)	13
15		4	15.0	17.0	SS	4 2 2 2		Similar Soil (saturated, non-plastic)	1
18							18.0		
20		5	20.0	22.0	SS	2 2 2 2		Grey SILT; little CLAY; trace f SAND (saturated, slightly-plastic)	22

SS Split Spoon Sample
NX Rock Core
SH Undisturbed Sample (Shelby Tube)
Estimated Groundwater

Drillers: Tony Mallory; Cory Farmer

Inspector: ______

ATLANTIC TESTING LABORATORIES, Limited

Subsurface Investigation

Boring No.: B-10 Report No.: CD7159-01-01-11 Sheet 2 of 2

f - fine, m - medium, c - course; and - 35-50%, some - 20-35%, little - 10-20%, trace - 0-10%

DEPTH	METHOD OF ADVANCE	SAMPLE NO.	DEPTH OF SAMPLE From	DEPTH OF SAMPLE To	SAMPLE TYPE	BLOWS ON SAMPLER PER 6" 2" O.D. SAMPLER	DEPTH OF CHANGE	CLASSIFICATION OF MATERIAL	RECOVERY (Inches)
25		6	25.0	27.0	SS	2 2 1 2		Similar Soil; no CLAY (saturated, non-plastic)	15
30		7	30.0	32.0	SS	2 1 1 2		Similar Soil; trace CLAY (saturated, very slightly plastic)	17
32			32.0	34.0	SH			Shelby Tube - Grey SILT; some CLAY; trace f SAND (moderately plastic, saturated)	22
35		8	35.0	37.0	SS	1 1 1 2		Similar Soil; little CLAY (saturated, slightly plastic)	18
40		9	40.0	42.0	SS	1 1 1 1		Similar Soil; trace CLAY (saturated, very slightly plastic)	22
45		10	45.0	47.0	SS	1 1 2 1		Similar Soil (saturated, very slightly plastic)	6
50		11	50.0	51.3	SS	2 2 100/4"	51.3	Similar Soil; little CLAY (saturated, slightly plastic)	6
51.3	NX CORE		51.3	56.3	NX	RUN 1	56.3	Grey Dolostone 60" or 100% Recovery 8 Pieces (50") - 17% Chips and Fragments 6 Pieces longer than 4" (46") - RQD=77%	
								Boring terminated at 56.3 feet.	

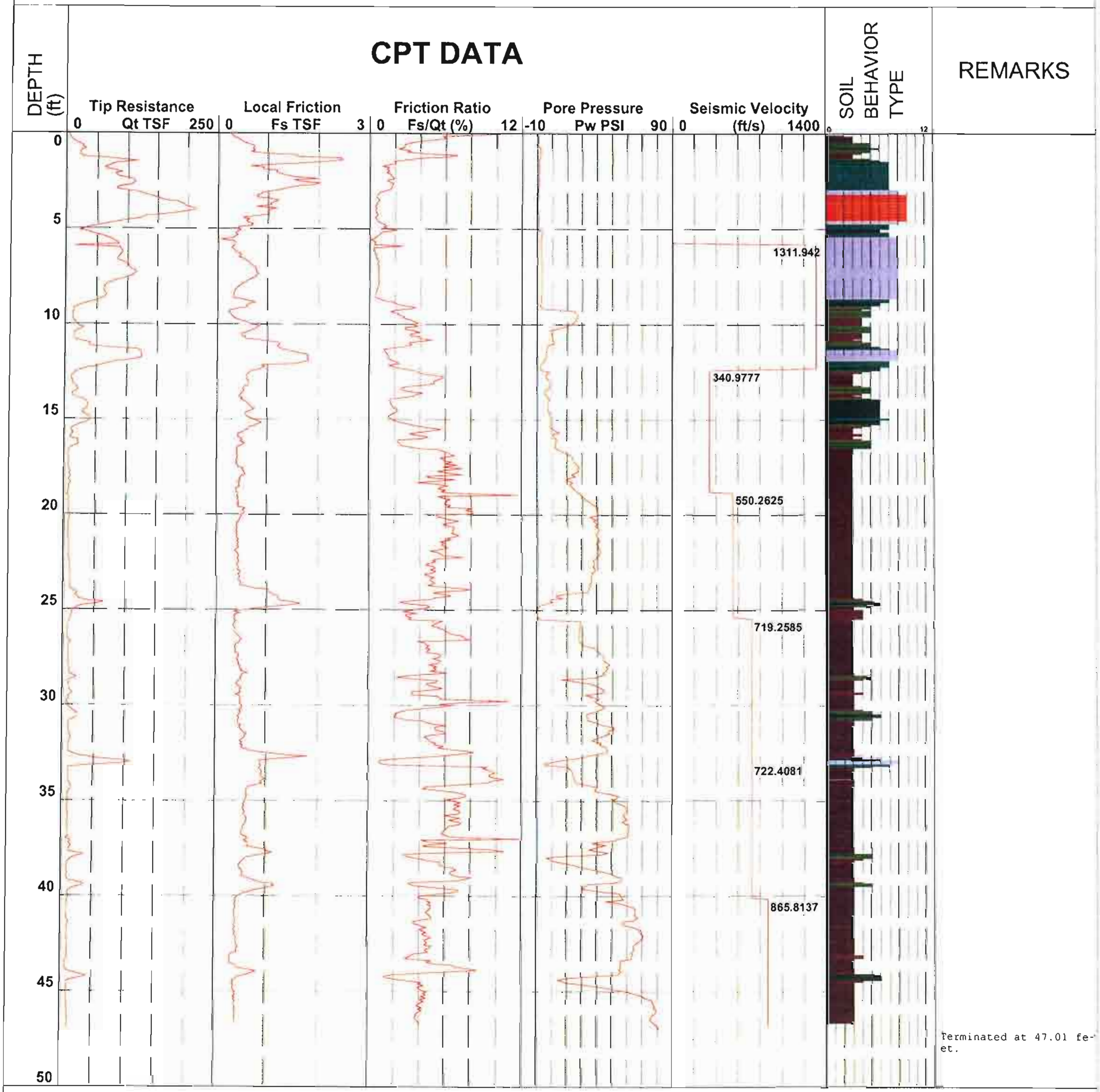
Notes:

1. Borehole backfilled with on-site soil.

ATL-LOG1 CD7159 CIVIL ENGINEERING ASSOCIATES.GPJ LOG-WELL.GDT 1/20/11

ATLANTIC TESTING LABORATORIES, Limited

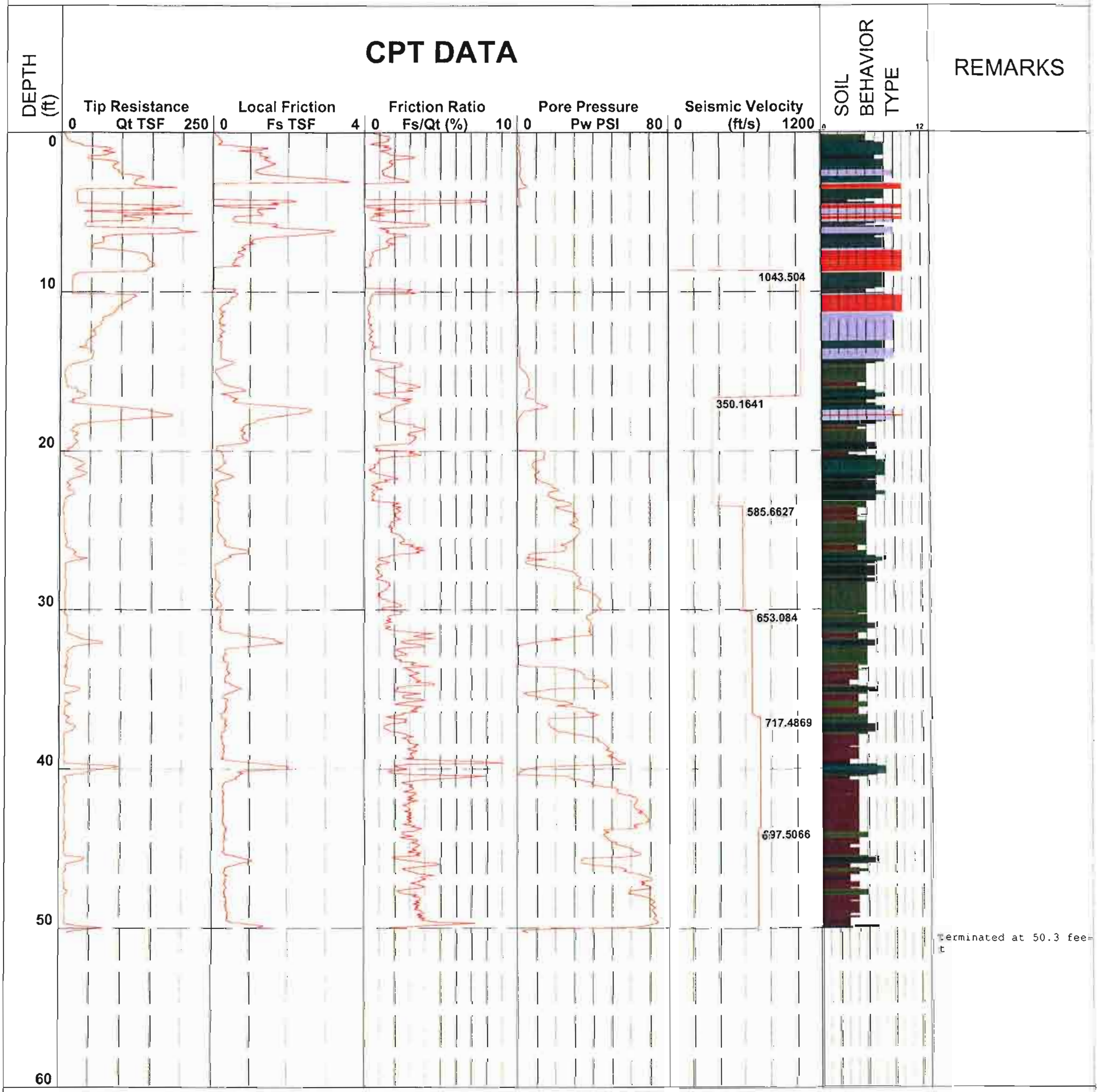
Job #	CD7159	Location	Colchester	Operator	Adam Schneider
Cone #	DSG1001	Hole #	B-1	Date	1/11/2011 4:34:41 PM
Northerning		Easting		Surface Elevation	



1 - sensitive fine grained
2 - organic material
3 - clay
4 - silty clay to clay
5 - clayey silt to silty clay
6 - sandy silt to clayey silt
7 - silty sand to sandy silt
8 - sand to silty sand
9 - sand
10 - gravelly sand to sand
11 - very stiff fine grained (*)
12 - sand to clayey sand (*)

ATLANTIC TESTING LABORATORIES, Limited

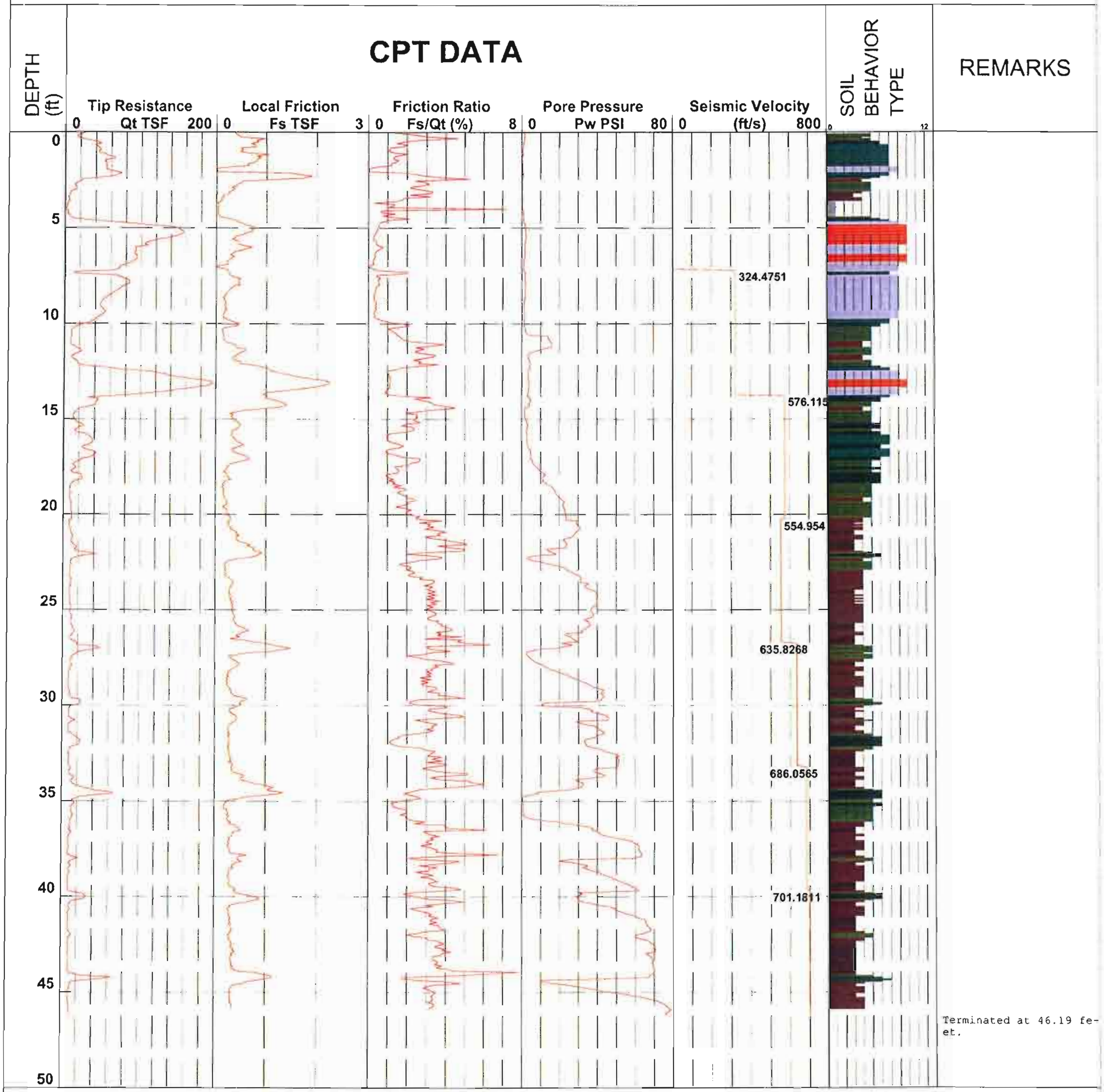
Job #	CD7159	Location	Colchester	Operator	Adam Schneider
Cone #	DSG1001	Hole #	B-2	Date	1/11/2011 3:50:16 PM
Northerning		Easting		Surface Elevation	



- 1 - sensitive fine grained
- 2 - organic material
- 3 - clay
- 4 - silty clay to clay
- 5 - clayey silt to silty clay
- 6 - sandy silt to clayey silt
- 7 - silty sand to sandy silt
- 8 - sand to silty sand
- 9 - sand
- 10 - gravelly sand to sand
- 11 - very stiff fine grained (*)
- 12 - sand to clayey sand (*)

ATLANTIC TESTING LABORATORIES, Limited

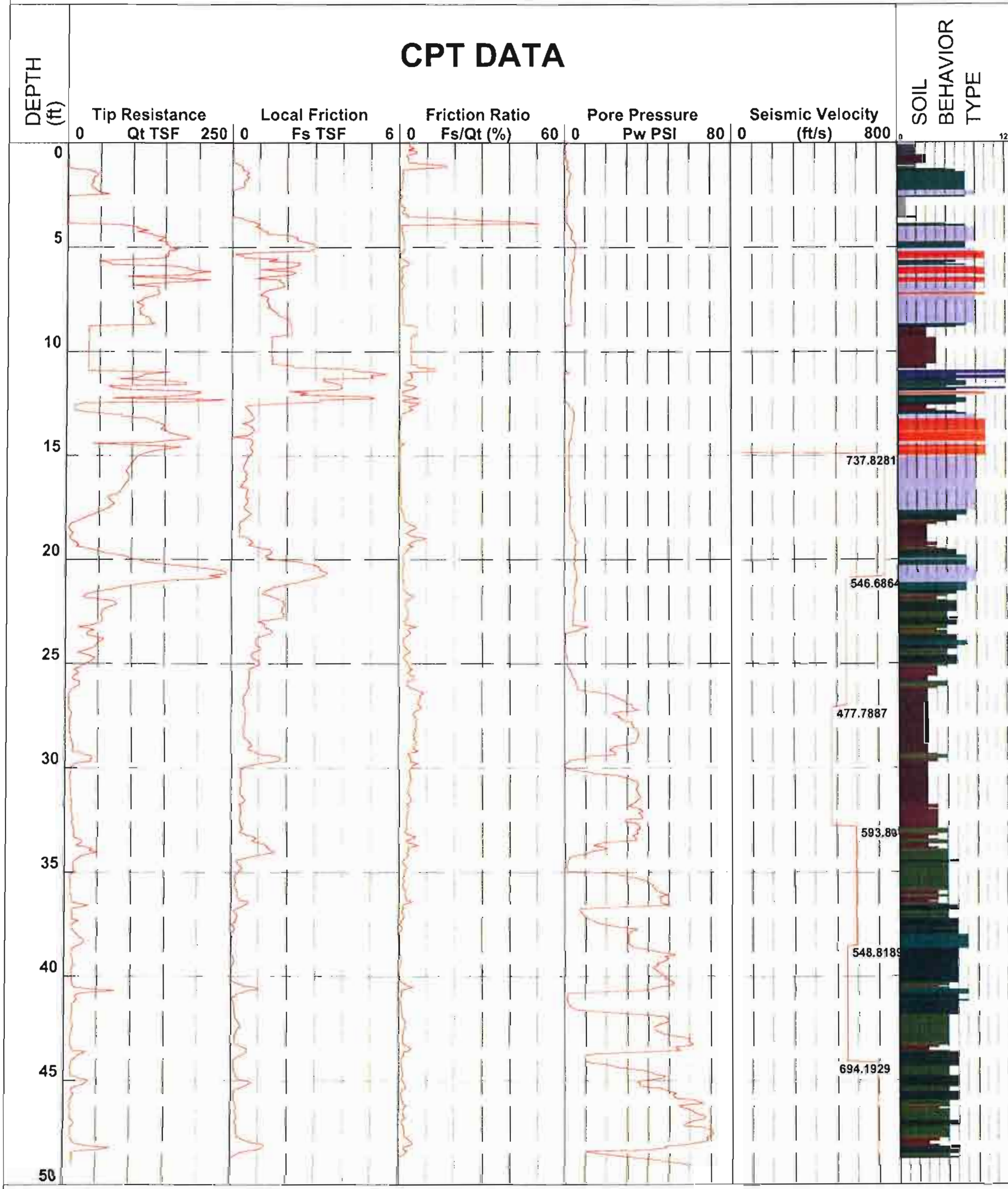
Job #	CD7159	Location	Colchester	Operator	Adam Schneider
Cone #	DSG1001	Hole #	B-3	Date	1/11/2011 5:08:11 PM
Northerning		Easting		Surface Elevation	



1 - sensitive fine grained	4 - silty clay to clay	7 - silty sand to sandy silt	10 - gravelly sand to sand
2 - organic material	5 - clayey silt to silty clay	8 - sand to silty sand	11 - very stiff fine grained (*)
3 - clay	6 - sandy silt to clayey silt	9 - sand	12 - sand to clayey sand (*)

ATLANTIC TESTING LABORATORIES, Limited

Job #	CD7159	Location	Colchester	Operator	Adam Schneider
Cone #	DSG1001	Hole #	B-4	Date	1/11/2011 2:49:54 PM
Northerning		Easting		Surface Elevation	



REMARKS

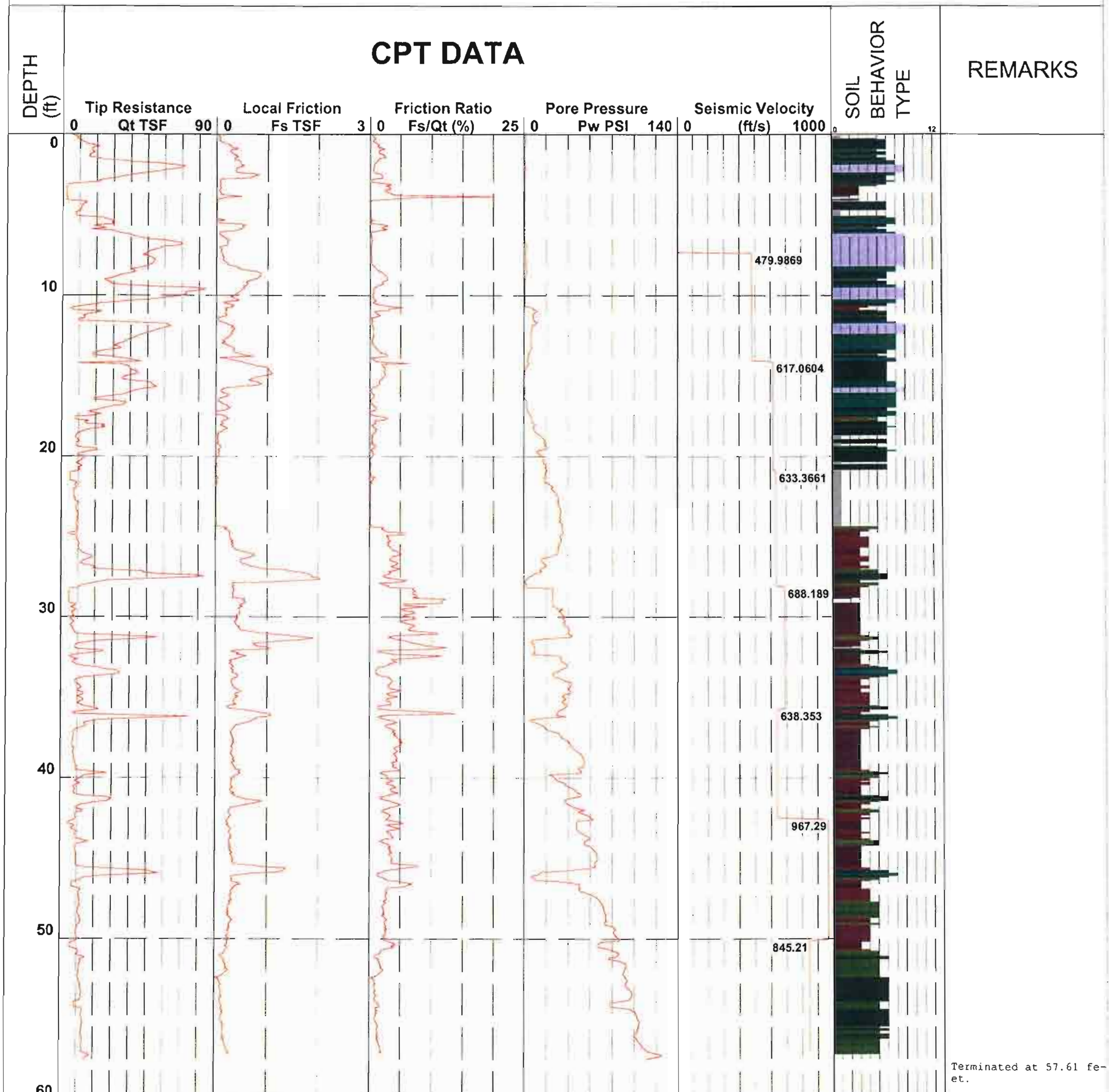
Refusal was encountered at 9 feet, hole was augered to 10 feet and the push restarted

Terminated at 49.05 feet

1 - sensitive fine grained	4 - silty clay to clay	7 - silty sand to sandy silt	10 - gravelly sand to sand
2 - organic material	5 - clayey silt to silty clay	8 - sand to silty sand	11 - very stiff fine grained (*)
3 - clay	6 - sandy silt to clayey silt	9 - sand	12 - sand to clayey sand (*)

ATLANTIC TESTING LABORATORIES, Limited

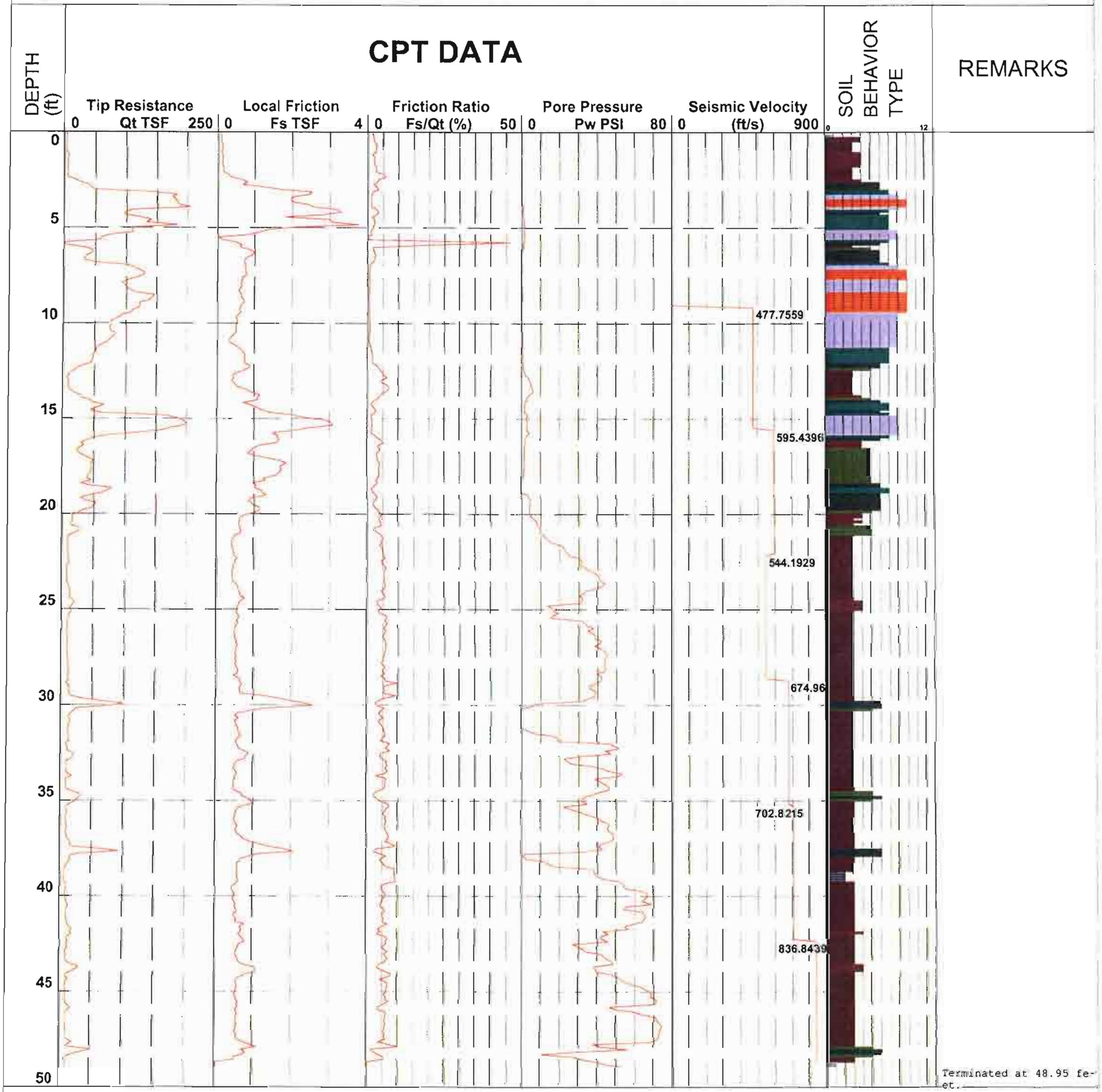
Job #	CD7159	Location	Colchester	Operator	Adam Schneider
Cone #	DSG1001	Hole #	B-6	Date	1/11/2011 2:18:06 PM
Northerning		Easting		Surface Elevation	



1 - sensitive fine grained	4 - silty clay to clay	7 - silty sand to sandy silt	10 - gravelly sand to sand
2 - organic material	5 - clayey silt to silty clay	8 - sand to silty sand	11 - very stiff fine grained (*)
3 - clay	6 - sandy silt to clayey silt	9 - sand	12 - sand to clayey sand (*)

ATLANTIC TESTING LABORATORIES, Limited

Job #	CD7159	Location	Colchester	Operator	Adam Schneider
Cone #	DSG1001	Hole #	B-7	Date	1/11/2011 5:38:18 PM
Northerning		Easting		Surface Elevation	

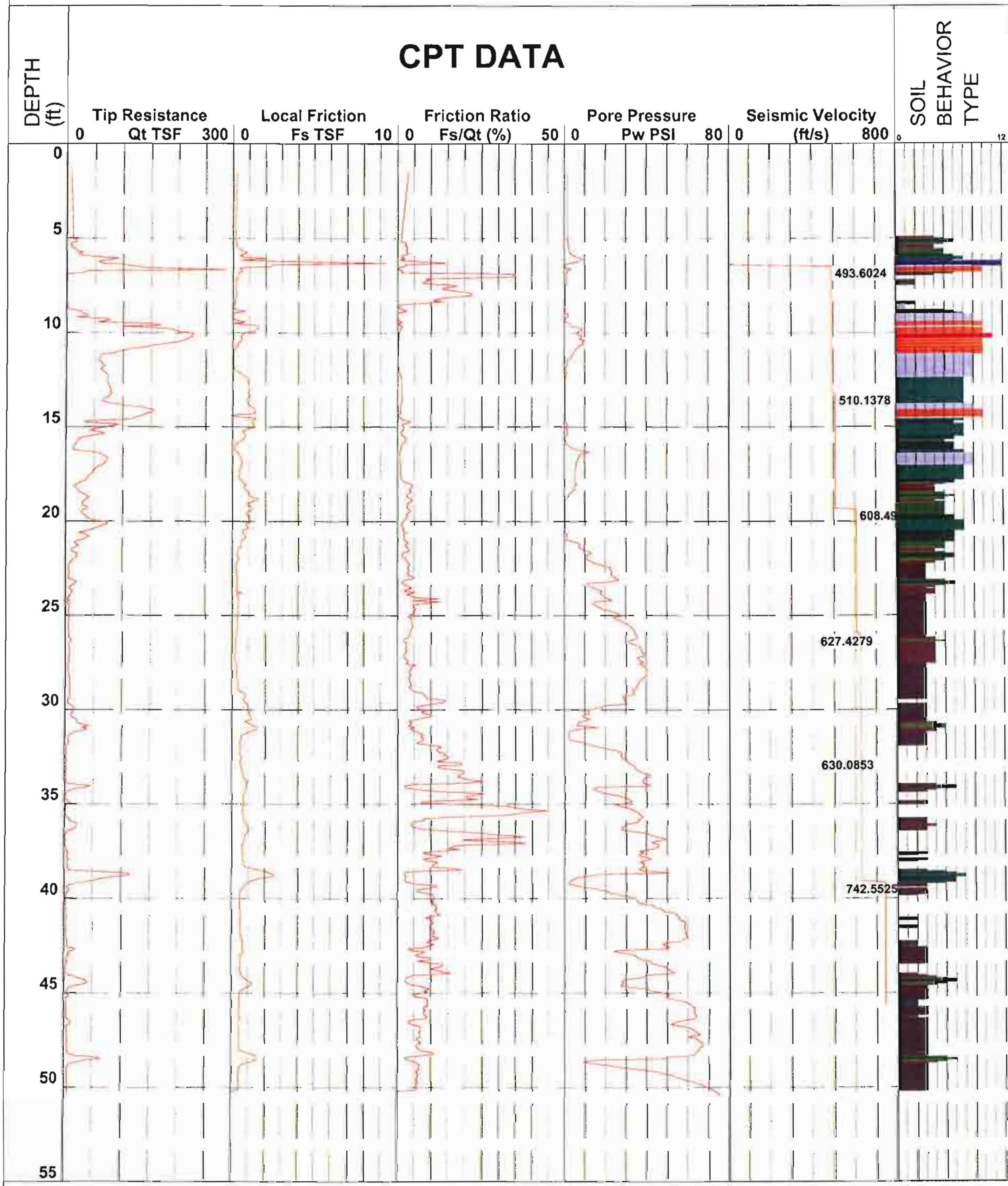


1 - sensitive fine grained
2 - organic material
3 - clay
4 - silty clay to clay
5 - clayey silt to silty clay
6 - sandy silt to clayey silt
7 - silty sand to sandy silt
8 - sand to silty sand
9 - sand
10 - gravelly sand to sand
11 - very stiff fine grained (*)
12 - sand to clayey sand (*)

ATLANTIC TESTING LABORATORIES, Limited

Job #	CD7159	Location	Colchester	Operator	Adam Schneider
Cone #	DSG1001	Hole #	B-8	Date	1/11/2011 1:07:23 PM
Northerning		Easting		Surface Elevation	

CPT DATA



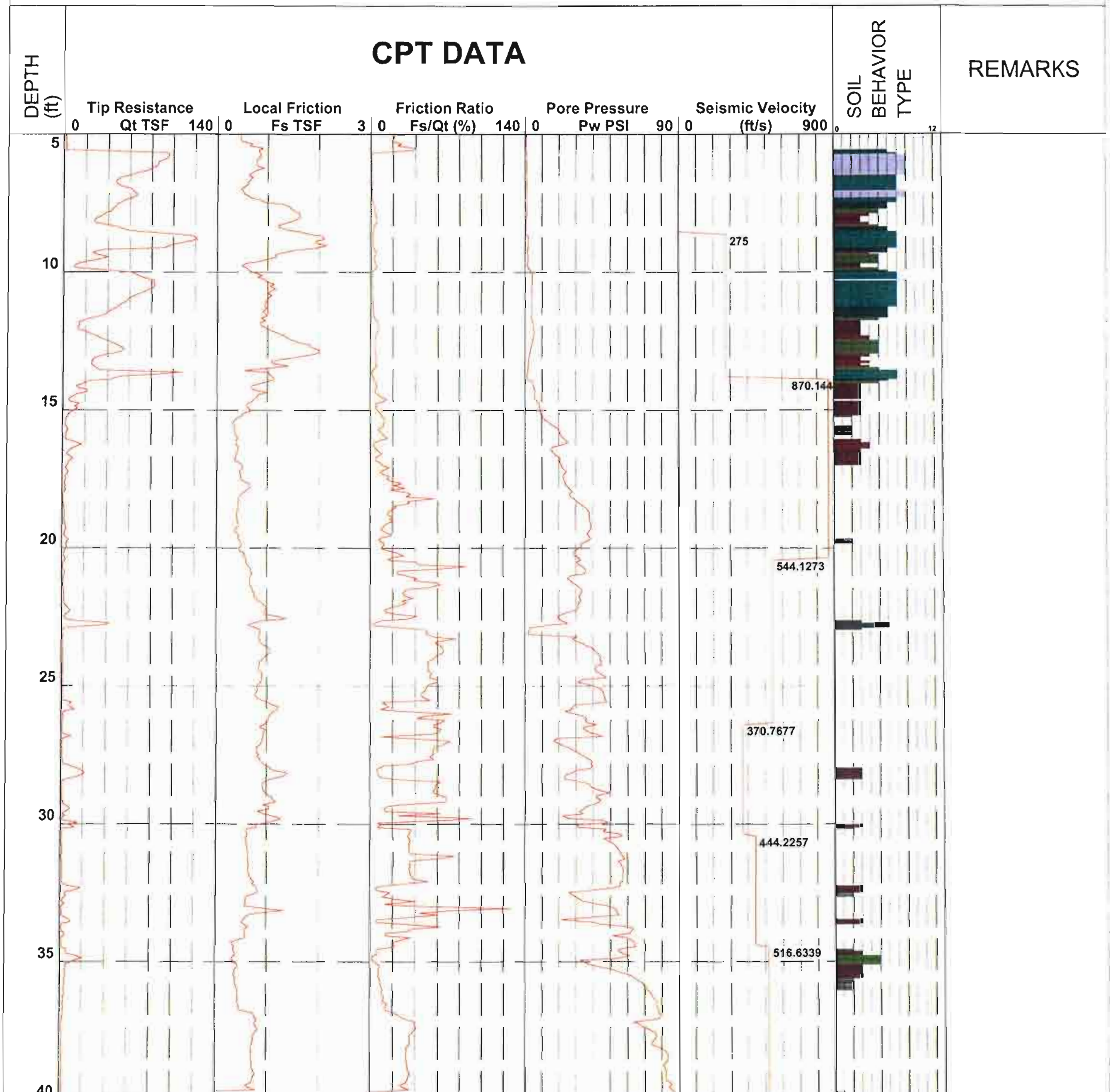
REMARKS

Terminated at 50.46 feet.

1 - sensitive fine grained	4 - silty clay to clay	7 - silty sand to sandy silt	10 - gravelly sand to sand
2 - organic material	5 - clayey silt to silty clay	8 - sand to silty sand	11 - very stiff fine grained (*)
3 - clay	6 - sandy silt to clayey silt	9 - sand	12 - sand to clayey sand (*)

ATLANTIC TESTING LABORATORIES, Limited

Job #	CD7159	Location	Colchester	Operator	Adam Schneider
Cone #	DSG1001	Hole #	B-9	Date	1/11/2011 12:11:42 PM
Northerning		Easting		Surface Elevation	



Terminated 39.86 feet.

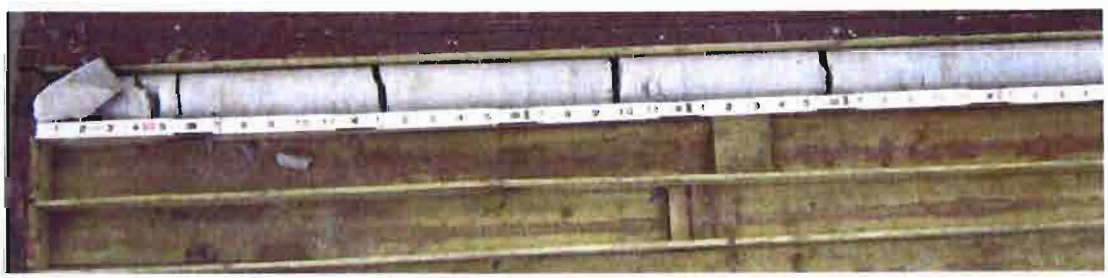
1 - sensitive fine grained	4 - silty clay to clay	7 - silty sand to sandy silt	10 - gravelly sand to sand
2 - organic material	5 - clayey silt to silty clay	8 - sand to silty sand	11 - very stiff fine grained (*)
3 - clay	6 - sandy silt to clayey silt	9 - sand	12 - sand to clayey sand (*)

ATLANTIC TESTING LABORATORIES

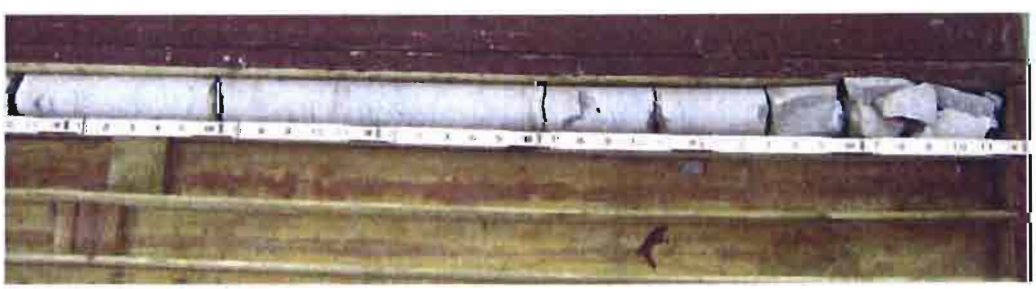
Rock Core Photographs
Proposed Building
Colchester, Vermont

Boring B-10, Run 1
Grey Dolostone
60" or 100% Recovery
8 Pieces (50") – 17% Chips and Fragments
6 Pieces longer than 4" (46") – RQD=77%

Entire Core



Top Portion of Core



Bottom Portion of Core

Milton Square Site
SPT, Water Well Log, and SCPT Data

Milton Square SPT Data

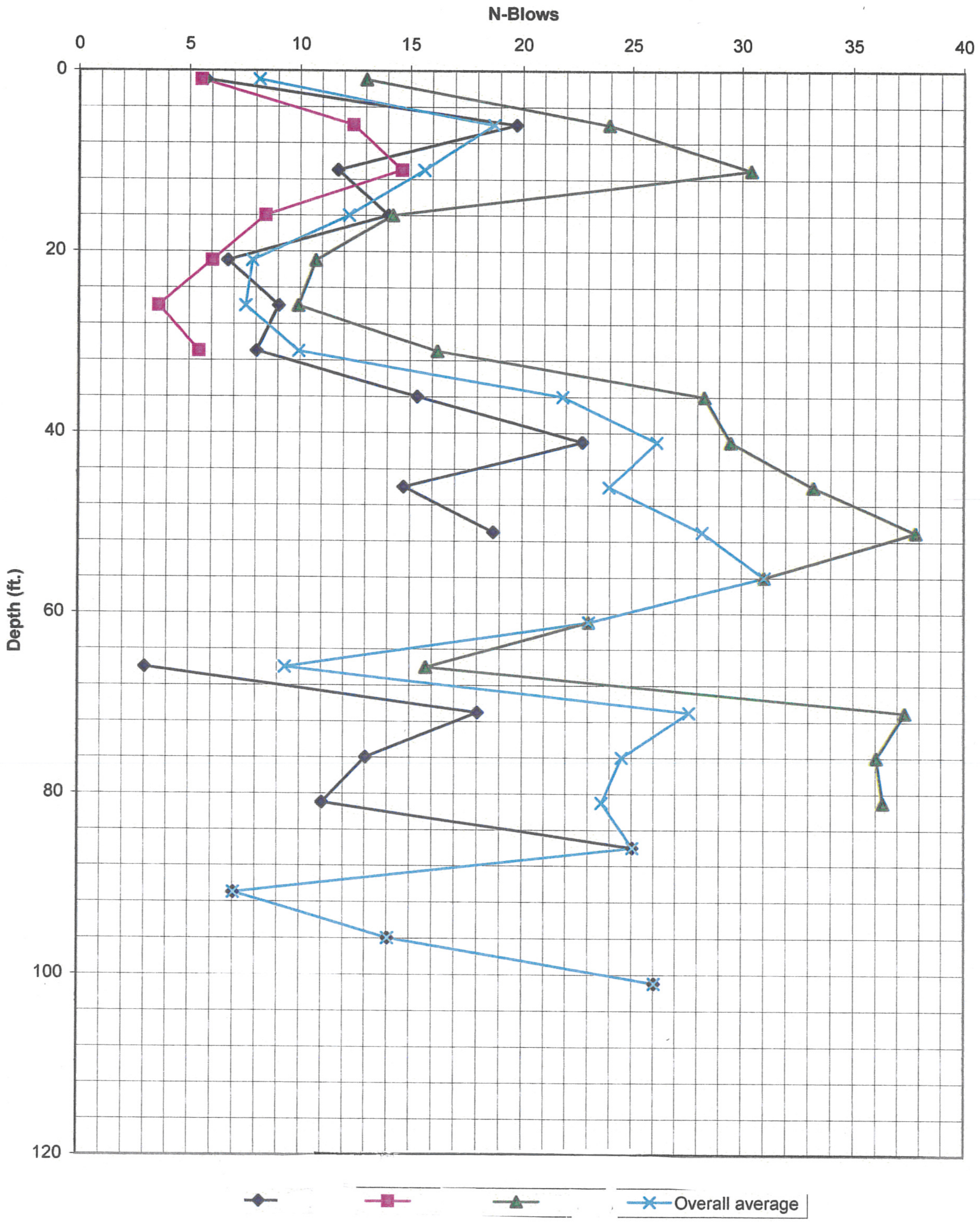


Figure 1

Well Details

Date Completed	09/24/1986
Date Received	10/10/1986
Driller	36 Chevalier Drilling Company Inc
Well Report Number	606
Tag	158F
Comments	
Town	Milton
Map Cell	12B7
Tax Map	
E911 Address	
Subdivision	
Lot Number	
Owners First Name	SHIRLEY &
Owners Last Name	MADELINE MINOR
Purchaser First Name	
Purchaser Last Name	
Well Use	Business Establishment
Well Reason	New Supply
Drilling Method	Rotary (AP)
Well Depth	218.00 feet
Yield Gallons Per Minute	100.00
Yield Test Tested For Hours	0.00
Static Water Level	0.00 feet
Over Flowing	0
Overburden Thickness	0 feet
Casing Length	218.00 feet
Casing Diameter	6.00 inches
Casing Length Below Land Surface	0.00 feet
Casing Length Exposed	0.00
Casing Material	
Casing Weight	0.00 lbs/foot
Casing Finish	Above ground, finished
Liner Length	0.00 feet
Liner Diameter	0.00 inches
Liner Material	
Liner Weight	0.00 lbs/foot
Grout Type	
Seal Type	
Diameter Drilled In Bedrock	0.00 inches
Depth Drilled in Bedrock	0.00 feet
Screen Make Type	
Screen Material	
Screen Length	0.00 feet
Screen Diameter	0.00 inches

Screen Slot Size	0.000 inches
Depth of Screen	0.00 feet
Gravel Size Type	
Casing Sealing Method	Drive shoe only
Yield Test Method	Compressed air
Well Development	
Not Steel Casing	0
Water Analysis	0
Well Screen	0
AW Partial	0
Unique GIS Name	MJ606
Lat Degree	44
Lat Minutes	37
Lat Seconds	24.8941
Long Degree	73
Long Minutes	7
Long Seconds	33.6138
Location DeterminationMethod	screen digitized
Well Type	Gravel
Depth To Liner Top	0.00
Hydro Fractured	0
Hydro Fractured Resulting Flow	0.00
Well Location Submitted As A Dot On A Map	N

WellMainRecordNumber	StartingDepth	EndingDepth	WaterBearing	LithologyCode	Lithology
37154	0.00	90.00		S	FINE BR SAND
37154	90.00	150.00		I	FINE SIL
37154	150.00	212.00		C	HEAVY CLAY
37154	212.00	218.00		G	GRAVEL

If you would like search for a well or wells in a specific area the following link will rel to the ANR GIS Internet Mapping Program.
http://www.anr.state.vt.us/site/html/maps.htm

ATLANTIC TESTING LABORATORIES, Limited

Job #

Cone #

Northerning B-104

Location Milton, VT

Hole # B-104

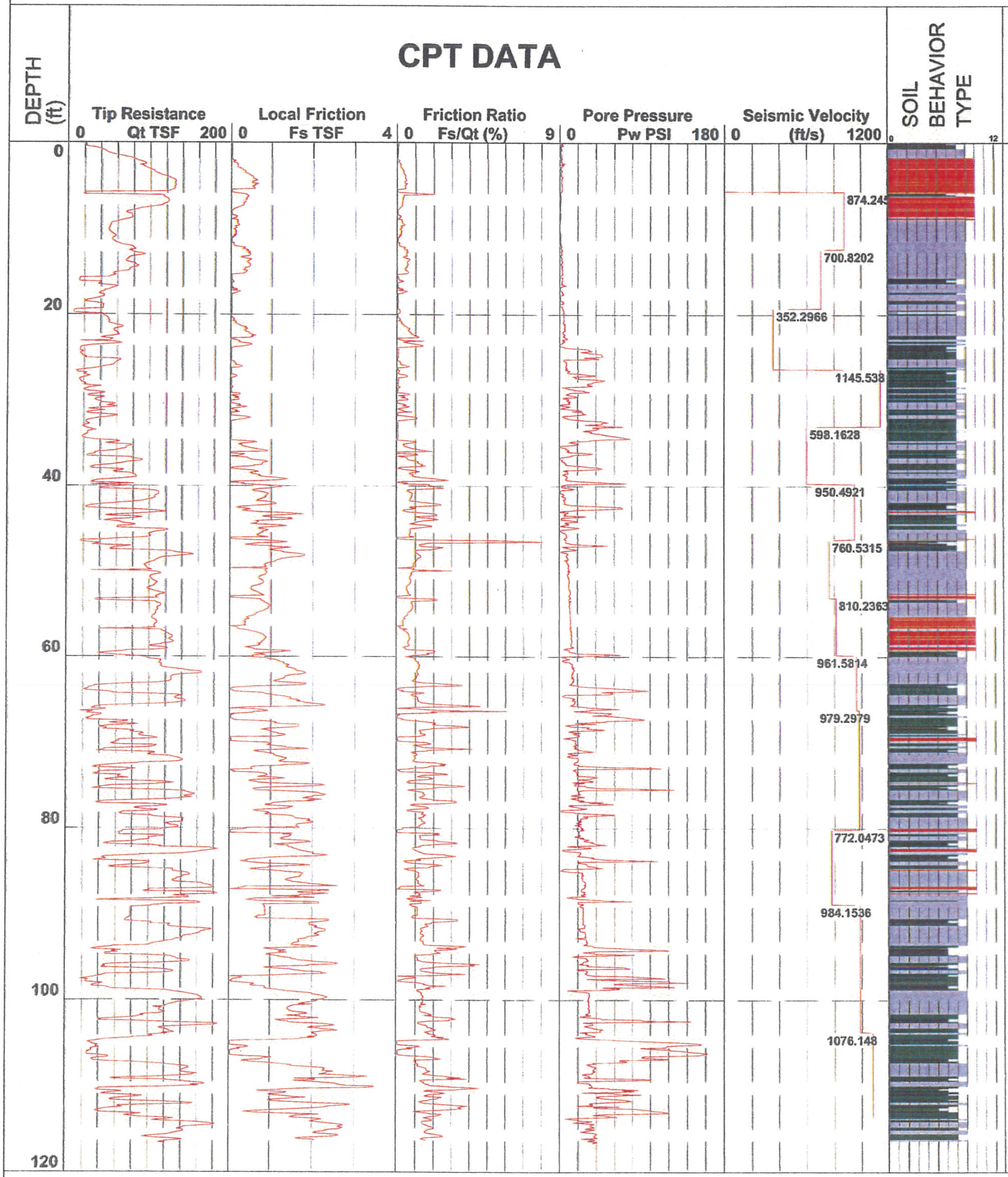
Easting B-104

Operator

Date

Surface Elevation

CPT DATA



REMARKS

Terminated at 116 ft

1 - sensitive fine grained

2 - organic material

3 - clay

4 - silty clay to clay

5 - clayey silt to silty clay

6 - sandy silt to clayey silt

7 - silty sand to sandy silt

8 - sand to silty sand

9 - sand

10 - gravelly sand to sand

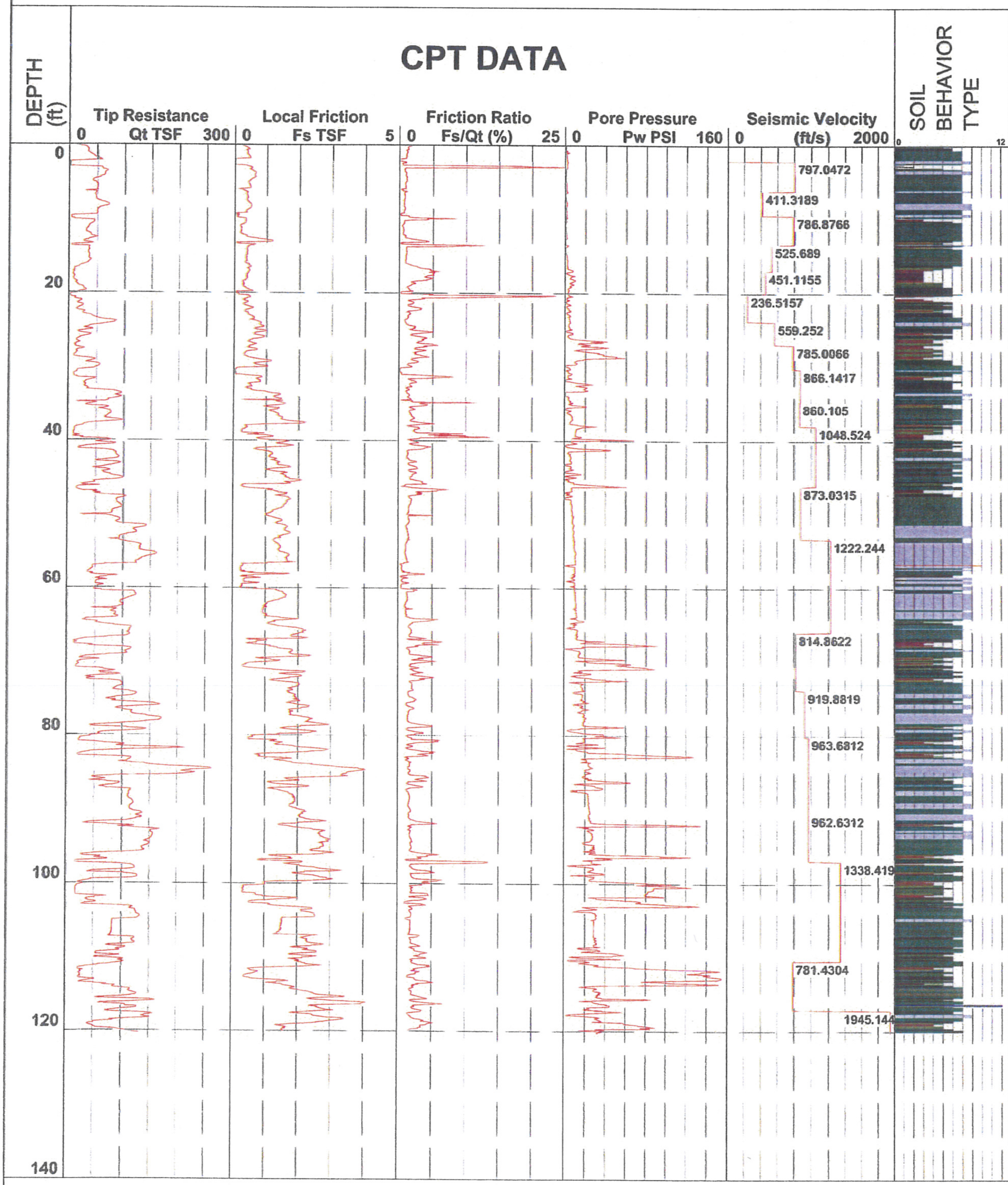
11 - very stiff fine grained (*)

12 - sand to clayey sand (*)

ATLANTIC TESTING LABORATORIES, Limited

Job #		Location	Milton, VT	Operator	
Cone #		Hole #	B-110	Date	
Northerning	B-110	Easting	B-110	Surface Elevation	

CPT DATA



REMARKS

Terminated at 120 ft

1 - sensitive fine grained	4 - silty clay to clay	7 - silty sand to sandy silt	10 - gravelly sand to sand
2 - organic material	5 - clayey silt to silty clay	8 - sand to silty sand	11 - very stiff fine grained (*)
3 - clay	6 - sandy silt to clayey silt	9 - sand	12 - sand to clayey sand (*)