Alaska University Transportation Center

University of Arkansas

Utilization of Screw Piles in High Seismicity Areas of Cold and Warm Permafrost

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Shear Wave Velocity Profiling in High Seismicity Areas of Cold and Warm Permafrost

a study performed in conjunction with the project

Utilization of Screw Piles in High Seismicity Areas of Cold and Warm Permafrost

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1.0 Introduction

This work was performed in support of the AUTC project "Utilization of Screw Piles in High Seismicity Areas of Cold and Warm Permafrost" under the direction of PI Dr. Kenan Hazirbaba. Surface wave testing was performed at 30 sites in the City of Fairbanks, AK from August 9-13, 2009 by personnel from the University of Arkansas. The goal of the testing was to develop shear wave velocity profiles at selected research sites and at various areas of cold and warm permafrost. The shear wave velocity profiles provide a key parameter in determining the dynamic response of piles and soil-pile interaction under dynamic loading. The Spectral Analysis of Surface Waves (SASW) method (Stokoe et al., 1994) was used to determine shear wave velocity profile at each site to a depth of between 30 and 60 meters.

2.0 Overview of the SASW Test Method

The SASW test method is a nondestructive and nonintrusive seismic method that utilizes the dispersive nature of Rayleigh-type surface waves propagating through a layered media to determine the shear wave velocity profile of the material (Stokoe et al., 1994). Dispersion in surface wave velocity arises from changing stiffness properties of the soil and rock layers with depth, which caused the velocity to vary with wavelength or frequency. This phenomenon is illustrated in Figure 1 for a multi-layered solid. A high-frequency surface wave, which propagates with a short wavelength, only stresses material near the exposed surface and thus only samples the properties of the shallow, near-surface material (Figure 1b). A lower-frequency surface wave, which has a longer wavelength, stresses material to a greater depth and thus samples the properties of the shallower and deeper materials (Figure 1c). Spectral analysis is used to separate the waves by frequency and wavelength to determine the experimental ("field") dispersion curve for the site. An analytical, forward-modeling procedure is then used to theoretically match the field dispersion curve with a one-dimensional layered system of varying layer stiffnesses and thicknesses (Joh, 1996). The one-dimensional shear wave velocity profile that generates a dispersion curve that most closely matches the field dispersion curve is presented as the shear wave velocity profile at the site.

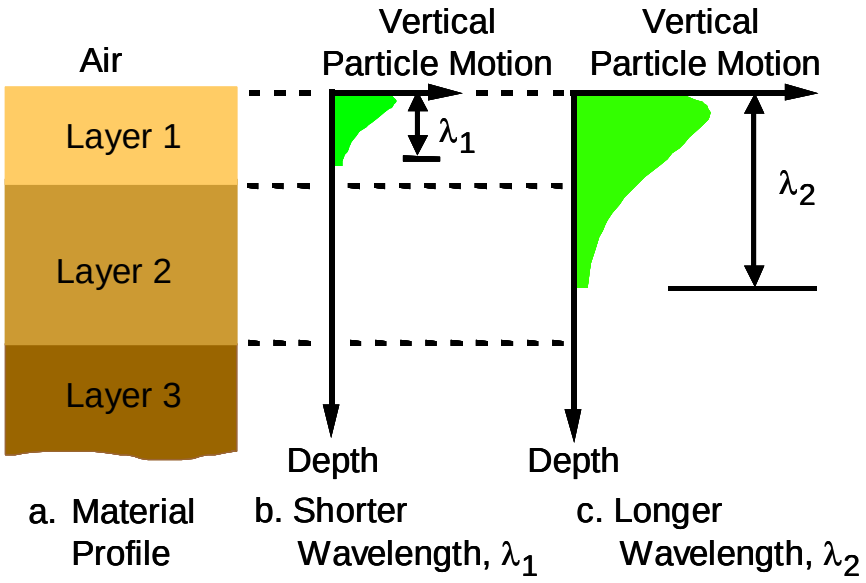


Figure 1 Illustration of Surface Waves with Different Wavelengths Sampling Different Materials in a Layered System which Results in Dispersion in Wave Velocities.

3.0 Field Equipment and Testing Procedures

SASW testing in the field involves generating surface waves at one point on the exposed material surface and measuring the motions perpendicular to the surface created by the passage of surface waves past two or more measurement points. All measurement points are arranged on the exposed surface along a single radial path from the source. Successively longer spacings between the receivers and between the source and first receiver are used to measure progressively longer and longer wavelengths. This general testing configuration for one source/receiver set-up is illustrated in Figure 2. In this example, three receivers are used at each source/receiver set-up. This arrangement enables two sets of SASW test results to be obtained at the same time. The middle receiver (receiver #2) is located at the center line of the test array at all times. When different spacings are used and/or reverse directions are tested, only receivers #1 and #3 and the source are moved.

Distances between receivers of 0.5 to 80 meters are typically used to profile to depths of about 30 to 60 m (larger spacings have been used with specialized vibroseis trucks to profile to depths of 600 m). This number and progression of receiver spacings results in significant overlapping of the individual dispersion curves used to develop a composite field curve, thereby enhancing the test reliability and confirming global lateral uniformity over the test array.

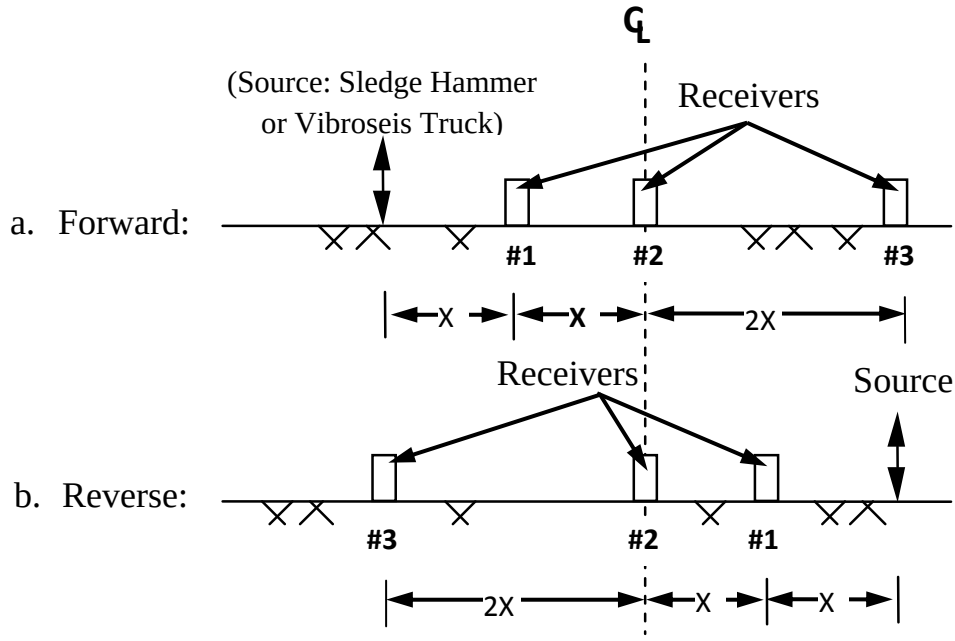


Figure 2 Common-Middle-Receiver Geometry Used in SASW Testing With Three Receivers.

Regardless of the spacing between receivers, at no point in the data analyses are wavelengths considered that are longer than twice the distance between the source and the first receiver in the receiver pair. This geometry results in minimizing near-field effects while simultaneously recording long wavelengths.

For the testing in Fairbanks, typical spacings consisted of 0.6, 1.2, 2.4, 4.8, 7.6, 15.2, 30.5, 61.0 meters. A 4.5 kg sledgehammer was used as the surface wave source for spacings less than 7 meters to develop high frequency waves for near surface characterization. Both a forward and reverse receiver orientation was used with spacings less than 7 meters to improve data quality and account for variability in the soil and phase differences in receivers. For receiver spacings greater than 7 meters, a vibroseis source owned and operated by the University of Arkansas was used. Figure 3 is a photograph of this vibroseis truck, called “The Hawg”. The Hawg is capable of operating at frequencies between 2 – 500 Hz. However, its optimal frequency range is between 10 – 200 Hz, where it can produce up to 6000 lbs of peak dynamic force (12000 lbs peak-to-peak). The use of the vibroseis truck significantly increased the depth of investigation at each site. Only a forward receiver orientation was used with the vibroseis truck due to position limitations.

Figure 3 Photograph of The Hawg vibroseis truck owned and operated by the University of Arkansas.

Geospace model GS-11D transducers, which have a natural frequency of 4.5 Hz, were used for spacing less than 7 meters, whereas Mark products Model L-4C transducers, which have a natural frequency of 1 Hz, were used for longer spacings. These receivers are one-dimensional transducers that only measure vertical particle motion. The key points with regard to these receivers are that: (1) they have significant output over the measurement frequency range, (2) they are matched so that any differences in phase are negligible over the measurement frequency range, (3) they are coupled well to the soil or rock, and (4) the coupling is similar for each receiver.

4.0 Data Reduction and Forward Modeling Procedures

In SASW testing, data is collected in the field in the form of phase plots and coherence function between individual receiver pairs. That data is reduced and interpreted using the program WinSASW, developed by Dr. Sung Ho Joh at the University of Texas at Austin (Joh, 1996). Data Reduction consists of the following steps. For each receiver pair, the phase plot and

coherence function are loaded into WinSASW. A masking procedure is then performed to manually eliminate portions of the data with poor signal quality or portions of the data contaminated by the near-field waveform component. Figure 4 shows a typically phase and coherence plot from the 7.6 m spacing at Site 8 CRREL Array #2. The phase plots are unwrapped using the program and the surface wave phase velocity at each frequency is calculated using Equation 1 below:

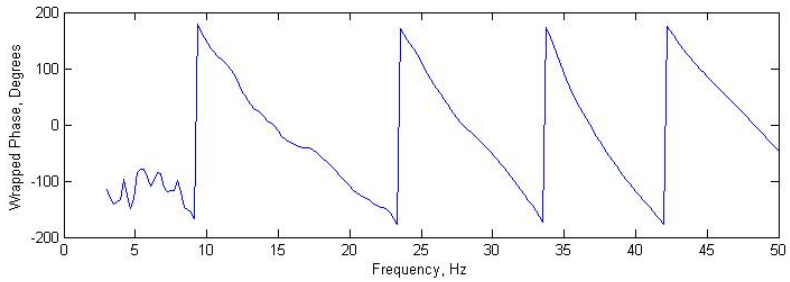
$$V_R = f \bullet \frac{360}{\phi} \bullet x \tag{1}$$

where V_R is the phase velocity in ft/sec or m/s, f is the frequency in Hertz (cycles per sec), ϕ is the phase angle in degrees (at frequency f), and x is the distance between the receivers in the same length units as used to represent V_R.

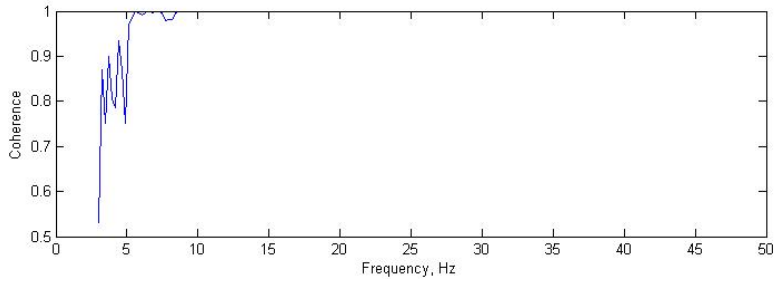
This process is repeated for each receiver spacing to develop a composite dispersion curve over the frequency/wavelength range of interest. The next data reduction step is to match a theoretical dispersion curve to the experimental dispersion curve measured in the field. The theoretical dispersion curve is generated based on a system of horizontal soil layers with various shear wave velocities, thicknesses, densities, and Poisson's ratios. Through an iterative process the properties of the layered system are changed to produce a match to the experimental dispersion curve. WinSASW, through an effective "3D" solution, accounts for the multiple modes of surface wave propagation and all body waves produced by the source. In the analysis, the final shear wave velocity profile is presented to a depth equal to 0.5 times the maximum wavelength in the experimental dispersion curve. A typical experimental dispersion curve with theoretical match from Site 8 CRREL Array #2 is shown in Figure 5, and the associated shear wave velocity profile is shown in Figure 6.

5.0 Site Locations and Selected Site Results

Thirty locations in the City of Fairbanks, AK were tested to obtain 43 separate shear wave velocity profiles. The sites were chosen based on a grid pattern and the local availability of a parking lot or road large enough to complete the testing. Locations of all 30 sites across the city are shown in Figure 7. The exact site locations (coordinates) and seismic site classification according to IBC (2009), ASCE/SEI 7-05 and FEMA 450 for each test location are provided in



a. Cross Power Specturm



b. Coherence Function

Figure 4 Phase and coherence plot measured of the 7.6 m spacing during SASW testing at Site 8 CRREL Array #2.

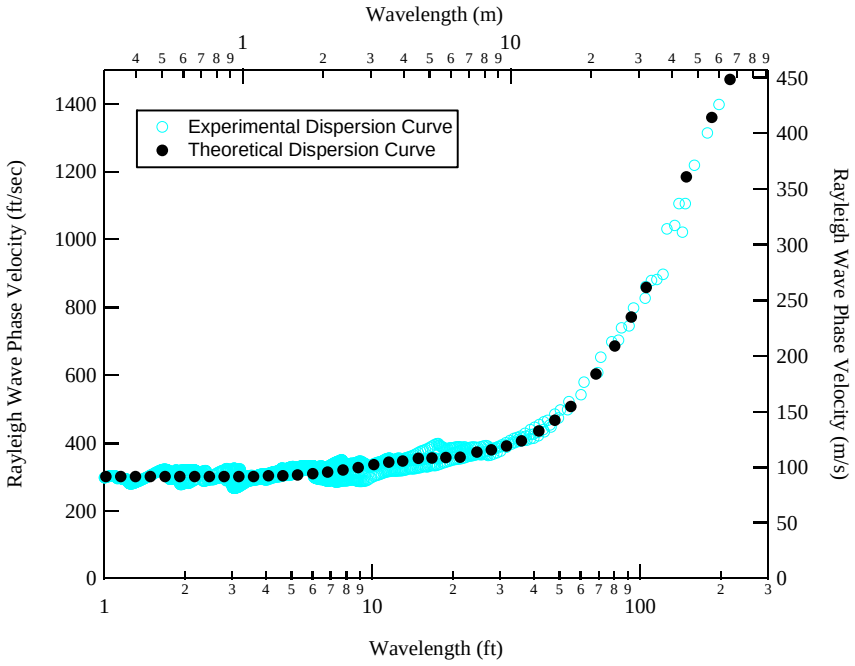


Figure 5 Experimental and theoricatical dispersion curve for Array #2 at Site 8 (CRREL)..

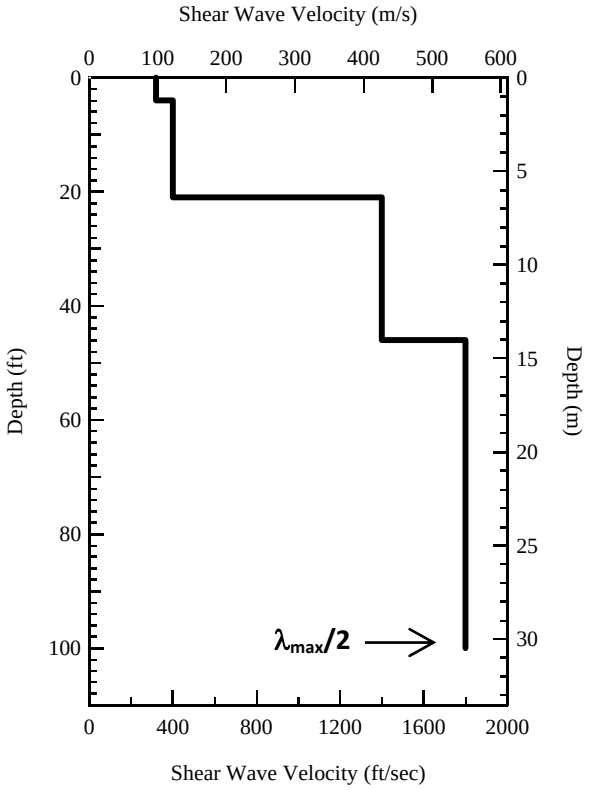


Figure 6 Shear wave velocity profile for Array #2 at Site 8 (CRREL).

Table 1. Site classification for seismic design is preferably based on shear wave velocity measurements of the upper 30 m of the site subsurface profile. The site classification is useful for the design of structures in seismically active areas and useful for assessing the overall stiffness of a site. The majority of sites across the city classify as Site Class D (stiff soil), however several sites were stiff enough to classify as Site Class C (very dense soil and soft rock). There was no apparent pattern between the location of Site Class C and D locations; however sites/profiles with an undisturbed surface layer (e.g. Site #5 Bunnel) tended to have higher average velocities than sites/profiles with an improved surface layer. This is likely due to the loss of the surface insulation layer and warming of the permafrost layer. Several sites (17, 18, 21, 23, and 29) had large variations in the dispersion curve likely caused by lateral variability at the site. These variations in dispersion data lead to multiple interpretations of the experimental dispersion curve resulting in multiple shear wave velocity profiles at the site. The specific results for all test locations can be found in Appendix A. The results from the three primary test sites are discussed below.

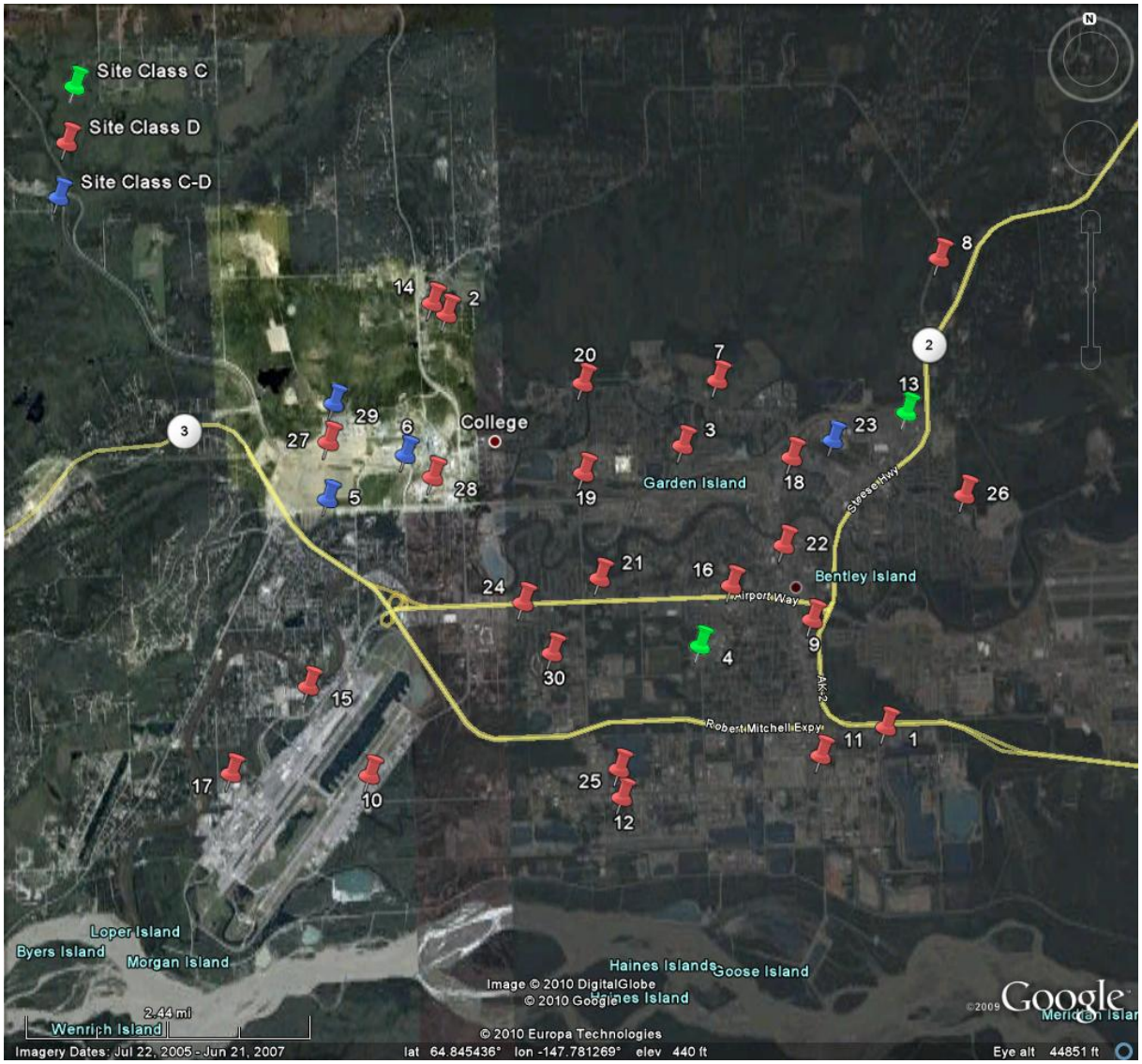


Figure 7 SASW Site Locations (Fairbanks, AK) courtesy of Google Earth.

Table 1 SASW site locations and seismic site classifications

Site #	Site Name	Latitude	Longitude	Vs30 (m/s)	Site Class[1]
1	Alaska Club	N 64.81805	W 147.69318	270	D
2	Army Rd	N 64.87063	W 147.81737	326	D
3	Auto Service Company	N 64.85356	W 147.74980	256	D
4	Big Dipper Ice Arena	N 64.82883	W 147.74654	592	C
5	Bunnel #1	N 64.84826	W 147.85384	366	D
5	Bunnel #2	N 64.84858	W147.85350	505	C
5	Bunnel #3	N 64.84856	W 147.85416	393	C
6	CCHRC #1	N 64.85344	W 147.83078	564	C
6	CCHRC #2	N 64.85361	W 147.83440	367	D
6	CCHRC #3	N 64.85383	W 147.83704	316	D
6	CCHRC #4	N 64.85388	W 147.83432	327	D
6	CCHRC #5	N 64.85220	W 147.83397	449	C
7	Creamer Field	N 64.86148	W 147.73906	319	D
8	CRREL #1	N 64.87554	W 147.67348	266	D
8	CRREL #2	N 64.87534	W 147.67323	296	D
8	CRREL #3	N 64.87502	W 147.67268	280	D
8	CRREL #4	N 64.87572	W 147.66975	310	D
9	Cushman St & 17th Ave	N 64.83160	W 147.71362	325	D
10	Fairbanks Airport	N 64.81409	W 147.84393	295	D
11	Fairbanks Chevy	N 64.81480	W147.71239	323	D
12	Frank Ave	N 64.81040	W 147.77069	334	D
13	Home Depot	N 64.85677	W 147.68427	383	C
14	Iniakuk Ave	N 64.87206	W 147.82143	302	D
15	King Rd	N 64.82526	W 147.86090	326	D
16	Lathrop High School	N 64.83612	W 147.73686	297	D
17	Mail Trail Rd	N 64.81480	W 147.88422	279-328	D
18	Monroe Catholic School	N 64.85168	W 147.71811	245-280	D
19	North Peger Rd	N 64.85056	W 147.77890	244	D
20	Old Pioneer Way	N 64.86164	W 147.77829	302	D
21	Pioneer Park	N 64.83752	W147.77513	276-309	D
22	Sadlers	N 64.84087	W 147.72121	263	D
23	Sams Club	N 64.85360	W 147.70610	354-454	C-D[2]
24	Sears	N 64.83482	W 147.79768	344	D
25	Shell St	N 64.81393	W147.77118	284	D
26	Tanana Middle School	N 64.84633	W 147.66811	262	D
27	UAF Farm	N 64.85536	W 147.85298	302	D
28	West Valley High School	N 64.85065	W 147.82289	286	D
29	WRRC #1	N 64.86034	W 147.85054	269-435	C-D[2]
29	WRRC #2	N 64.85981	W 147.85201	281-527	C-D[2]
29	WRRC #3	N 64.85960	W 147.85126	439-578	C
29	WRRC #4	N 64.85990	W 147.84976	304	D
29	WRRC #5	N 64.86002	W 147.85104	341	D
30	Zion Lutheran Church	N 64.82848	W 147.78969	308	D

Notes: 1) Sites classified according to IBC 2009.
2) C-D sites classifications are a result of lateral variability.

Three primary sites (#5 Bunnel, #6 CCHRC, and #8 CRREL) were investigated using multiple array locations to assess site variability for further project applications. Three separate array locations were used at Site #5 Bunnel. The Bunnel site map is shown in Figure 8. The arrays were positioned to provide a large coverage area without leaving the road. Array #1 is located directly on a gravel embankment and Arrays #2 and #3 are located to the right and left respectfully. The shear wave velocity profiles for each array location are shown in Figure 9. On initial inspection it is apparent Profiles 2 and 3 are stiffer than Profile 1 and encounter the stiffer layers at shallower depths. Profiles 2 and 3 have an increase in stiffness at approximately 4 meters while Profile 1 doesn't show that increase until 8 meters. Next, Profiles 2 and 3 encounter a high velocity layer, likely permafrost at a depth of 8 and 13 m. The layer is not seen on profile 1 until a depth of 20m. Moreover, the velocity in Profile 1 is 250 ft/sec lower, indicating a somewhat softer layer. Overall, the road seems to have a significant effect on the shear wave velocity compared to the unimproved areas of the site.

Site #6 is located at the Cold Climate Housing Research Center (CCHRC). Surface wave array locations are shown in Figure 10. Array locations #1, #2, and #3 are located on the gravel road with #3 being the closest to the research facility. Array location #4 is just north of the road and array location #5 is far south of the road in the forested area. The shear wave velocity profiles for each array location are shown in Figure 11. Profile 1 is the stiffest of the five profiles with higher velocities at shallower depths than the other profiles. This does not fit the trend seen at the Bunnel Site, however Profile 1 has undeveloped forested areas on both sides, which may influence the permafrost layer. Profiles 2 and 5 are very similar, with Profile 5 being slightly stiffer. This difference is likely caused by Profile 5 being further into the forested area than Profile 2. Profile 4 is the softest profile, which is different than the trend seen at the Bunnel Site; however, this area may have been modified when the building was constructed. Profile 3 has very similar shear wave velocities to Profiles 2 and 5, however Profile 3 encounters the final stiff layer almost 10 m deeper than Profiles 2 and 5. The layering difference may be caused by the proximity of Profile 3 to the building. Overall, Site #6 CCHRC has significant variability across the site, with variable layer thickness and wide ranging shear wave velocities.

The Cold Regions Research and Engineering Laboratory (CRREL) is the location of Site #8. Array locations #1, #2, and #3 are located on the west edge of the property near the pile

testing arrangement (Figure 12). Array location #4 is further north and on the east edge of the property. The shear wave velocities for each location are shown in Figure 13. It is clear that the different array locations have very similar profiles. All the profiles encounter a stiffer layer at approximately 6 m deep. The layer is likely lightly frozen permafrost and the depth, thickness, and stiffness of the permafrost layers is very uniform across the site with increasing stiffness with depth. Overall, Site #8 CRREL is a very uniform site with well defined layers.

6.0 Summary

SASW surface wave testing was performed at 30 sites in the City of Fairbanks, AK. The majority of sites in the Fairbanks area classify as Site Class D according to IBC (2009), however several sites had stiff subsurface layers that improved the Site Class to C. The three primary tests sites were located across Fairbanks and presented somewhat different subsurface stratification. Site #5 Bunnel showed some variability in the subsurface across the site. The array located on the road was significantly softer versus the off-road arrays. Overall, Bunnel had a very stiff subsurface profile with little variability once off the main road. Site # 6 CCHRC had the most variability with profiles varying considerably between array locations. The subsurface stiffness was similar to the Bunnel site, although a little softer, especially Profile #4. Site #8 CRREL had the most uniform subsurface across the site with only small differences between layer thicknesses. However, Bunnel and CCHRC had between 25% and 50% higher velocity than seen at the CRREL site. This is likely caused by a softening of the permafrost layer or a softer more weathered bedrock layer below the site. By and large, with 30 separate sites tested across the city of Fairbanks a good grid pattern has been established for future seismic/engineering work.

7.0 References

Joh, S.-H. (1996), “Advances in the Data Interpretation Technique for Spectral- Analysis-of-Surface-Waves (SASW) Measurements,” Ph.D. Dissertation, The University of Texas at Austin, 240 pgs.

Stokoe, K.H., II, Wright, S.G., Bay, J.A., and Roesset, J.M., 1994. Characterization of geotechnical sites by SASW method, in *Technical Report - Geophysical Characterization of Sites*, Woods, R.D. (editor), ISSMFE Technical Committee 10: Oxford Publishers, 13th International Conference on Soil Mechanics and Foundation Engineering, New Delhi, India.

Figure 8 SASW array location map for Site 5 (Bunnel).

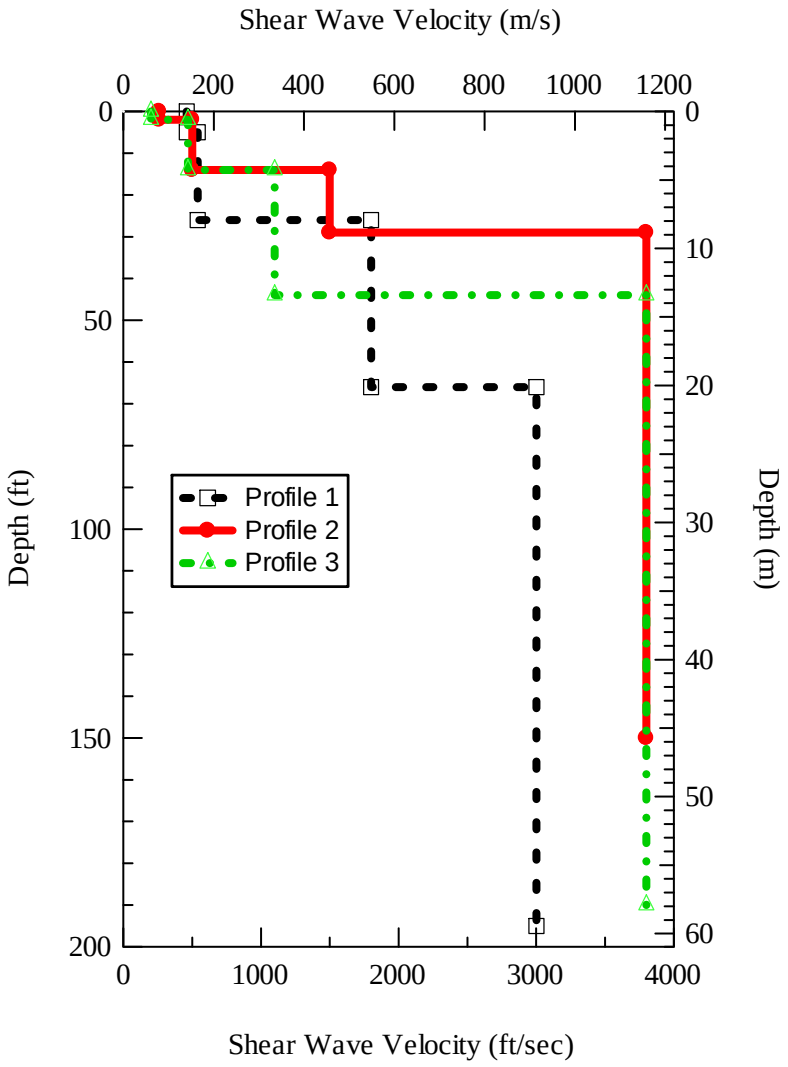


Figure 9 Shear wave velocity profile comparison for Site 5 (Bunnel).

Figure 10 SASW Array location map for Site 6 (CCHRC).

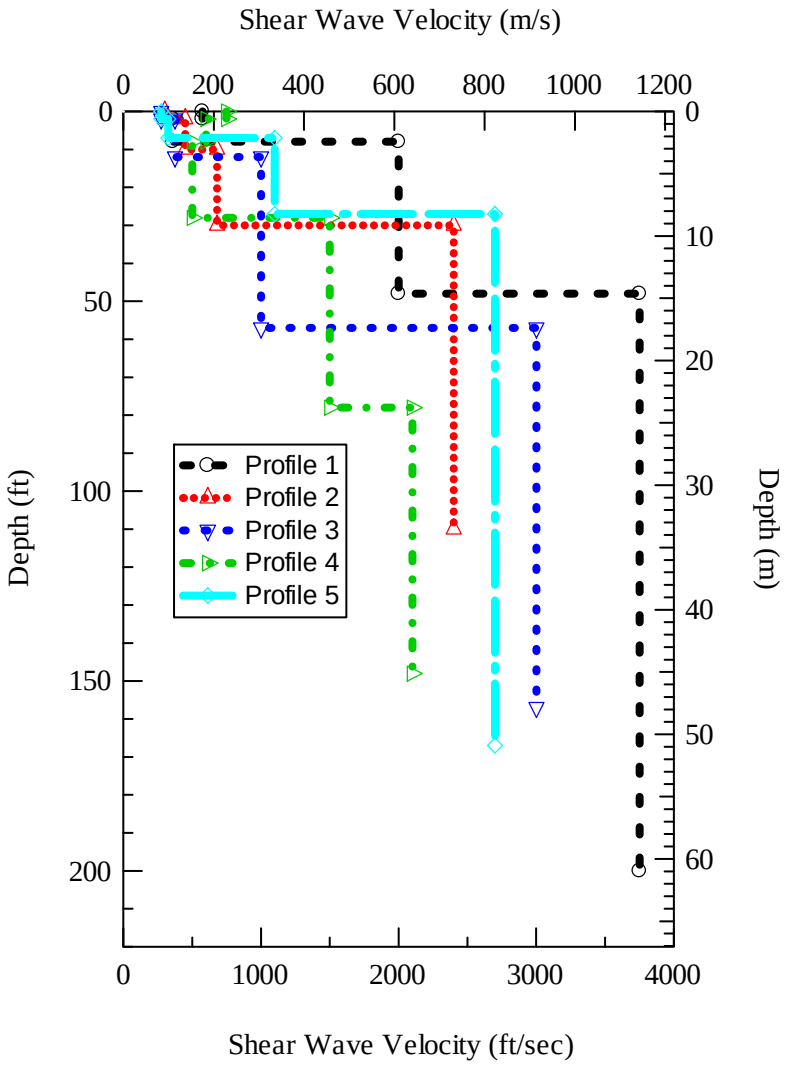


Figure 11 Shear wave velocity profile comparison for Site 6 (CCHRC).

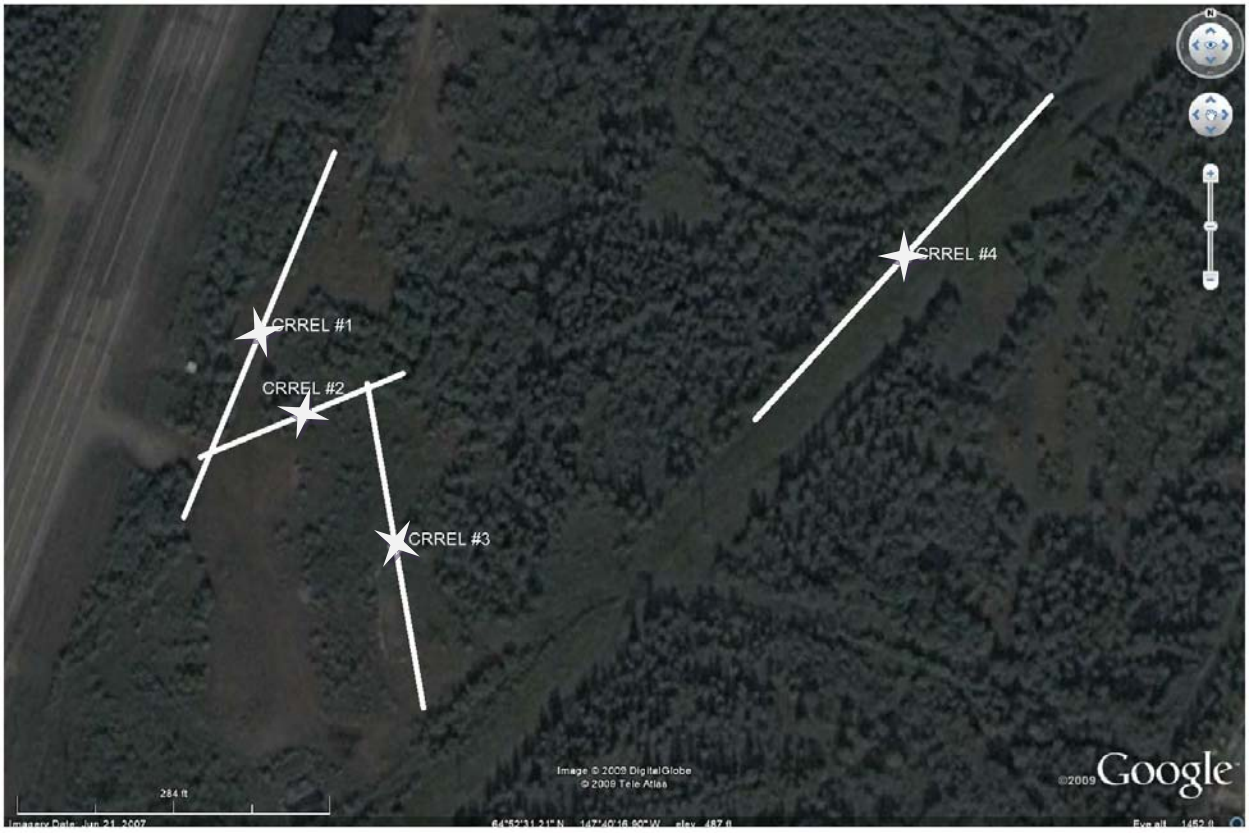


Figure 12 SASW Array location map for Site 8 (CRREL).

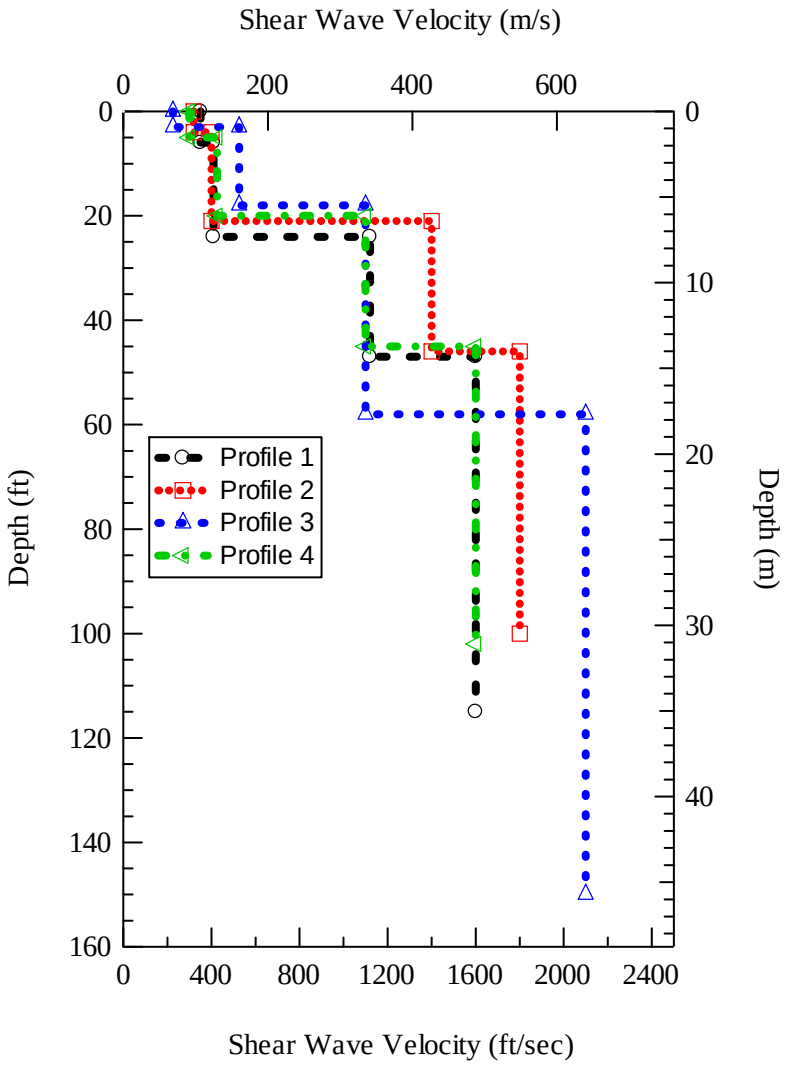


Figure 13 Shear wave velocity profile comparison for Site 8 (CRREL).

Appendix A

Site 1: Alaska Club

Figure 1 SASW Array location map for Site 1 (Alaska Club).

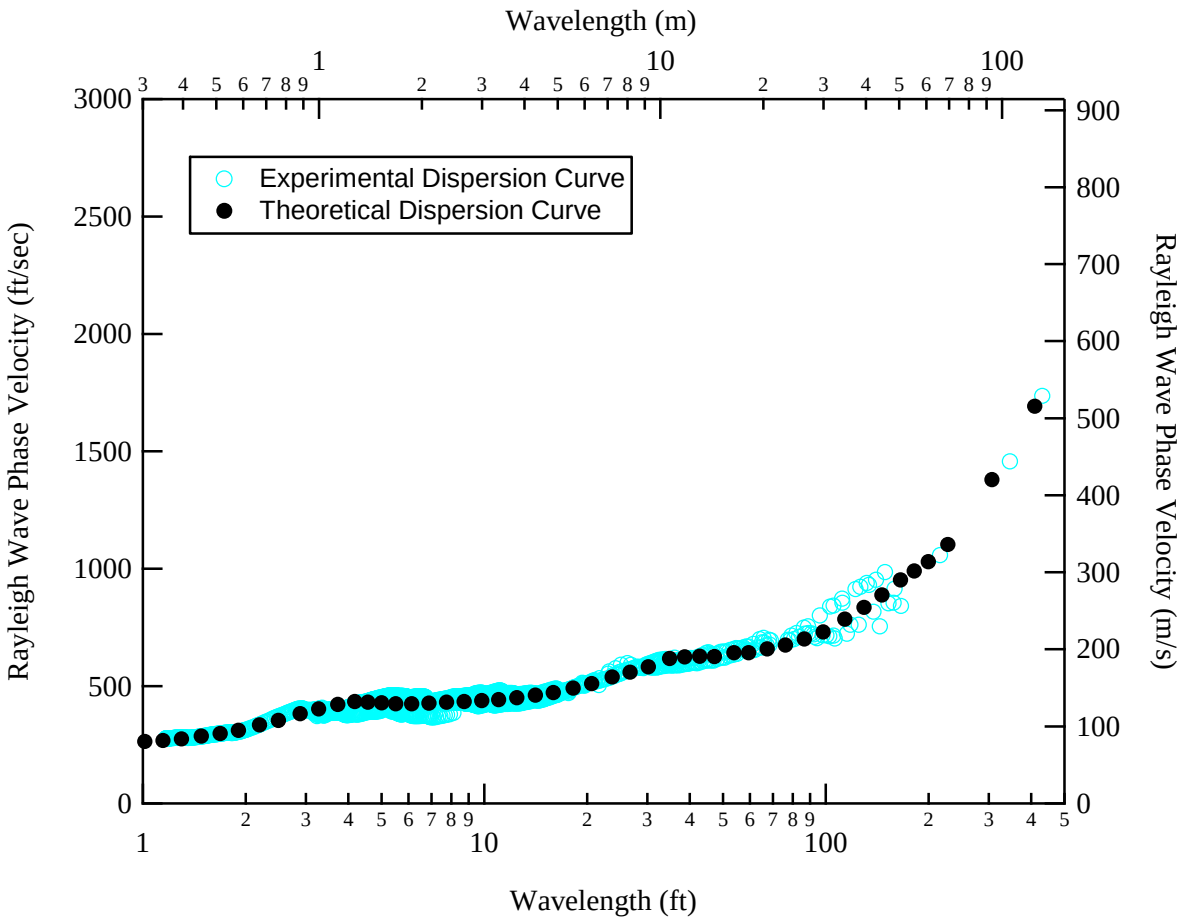


Figure 2 Experimental and theoretical dispersion data at Site 1 (Alaska Club).

Table 1 Final forward modeling soil profile for Site 1 (Alaska Club).

Layer No.	Thickness (m)	Depth to bottom (m)	P-wave velocity (m/s)	Shear wave velocity (m/s)	Poisson's Ratio	Unit Weight (kN/m^3)	Vs 30 Site Class (m/s)
1	0.2	0.2	160	80	0.30	17	270
2	2.7	2.9	290	150	0.30	17	
3	13.7	16.6	440	220	0.30	19	D
4	44.4	61.0	910	460	0.33	20	

Note: maximum depth of profile is approximately equal to maximum experimental wavelength/two.

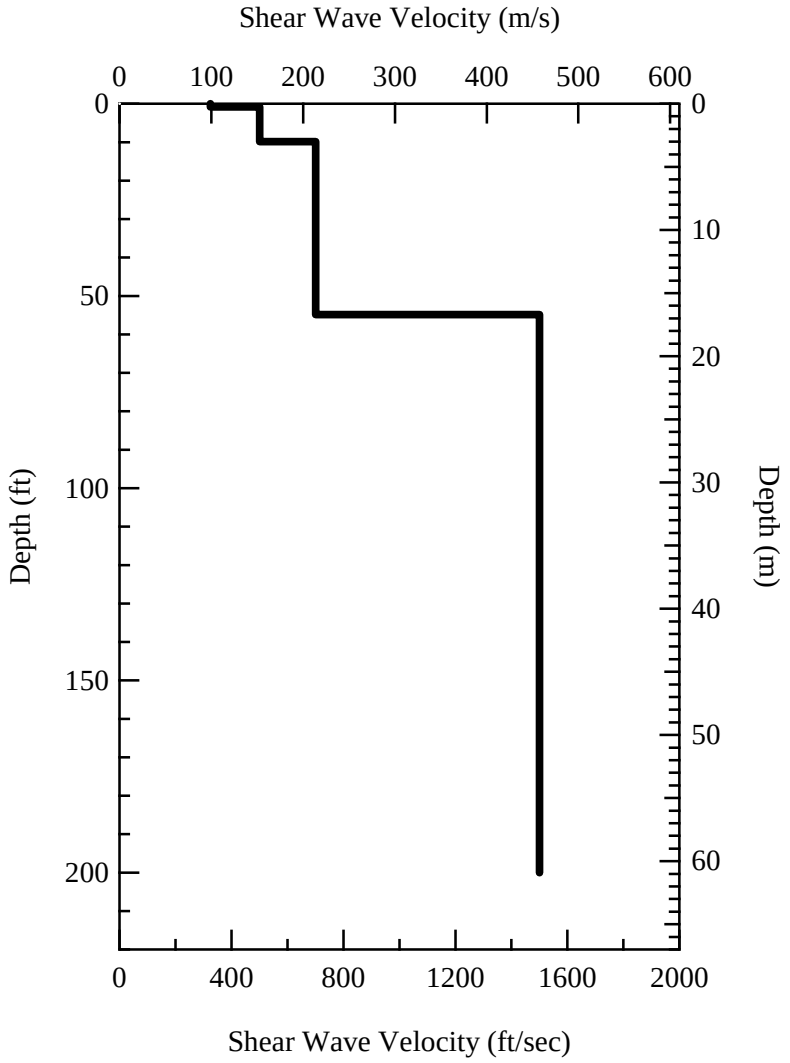


Figure 3 Shear wave velocity profile for Site 1 (Alaska Club)

Site 2: Army Road

Figure 4 SASW Array location map for Site 2 (Army Road).

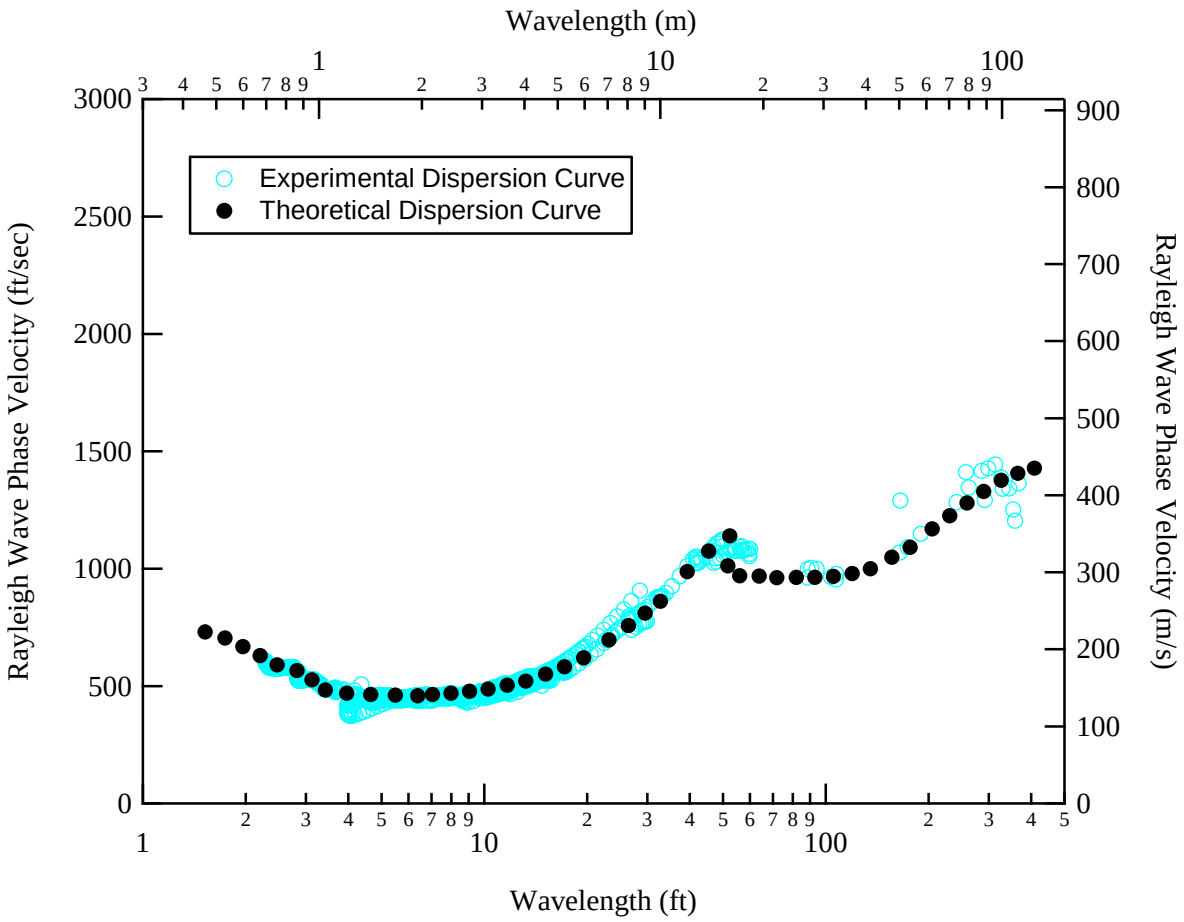


Figure 5 Experimental and theoretical dispersion data at Site 2 (Army Road).

Table 2 Final forward modeling soil profile for Site 2 (Army Road).

Layer No.	Thickness (m)	Depth to bottom (m)	P-wave velocity (m/s)	Shear wave velocity (m/s)	Poisson's Ratio	Unit Weight (kN/m^3)	Vs 30 Site Class (m/s)
1	1.8	1.8	260	140	0.30	16	326
2	1.2	3.0	510	270	0.30	17	
3	7.6	10.6	740	400	0.30	18	D
4	10.7	21.3	510	270	0.30	17	
5	34.7	56.0	1030	520	0.33	19	

Note: maximum depth of profile is approximately equal to maximum experimental wavelength/two.

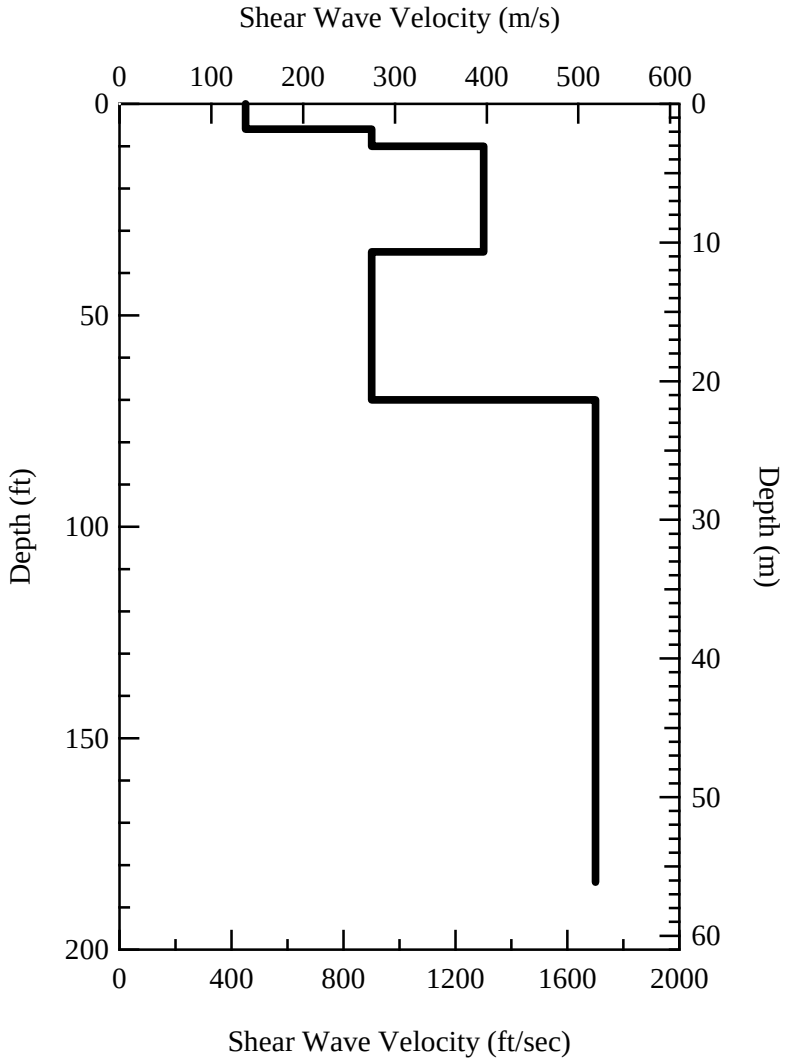


Figure 6 Shear wave velocity profile for Site 2 (Army Road).

Site 3: Auto Service Company

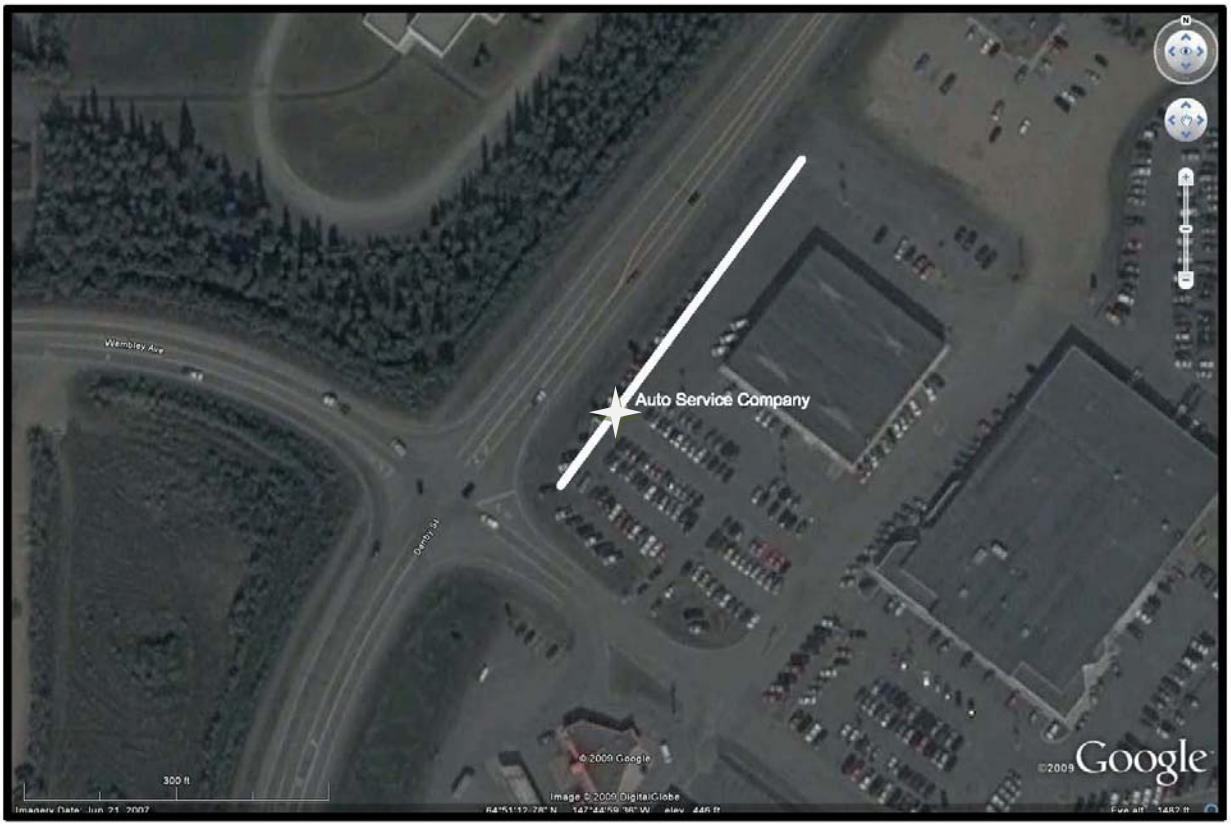


Figure 7 SASW Array location map for Site 3 (Auto Service Company).

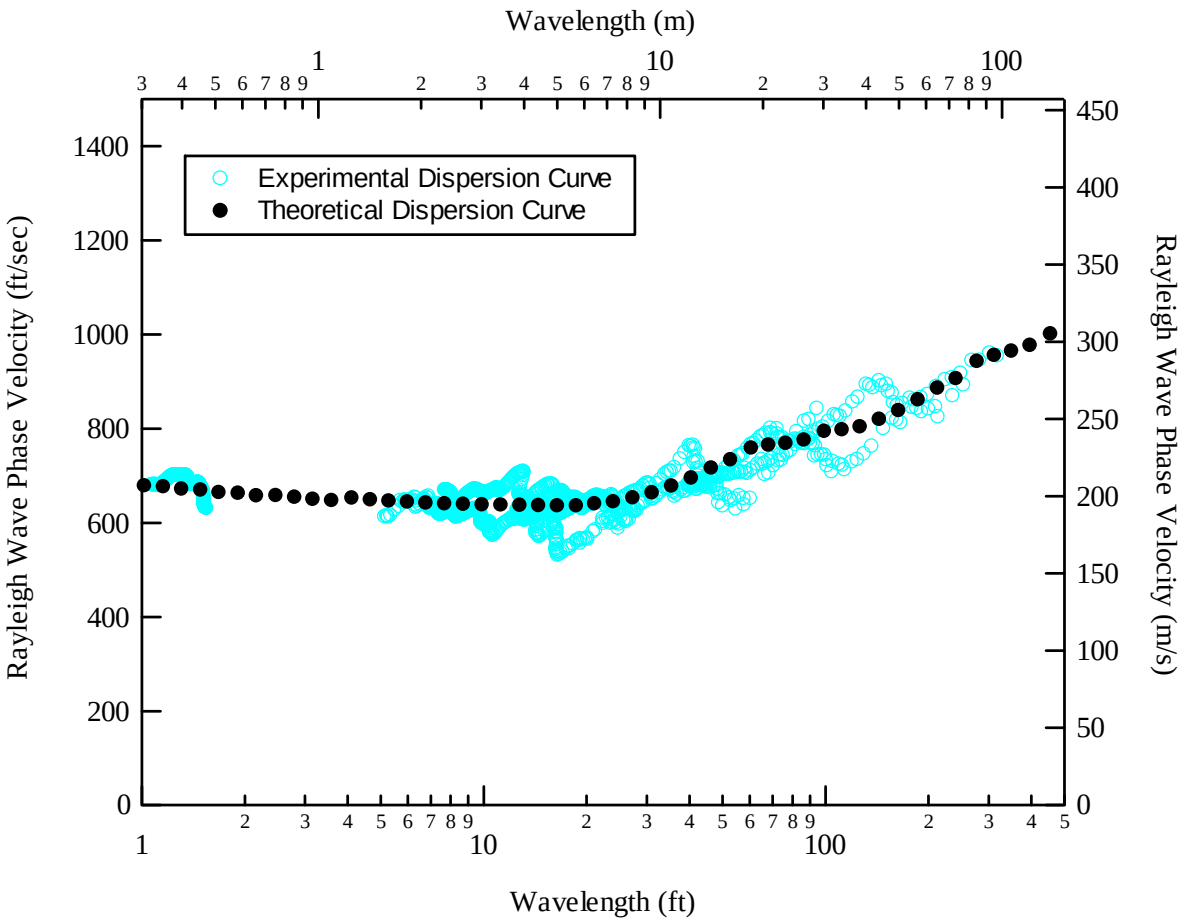


Figure 8 Experimental and theoretical dispersion data at Site 3 (Auto Service Company).

Table 3 Final forward modeling soil profile for Site 3 (Auto Service Company).

Layer No.	Thickness (m)	Depth to bottom (m)	P-wave velocity (m/s)	Shear wave velocity (m/s)	Poisson's Ratio	Unit Weight (kN/m^3)	Vs 30 Site Class (m/s)
1	0.2	0.2	410	220	0.30	16	256
2	5.5	5.7	380	210	0.30	17	
3	22.9	28.6	500	270	0.30	18	D
4	20.1	48.7	680	340	0.33	19	

Note: maximum depth of profile is approximately equal to maximum experimental wavelength/two.

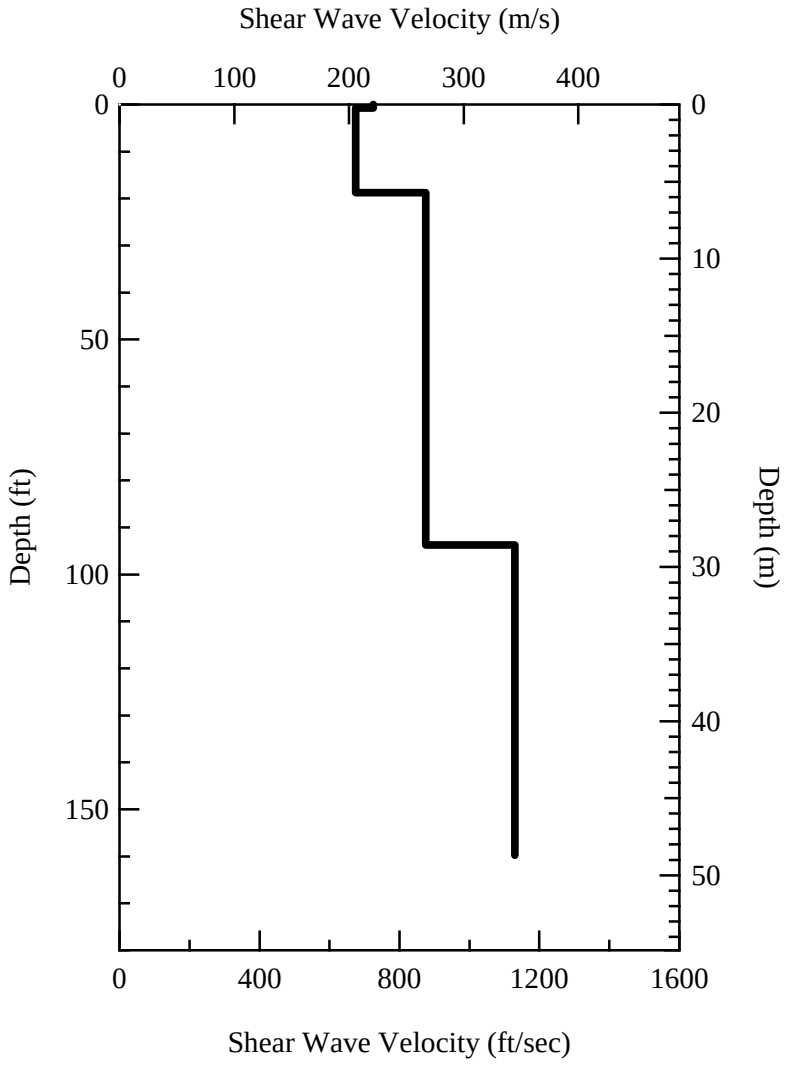


Figure 9 Shear wave velocity profile for Site 3 (Auto Service Company).

Site 4: Big Dipper Ice Arena

Figure 10 SASW Array location map for Site 4 (Big Dipper Ice Arena).

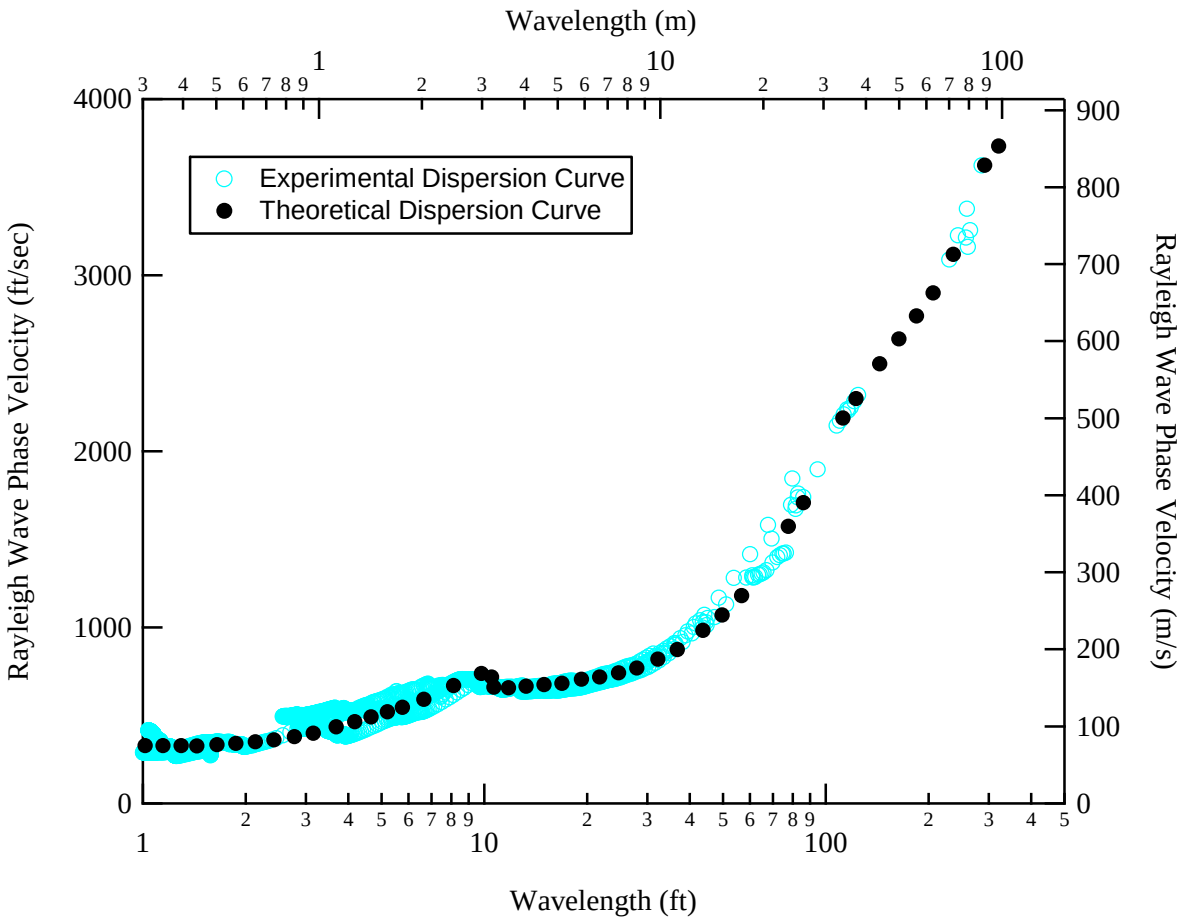


Figure 11 Experimental and theoretical dispersion data at Site 4 (Big Dipper Ice Arena).

Table 4 Final forward modeling soil profile for Site 4 (Big Dipper Ice Arena).

Layer No.	Thickness (m)	Depth to bottom (m)	P-wave velocity (m/s)	Shear wave velocity (m/s)	Poisson's Ratio	Unit Weight (kN/m^3)	Vs 30 Site Class (m/s)
1	0.4	0.4	200	110	0.30	17	592
2	4.9	5.3	460	240	0.30	17	C
3	38.4	43.7	2660	910	0.33	19	

Note: maximum depth of profile is approximately equal to maximum experimental wavelength/two.

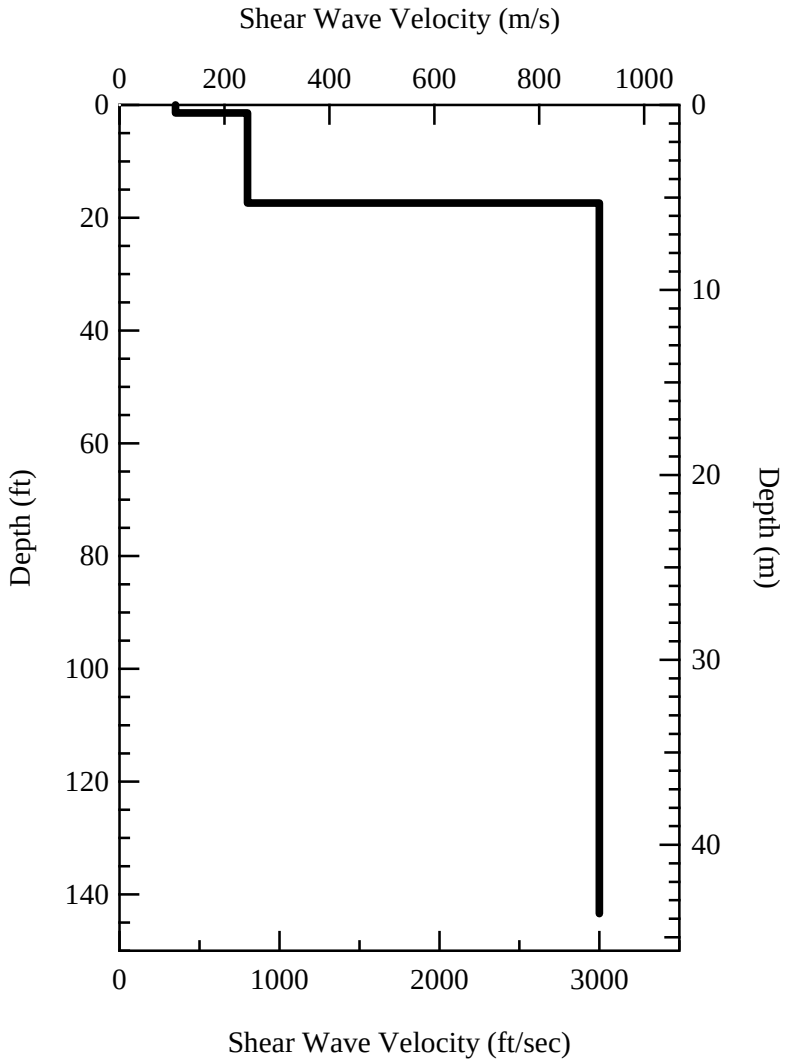


Figure 12 Shear wave velocity profile for Site 4 (Big Dipper Ice Arena).

Site 5: Bunnel

Figure 13 SASW Array location map for Site 5 (Bunnel).

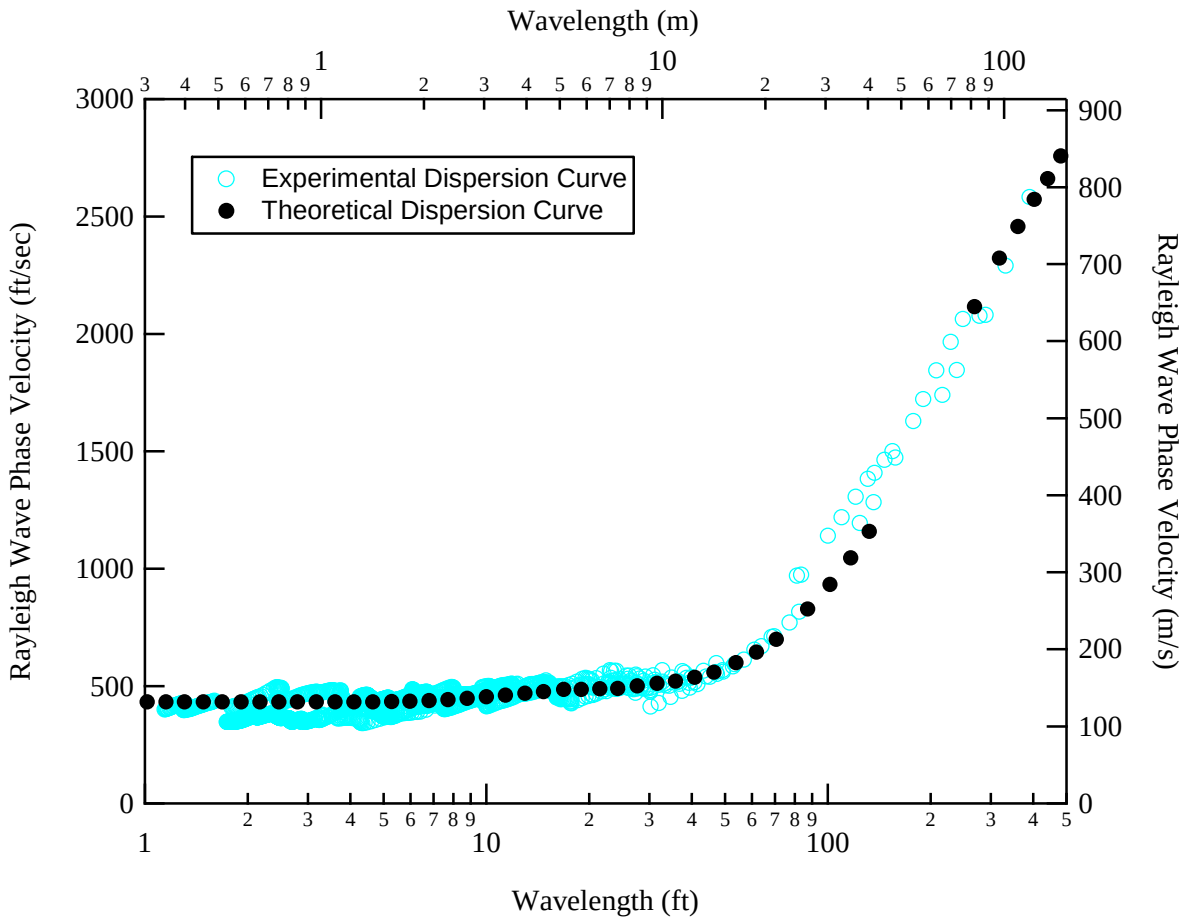


Figure 14 Experimental and theoretical dispersion data for Array #1 at Site 5 (Bunnel).

Table 5 Final forward modeling soil profile for Array #1 at Site 5 (Bunnel).

Layer No.	Thickness (m)	Depth to bottom (m)	P-wave velocity (m/s)	Shear wave velocity (m/s)	Poisson's Ratio	Unit Weight (kN/m^3)	Vs 30 (m/s)
1	1.5	1.5	260	140	0.30	16	366
2	6.4	7.9	310	160	0.30	16	
3	12.2	20.1	1090	550	0.30	17	D
4	39.3	59.4	1820	910	0.33	18	

Note: maximum depth of profile is approximately equal to maximum experimental wavelength/two.

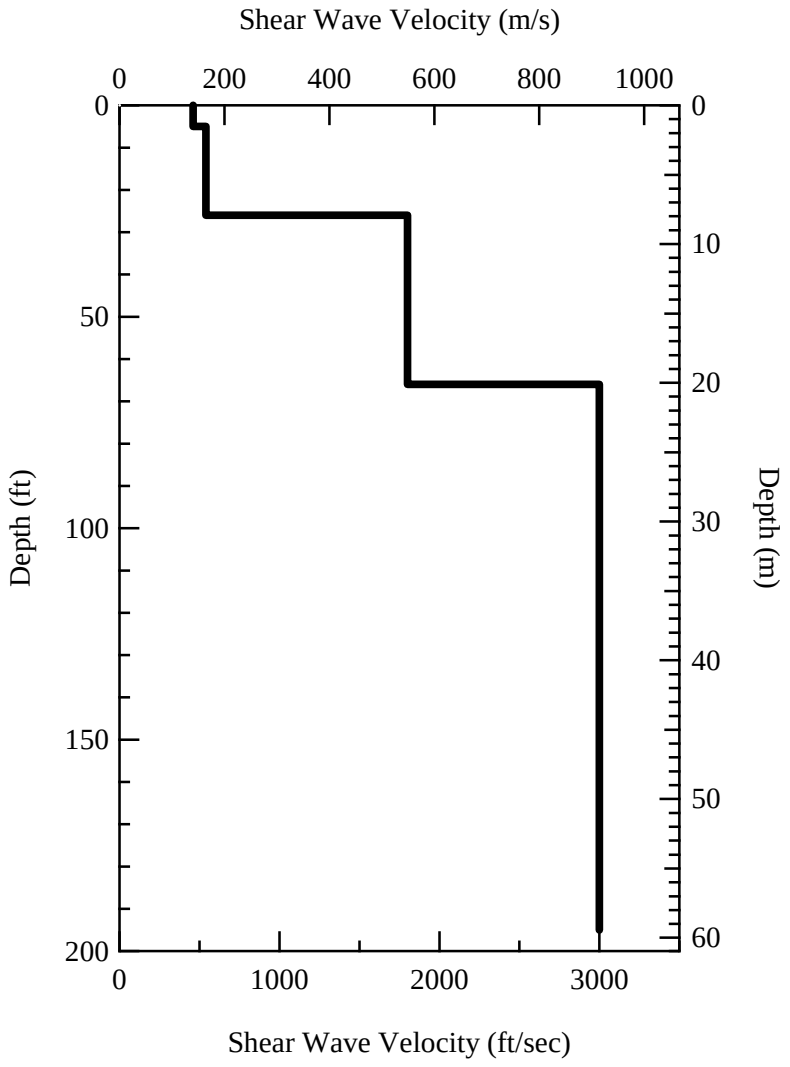


Figure 15 Shear wave velocity profile for Array #1 at Site 5 (Bunnel).

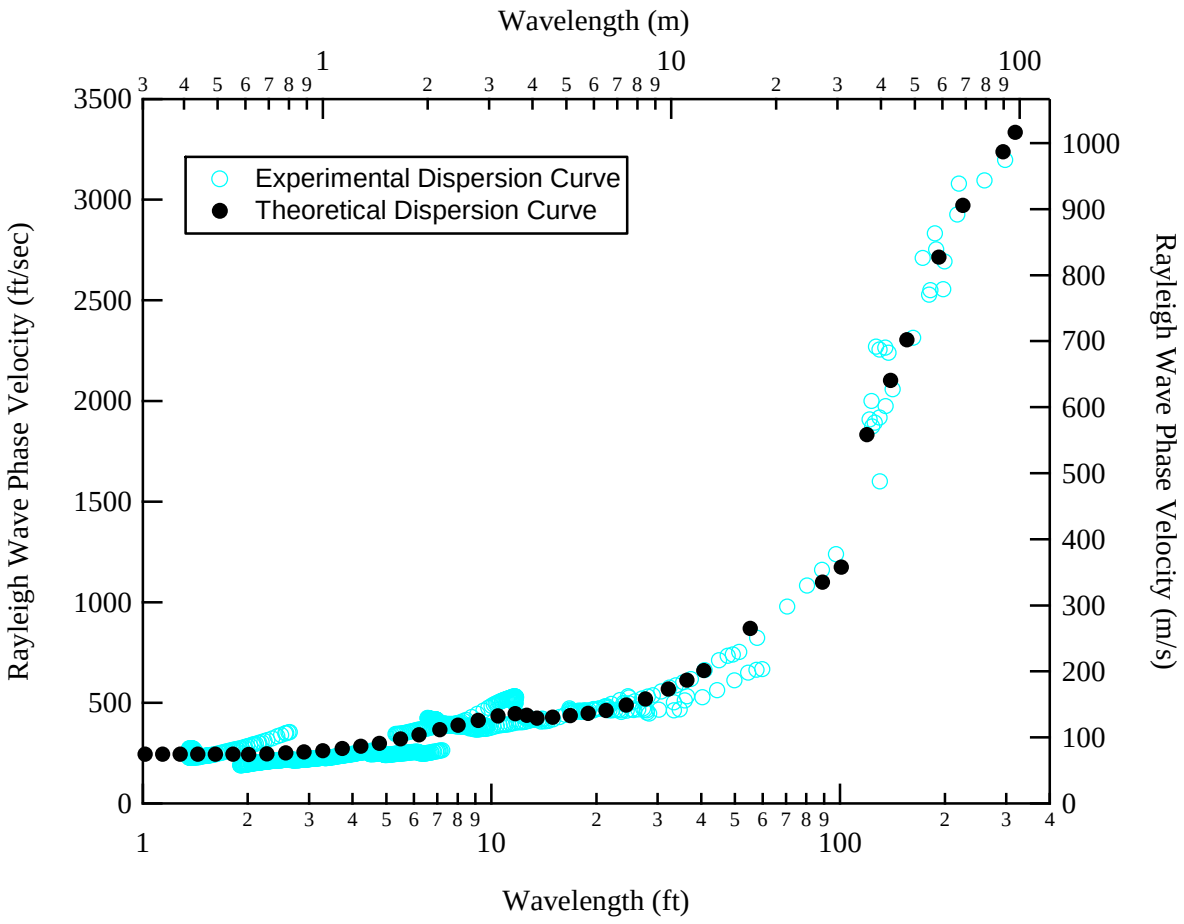


Figure 16 Experimental and theoretical dispersion data for Array #2 at Site 5 (Bunnel).

Table 6 Final forward modeling soil profile for Array #2 at Site 5 (Bunnel).

Layer No.	Thickness (m)	Depth to bottom (m)	P-wave velocity (m/s)	Shear wave velocity (m/s)	Poisson's Ratio	Unit Weight (kN/m^3)	Vs 30 (m/s)
1	0.6	0.6	150	80	0.30	16	505
2	3.7	4.3	290	150	0.30	16	
3	4.6	8.9	910	460	0.30	17	C
4	36.9	45.8	2300	1160	0.33	19	

Note: maximum depth of profile is approximately equal to maximum experimental wavelength/two.

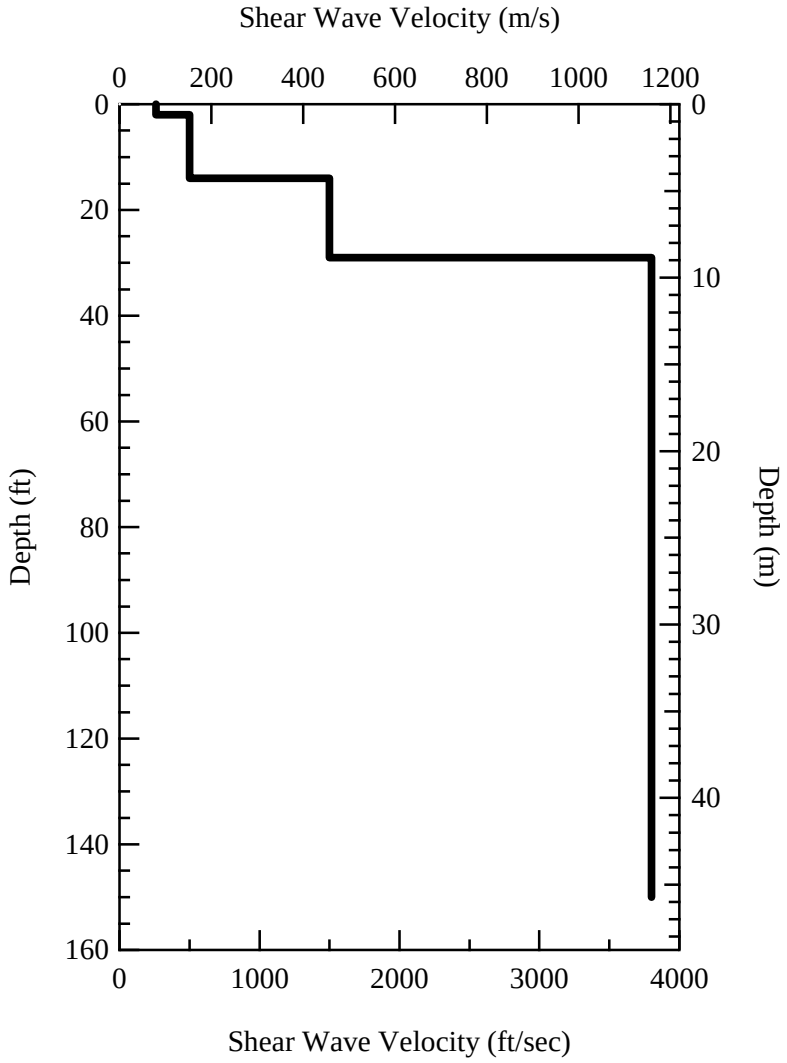


Figure 17 Shear wave velocity profile for Array #2 at Site 5 (Bunnel).

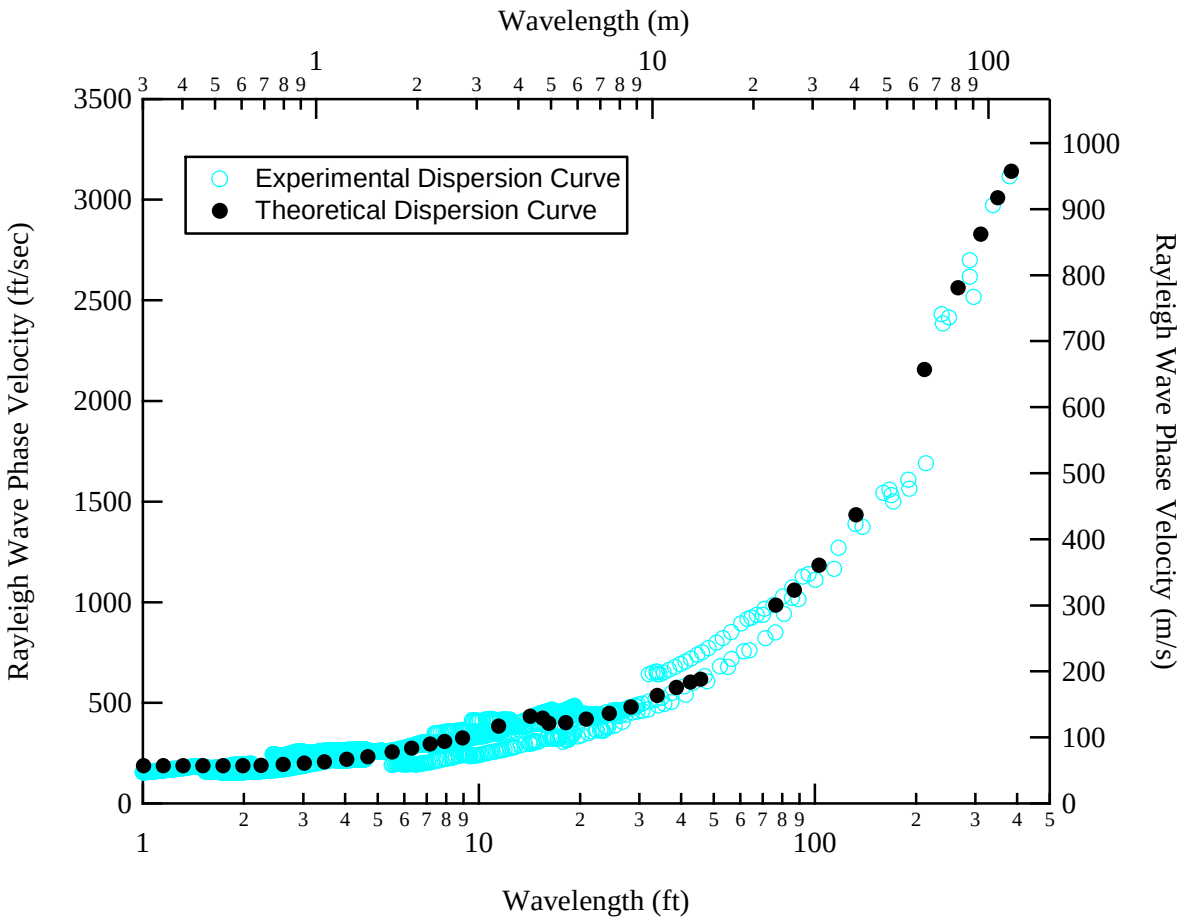


Figure 18 Experimental and theoretical dispersion data for Array #3 at Site 5 (Bunnel).

Table 7 Final forward modeling soil profile for Array #3 at Site 5 (Bunnel).

Layer No.	Thickness (m)	Depth to bottom (m)	P-wave velocity (m/s)	Shear wave velocity (m/s)	Poisson's Ratio	Unit Weight (kN/m^3)	Vs 30 (m/s)
1	0.6	0.6	110	60	0.30	16	393
2	3.7	4.3	270	140	0.30	16	
3	9.1	13.4	630	340	0.30	17	C
4	44.5	57.9	2300	1160	0.33	19	

Note: maximum depth of profile is approximately equal to maximum experimental wavelength/two.

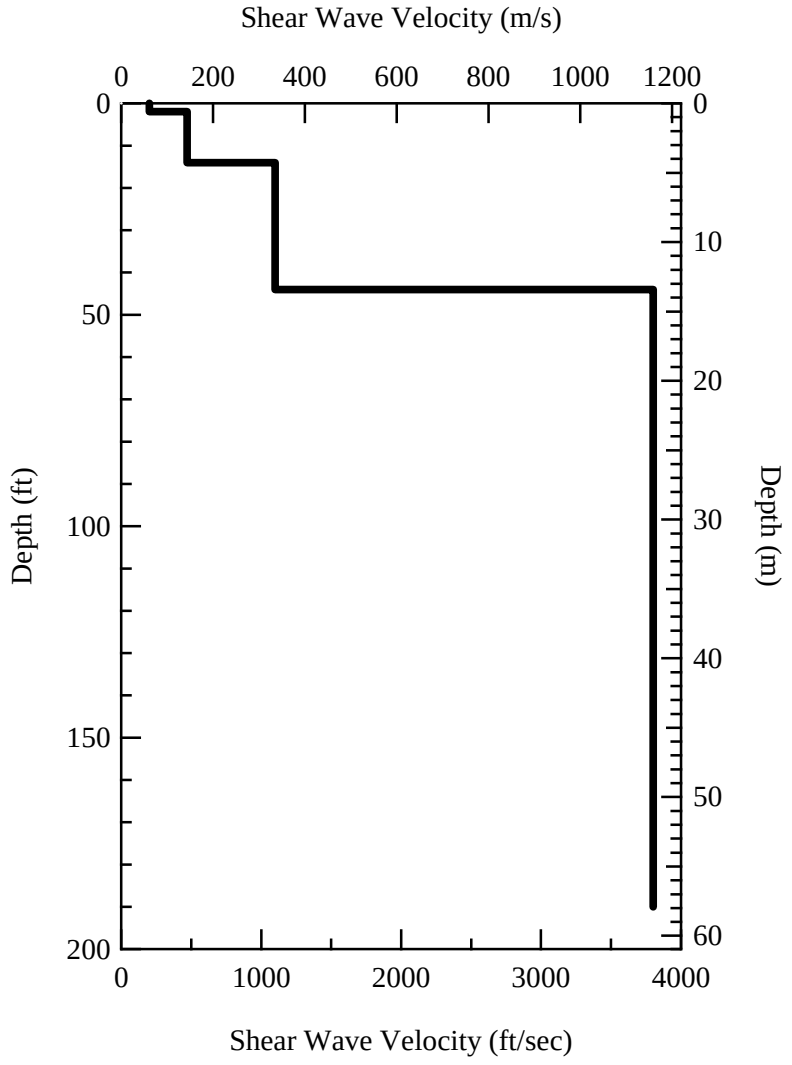


Figure 19 Shear wave velocity profile for Array #3 at Site 5 (Bunnel).

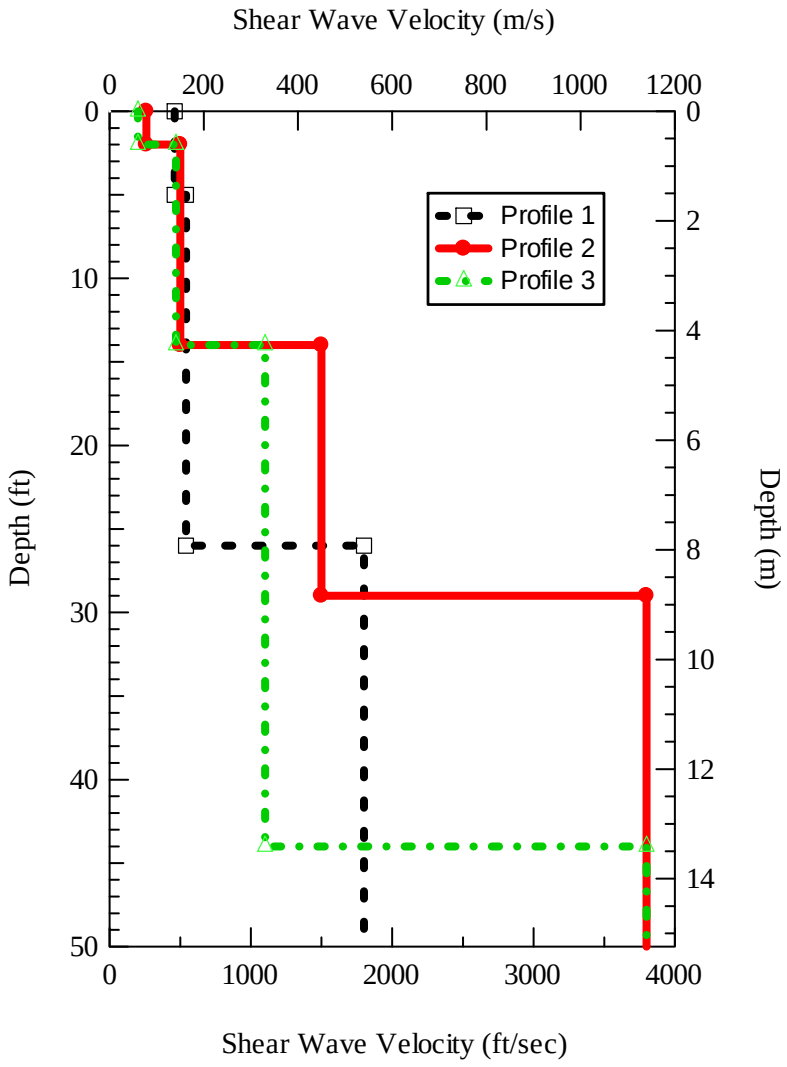


Figure 20 Shear wave velocity profile comparison for Site 5, 0-50ft. (Bunnel).

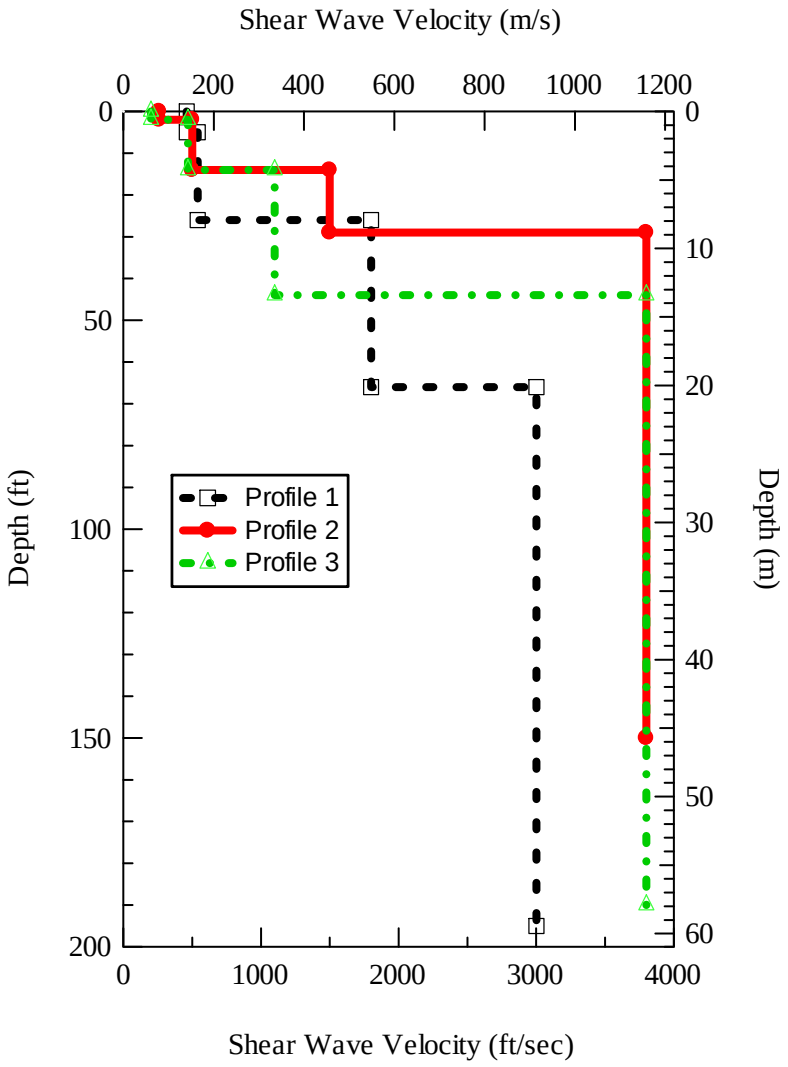


Figure 21 Shear wave velocity profile comparison for Site 5 (Bunnel).

Site #6 CCHRC

Figure 22 SASW Array location map for Site 6 (CCHRC).

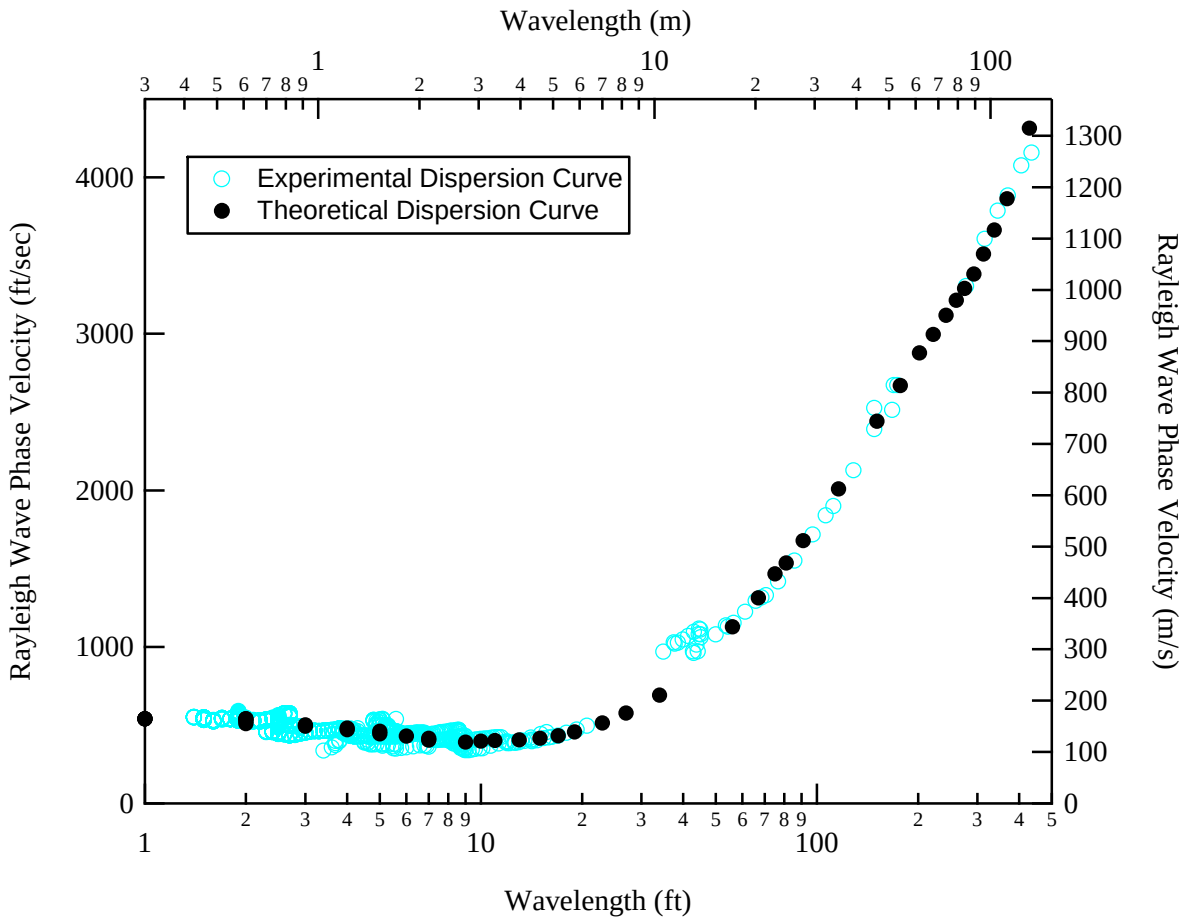


Figure 23 Experimental and theoretical dispersion data for Array #1 at Site 6 (CCHRC).

Table 8 Final forward modeling soil profile for Array #1 at Site 6 (CCHRC).

Layer No.	Thickness (m)	Depth to bottom (m)	P-wave velocity (m/s)	Shear wave velocity (m/s)	Poisson's Ratio	Unit Weight (kN/m^3)	Vs 30 Site Class (m/s)
1	0.6	0.6	330	180	0.30	17	564
2	1.8	2.4	210	110	0.30	16	
3	12.2	14.6	1210	610	0.30	18	C
4	46.4	61.0	2270	1140	0.33	19	

Note: maximum depth of profile is approximately equal to maximum experimental wavelength/two.

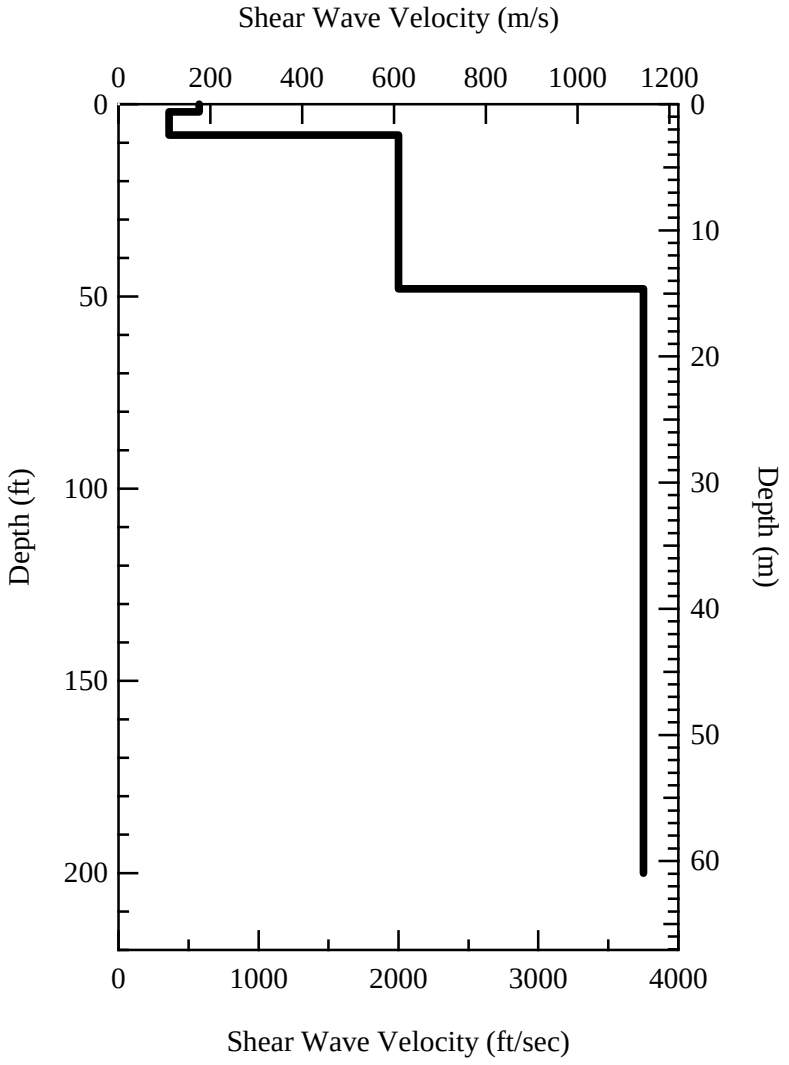


Figure 24 Shear wave velocity profile for Array #1 at Site 6 (CCHRC).

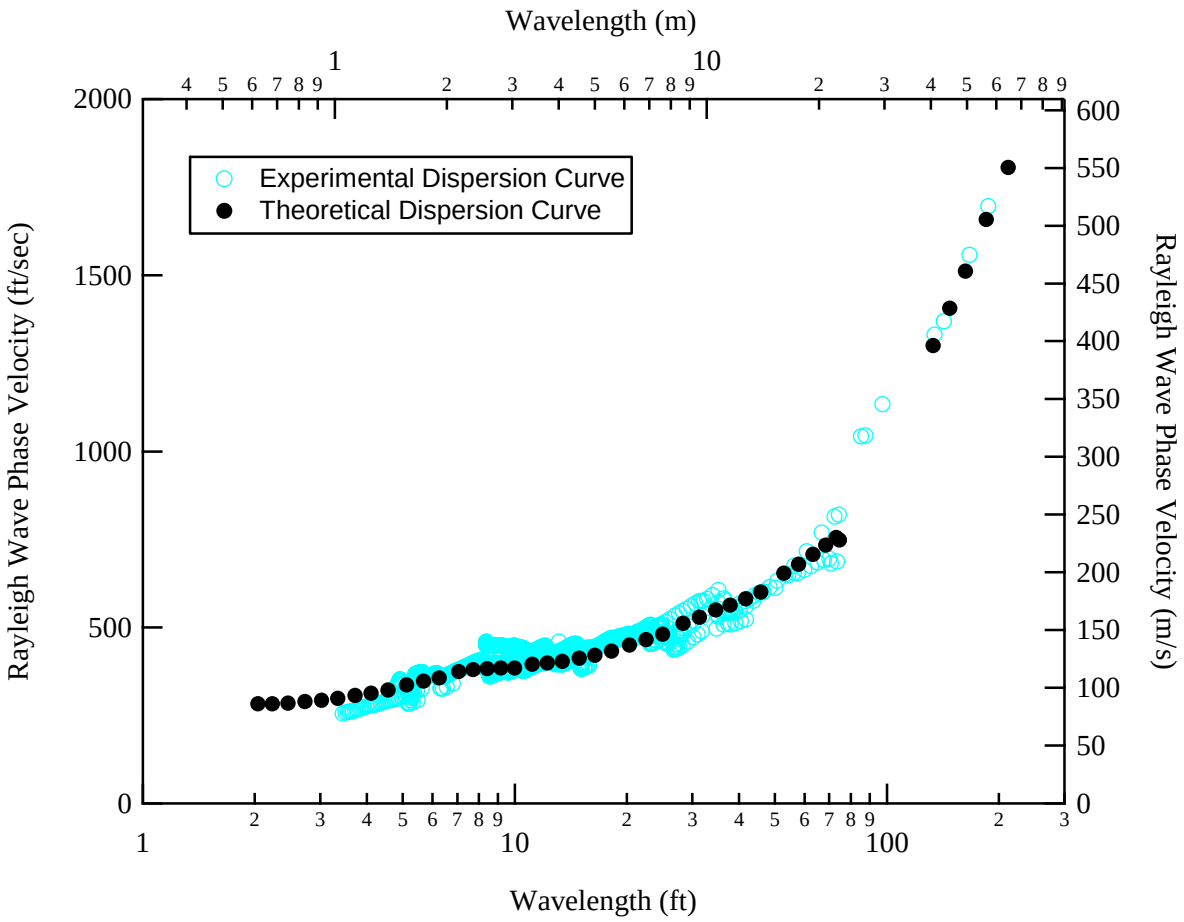


Figure 25 Experimental and theoretical dispersion data for Array #2 at Site 6 (CCHRC).

Table 9 Final forward modeling soil profile for Array #2 at Site 6 (CCHRC).

Layer No.	Thickness (m)	Depth to bottom (m)	P-wave velocity (m/s)	Shear wave velocity (m/s)	Poisson's Ratio	Unit Weight (kN/m^3)	Vs 30 Site Class (m/s)
1	0.6	0.6	170	90	0.30	17	367
2	2.4	3.0	260	140	0.30	17	
3	6.1	9.1	390	210	0.30	17	D
4	24.4	33.5	1370	730	0.33	19	

Note: maximum depth of profile is approximately equal to maximum experimental wavelength/two.

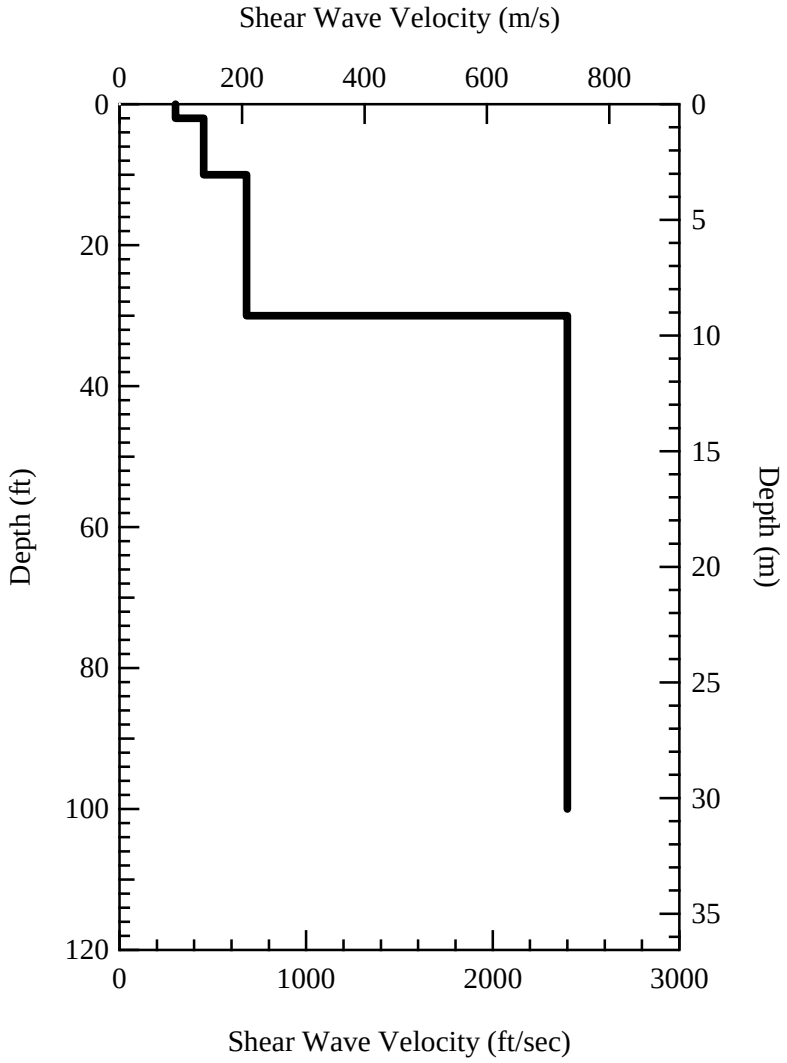


Figure 26 Shear wave velocity profile for Array #2 at Site 6 (CCHRC).

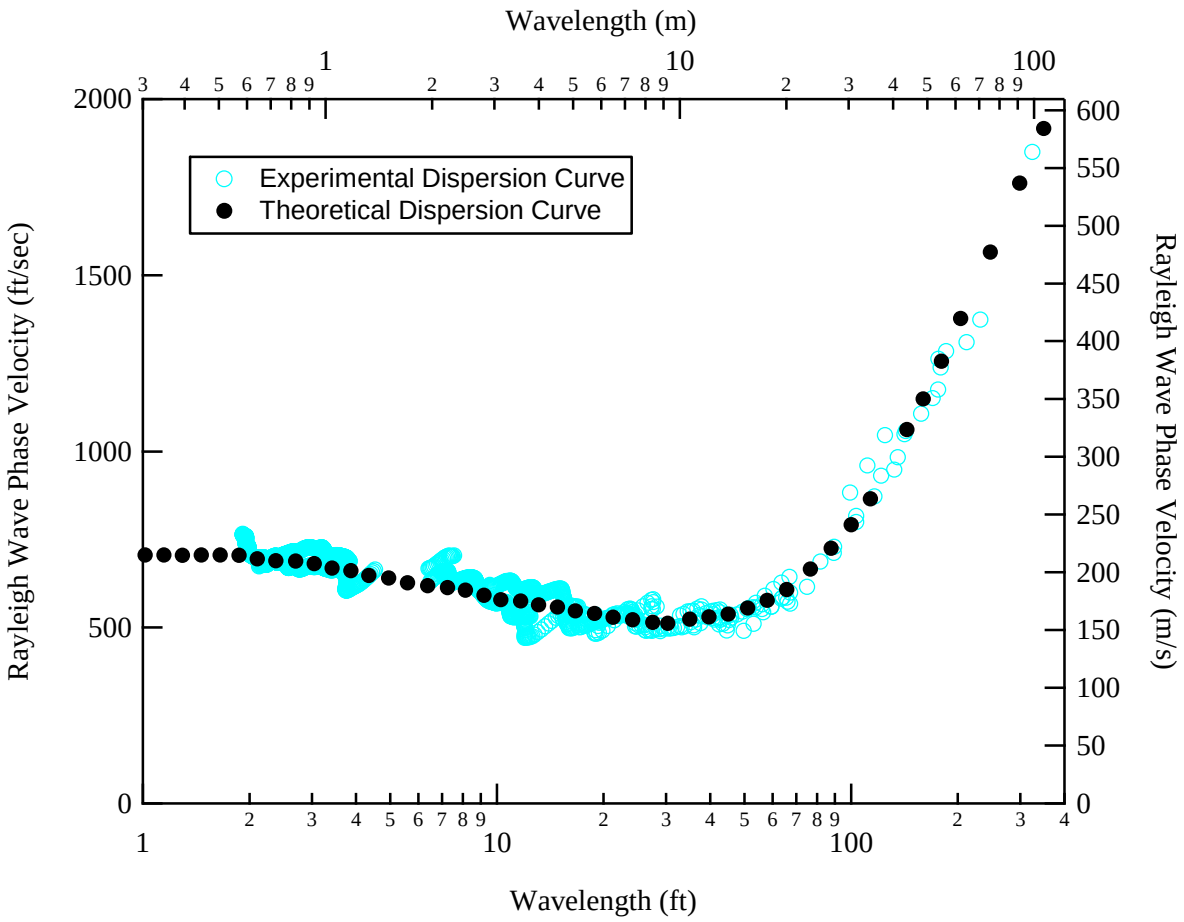


Figure 27 Experimental and theoretical dispersion data for Array #3 at Site 6 (CCHRC).

Table 10 Final forward modeling soil profile for Array #3 at Site 5 (CCHRC).

Layer No.	Thickness (m)	Depth to bottom (m)	P-wave velocity (m/s)	Shear wave velocity (m/s)	Poisson's Ratio	Unit Weight (kN/m^3)	Vs 30 Site Class (m/s)
1	0.6	0.6	430	230	0.30	17	316
2	1.8	1.8	340	180	0.30	17	
3	6.1	7.9	290	150	0.30	17	D
4	15.2	23.1	910	460	0.33	18	
5	21.3	44.4	1270	640	0.33	19	

Note: maximum depth of profile is approximately equal to maximum experimental wavelength/two.

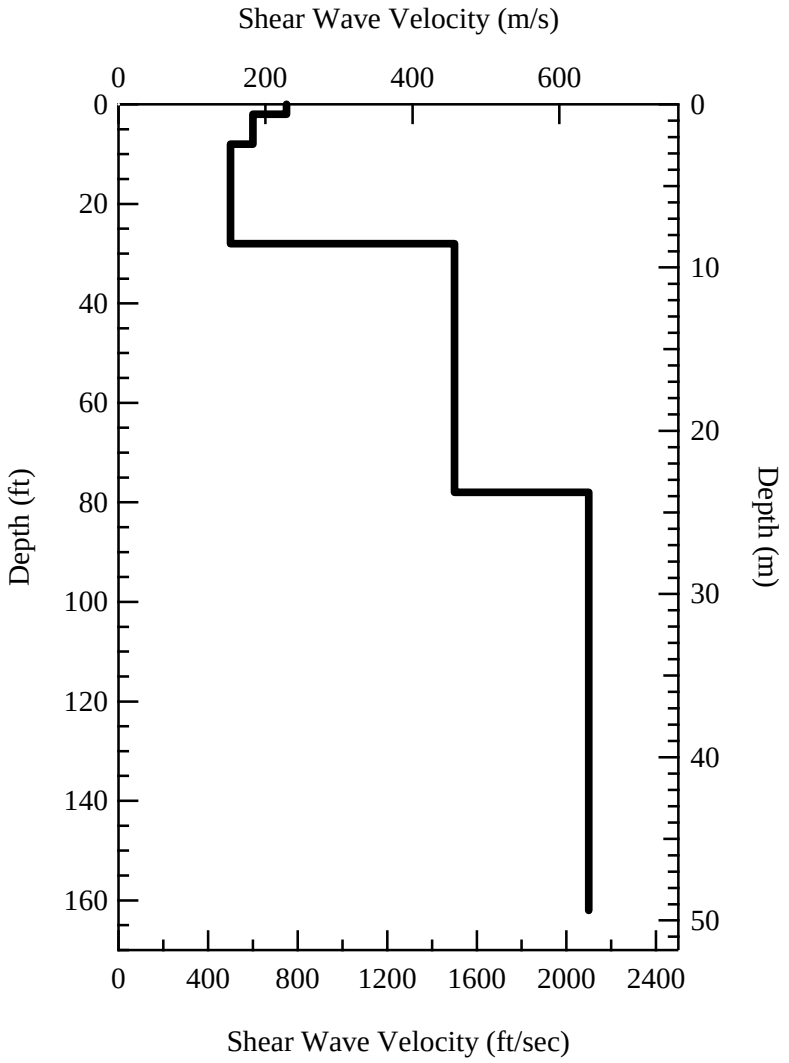


Figure 28 Shear wave velocity profile for Array #3 at Site 6 (CCHRC).

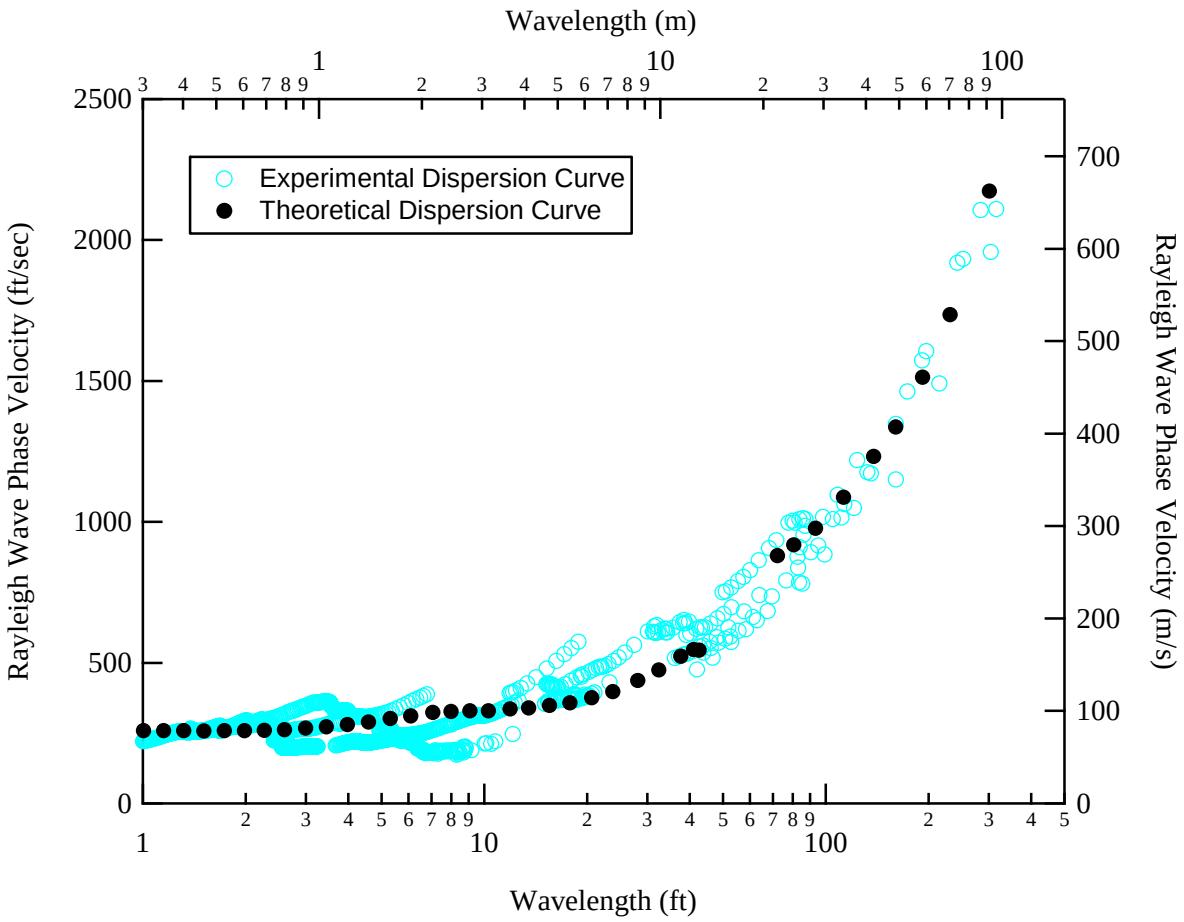


Figure 29 Experimental and theoretical dispersion data for Array #4 at Site 6 (CCHRC).

Table 11 Final forward modeling soil profile for Array #4 at Site 6 (CCHRC).

Layer No.	Thickness (m)	Depth to bottom (m)	P-wave velocity (m/s)	Shear wave velocity (m/s)	Poisson's Ratio	Unit Weight (kN/m^3)	Vs 30 Site Class (m/s)
1	0.6	0.6	160	80	0.30	16	327
2	3.0	3.6	210	110	0.30	17	
3	13.7	17.3	610	300	0.33	18	D
4	30.5	47.8	1820	910	0.33	19	

Note: maximum depth of profile is approximately equal to maximum experimental wavelength/two.

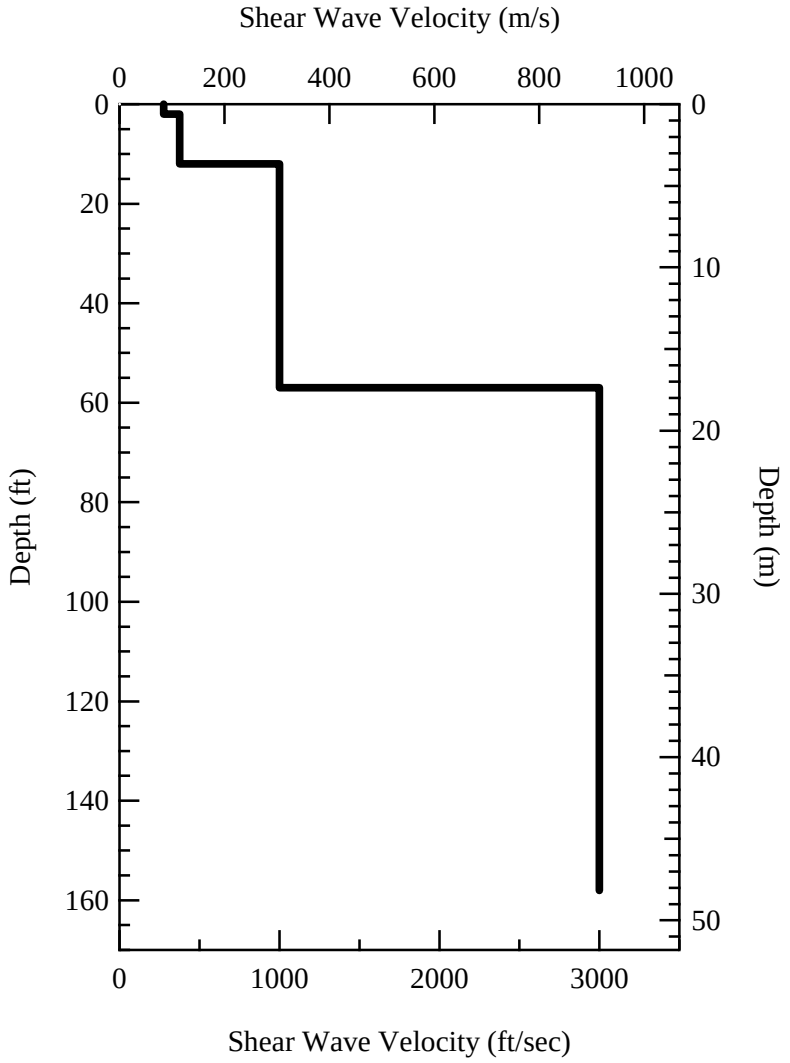


Figure 20 Shear wave velocity profile for Array #4 at Site 6 (CCHRC).

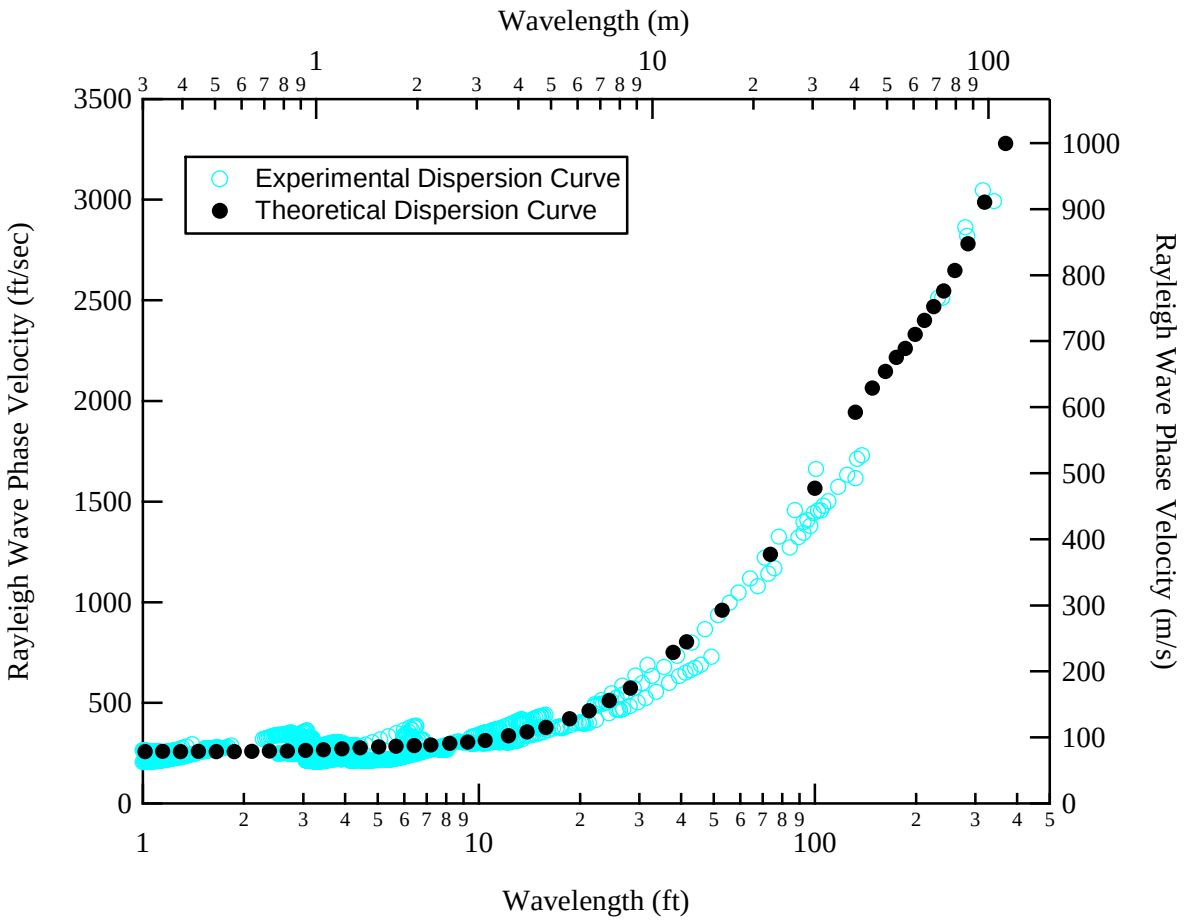


Figure 31 Experimental and theoretical dispersion data for Array #5 at Site 6 (CCHRC).

Table 12 Final forward modeling soil profile for Array #5 at Site 6 (CCHRC).

Layer No.	Thickness (m)	Depth to bottom (m)	P-wave velocity (m/s)	Shear wave velocity (m/s)	Poisson's Ratio	Unit Weight (kN/m^3)	Vs 30 Site Class (m/s)
1	0.6	0.6	160	80	0.30	16	449
2	1.5	2.1	190	100	0.30	17	
3	6.1	8.2	670	340	0.33	18	C
4	42.7	50.9	1630	820	0.33	19	

Note: maximum depth of profile is approximately equal to maximum experimental wavelength/two.

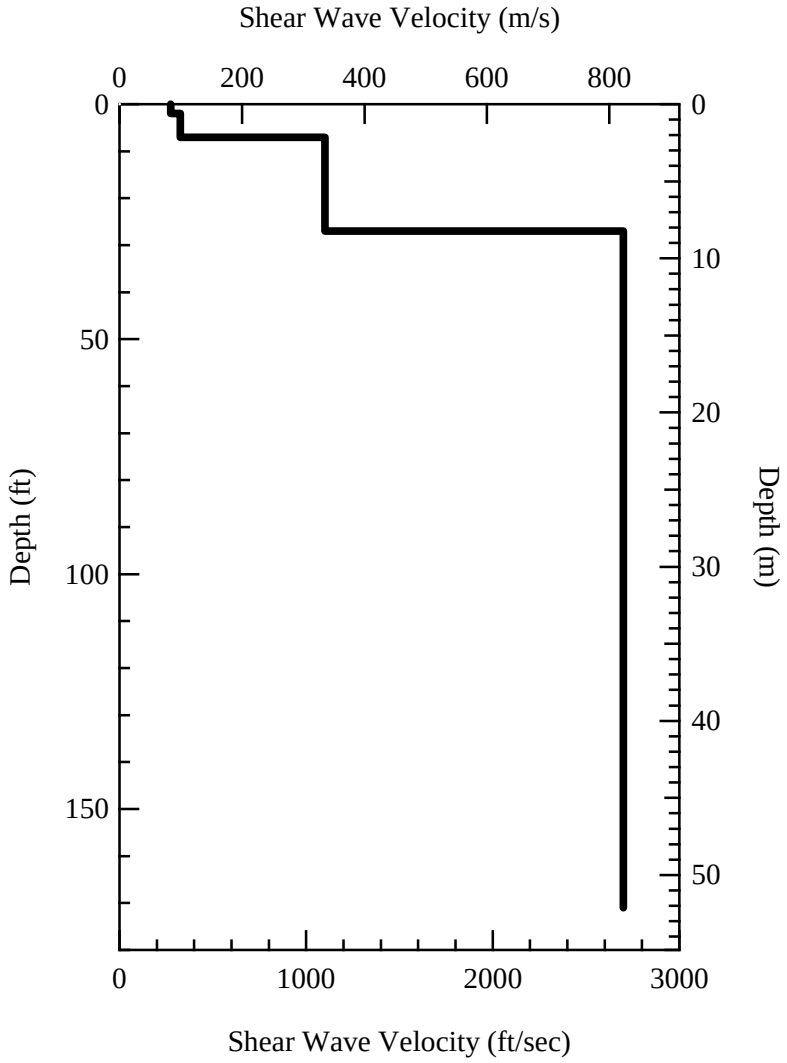


Figure 32 Shear wave velocity profile for Array #5 at Site 6 (CCHRC).

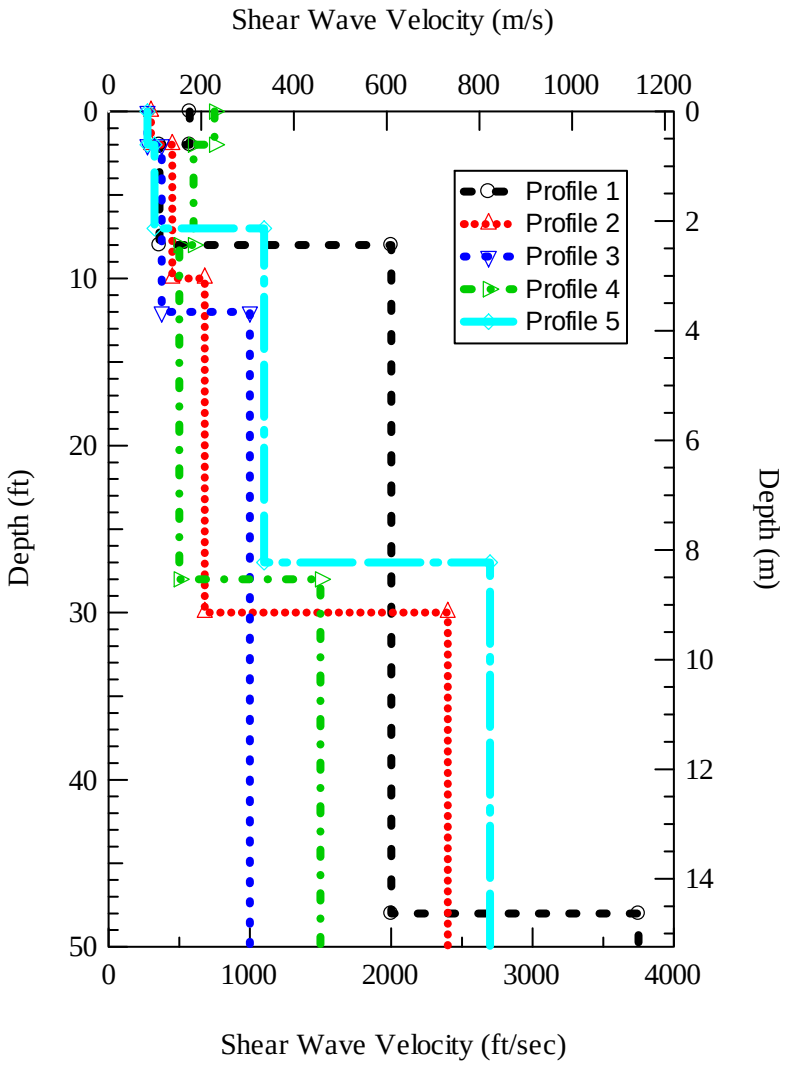


Figure 33 Shear wave velocity profile comparison for Site 6, 0-50ft. (CCHRC).

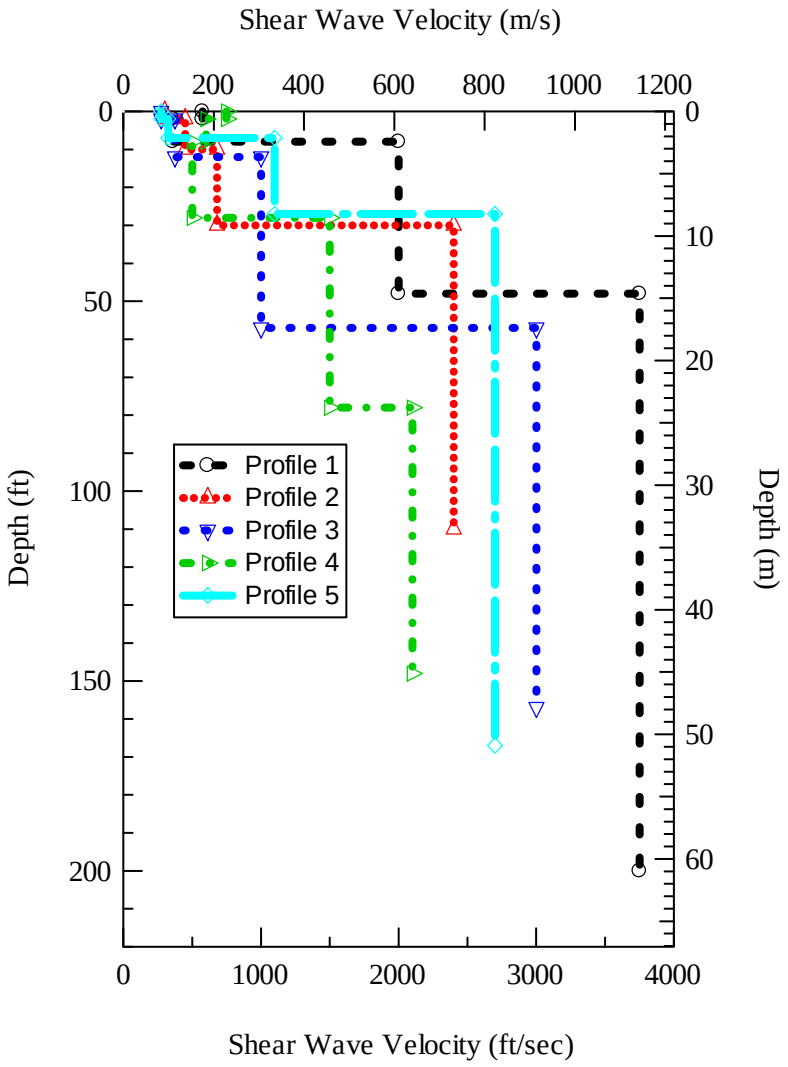


Figure 34 Shear wave velocity profile comparison for Site 6 (CCHRC).

Site 7: Creamer Field

Figure 35 SASW Array location map for Site 7 (Creamer Field).

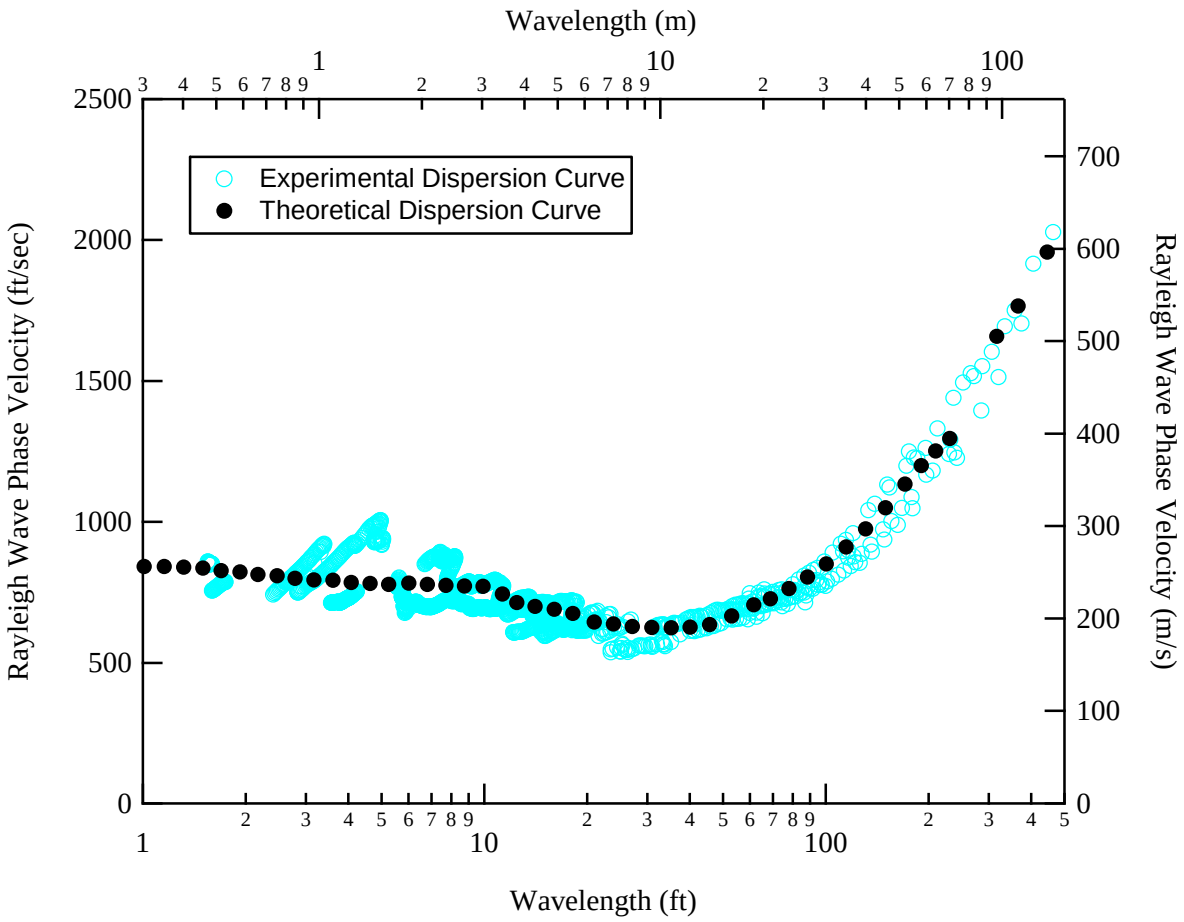


Figure 36 Experimental and theoretical dispersion data at Site 7 (Creamer Field).

Table 13 Final forward modeling soil profile for Site 7 (Creamer Field).

Layer No.	Thickness (m)	Depth to bottom (m)	P-wave velocity (m/s)	Shear wave velocity (m/s)	Poisson's Ratio	Unit Weight (kN/m^3)	Vs 30 Site Class (m/s)
1	0.3	0.3	510	270	0.30	17	319
2	2.7	3.0	460	250	0.30	17	
3	3.0	6.0	270	150	0.30	16	D
4	13.7	19.7	570	300	0.30	18	
5	41.3	61.0	1210	610	0.33	19	

Note: maximum depth of profile is approximately equal to maximum experimental wavelength/two.

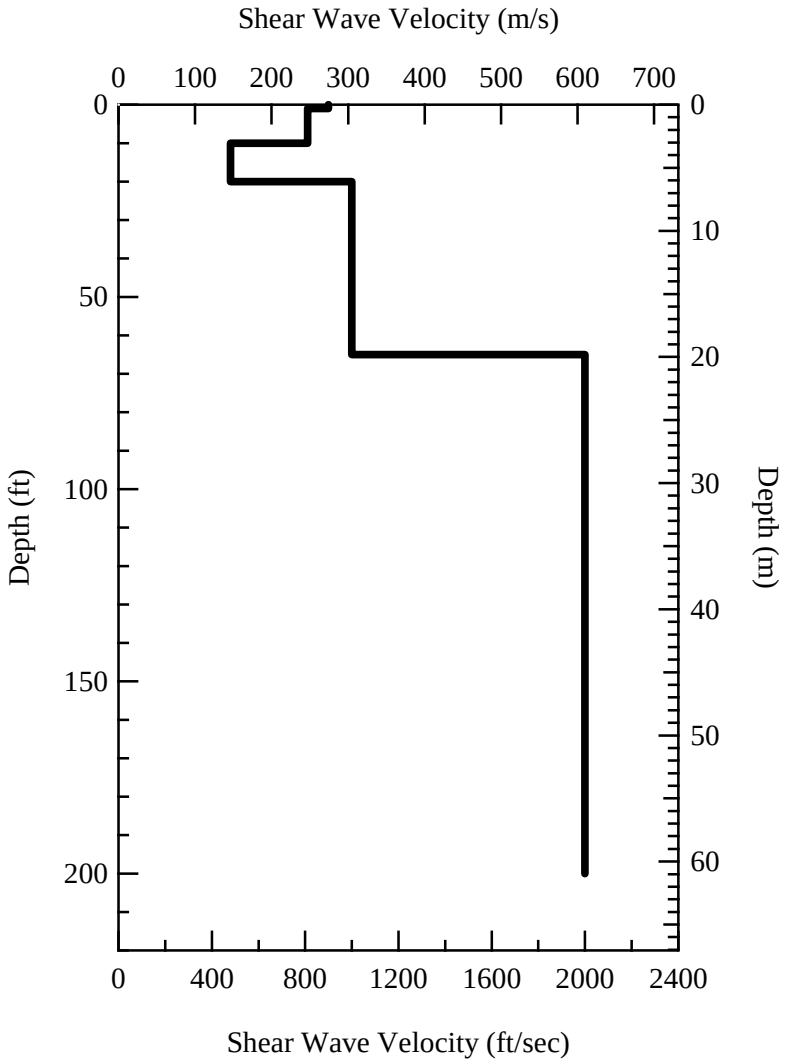


Figure 37 Shear wave velocity profile for Site 7 (Creamer Field).

Site 8: CRREL

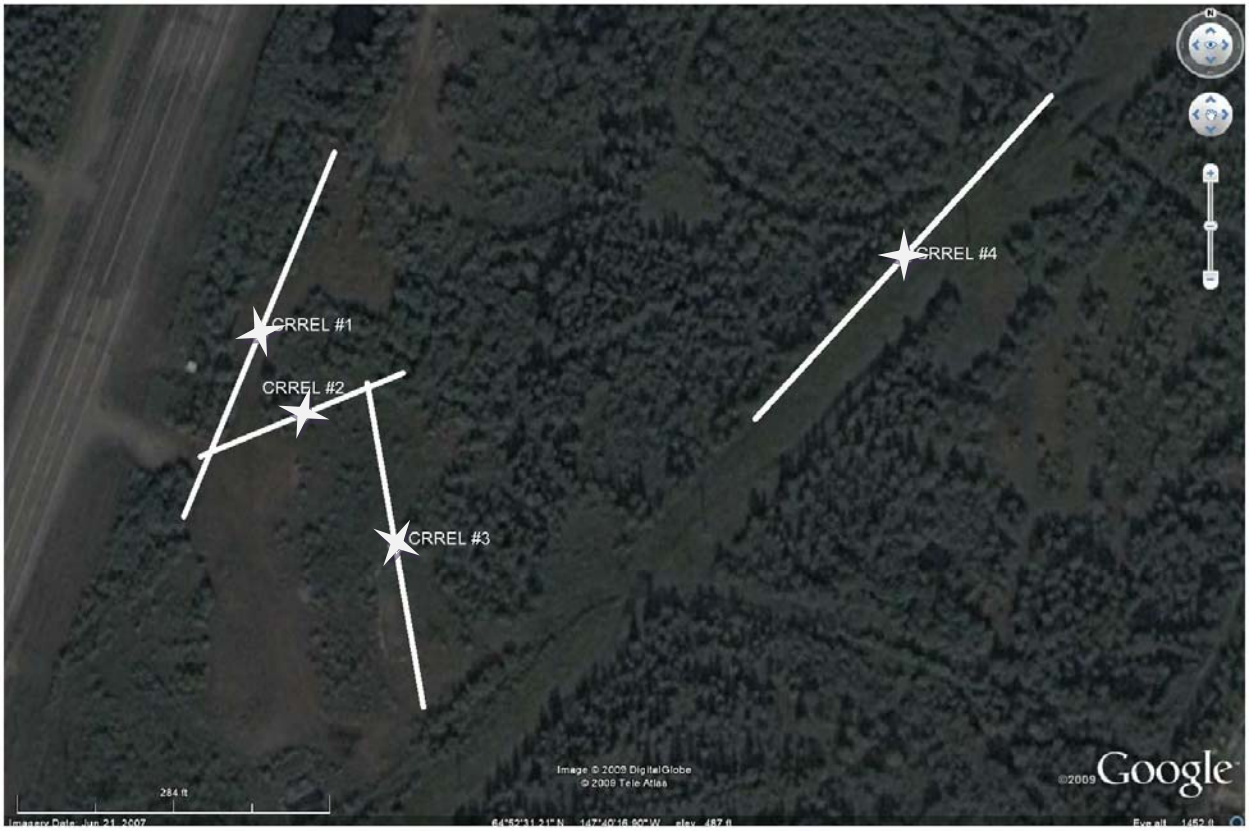


Figure 38 SASW Array location map for Site 8 (CRREL).

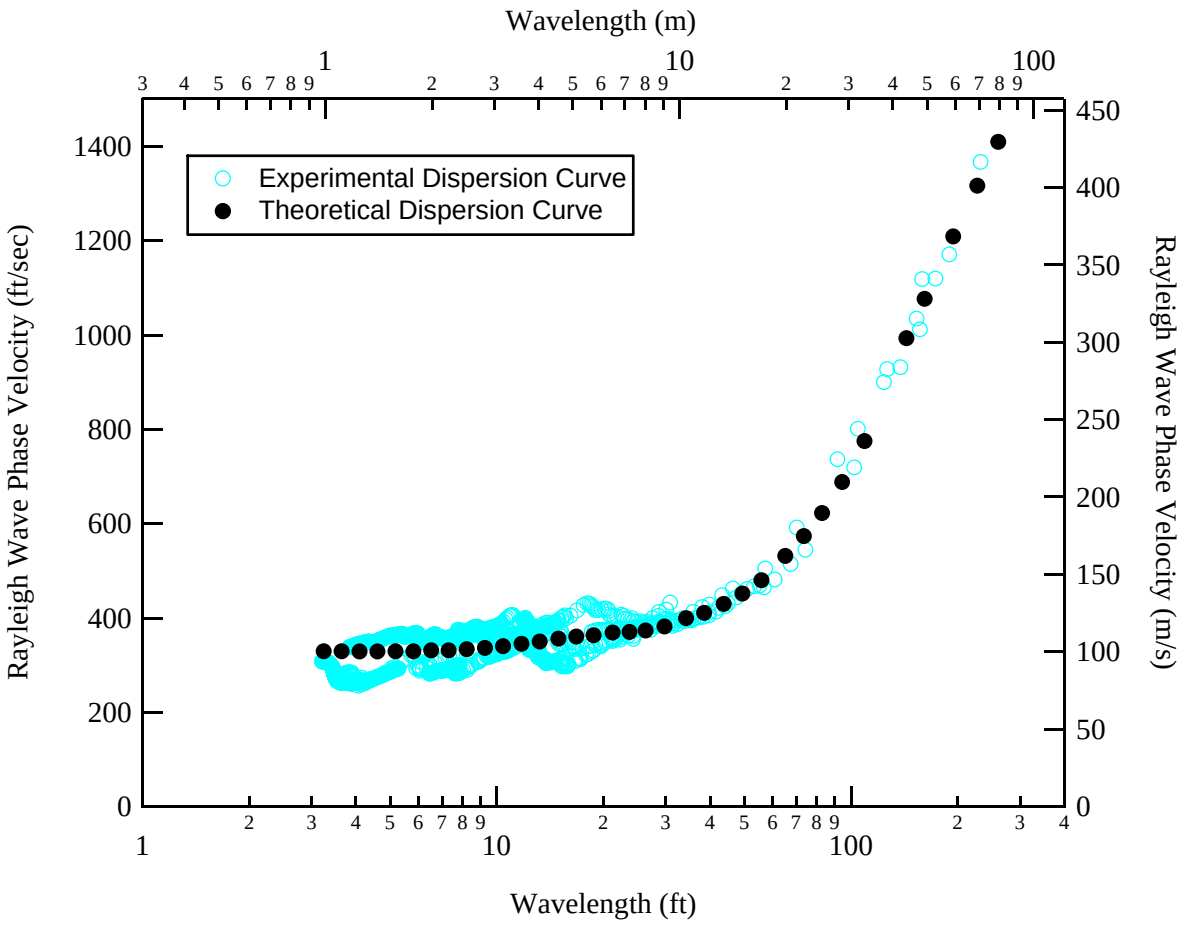


Figure 39 Experimental and theoretical dispersion data for Array #1 at Site 8 (CRREL).

Table 14 Final forward modeling soil profile for Array #1 at Site 8 (CRREL).

Layer No.	Thickness (m)	Depth to bottom (m)	P-wave velocity (m/s)	Shear wave velocity (m/s)	Poisson's Ratio	Unit Weight (kN/m^3)	Vs 30 Site Class (m/s)
1	1.8	1.8	200	110	0.30	16	266
2	5.5	7.3	230	120	0.30	17	
3	7.0	14.3	680	340	0.33	18	D
4	20.7	35.0	970	490	0.33	18	

Note: maximum depth of profile is approximately equal to maximum experimental wavelength/two.

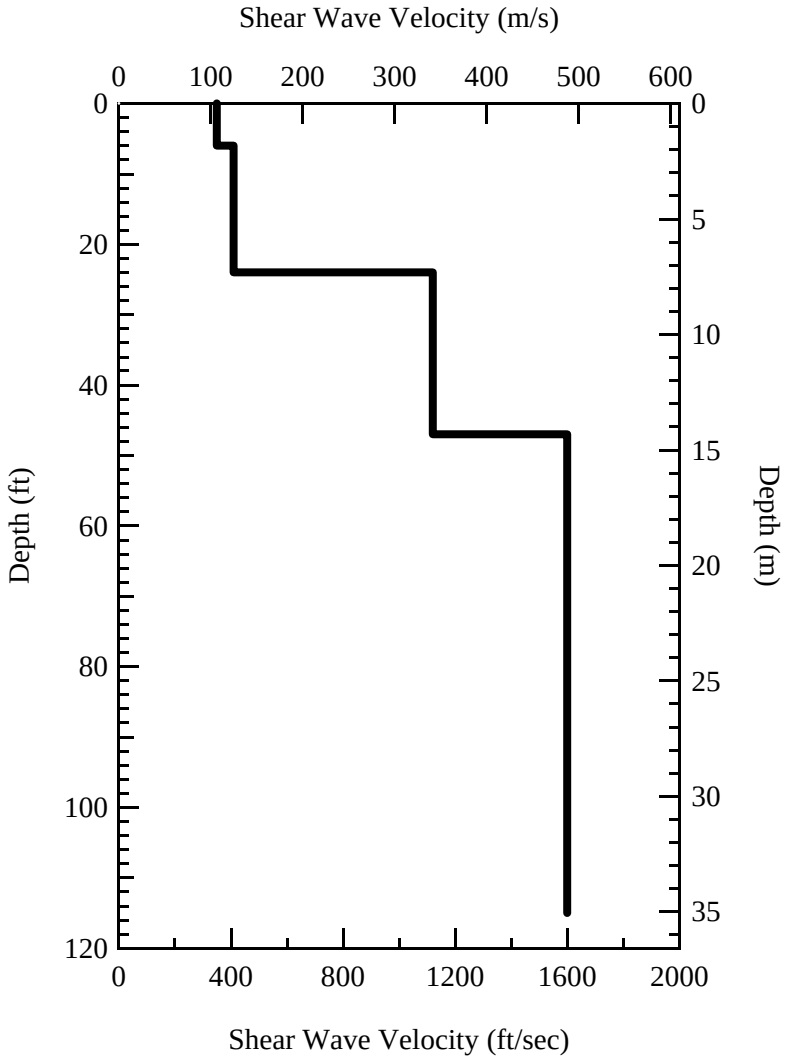


Figure 40 Shear wave velocity profile for Array #1 at Site 8 (CRREL).

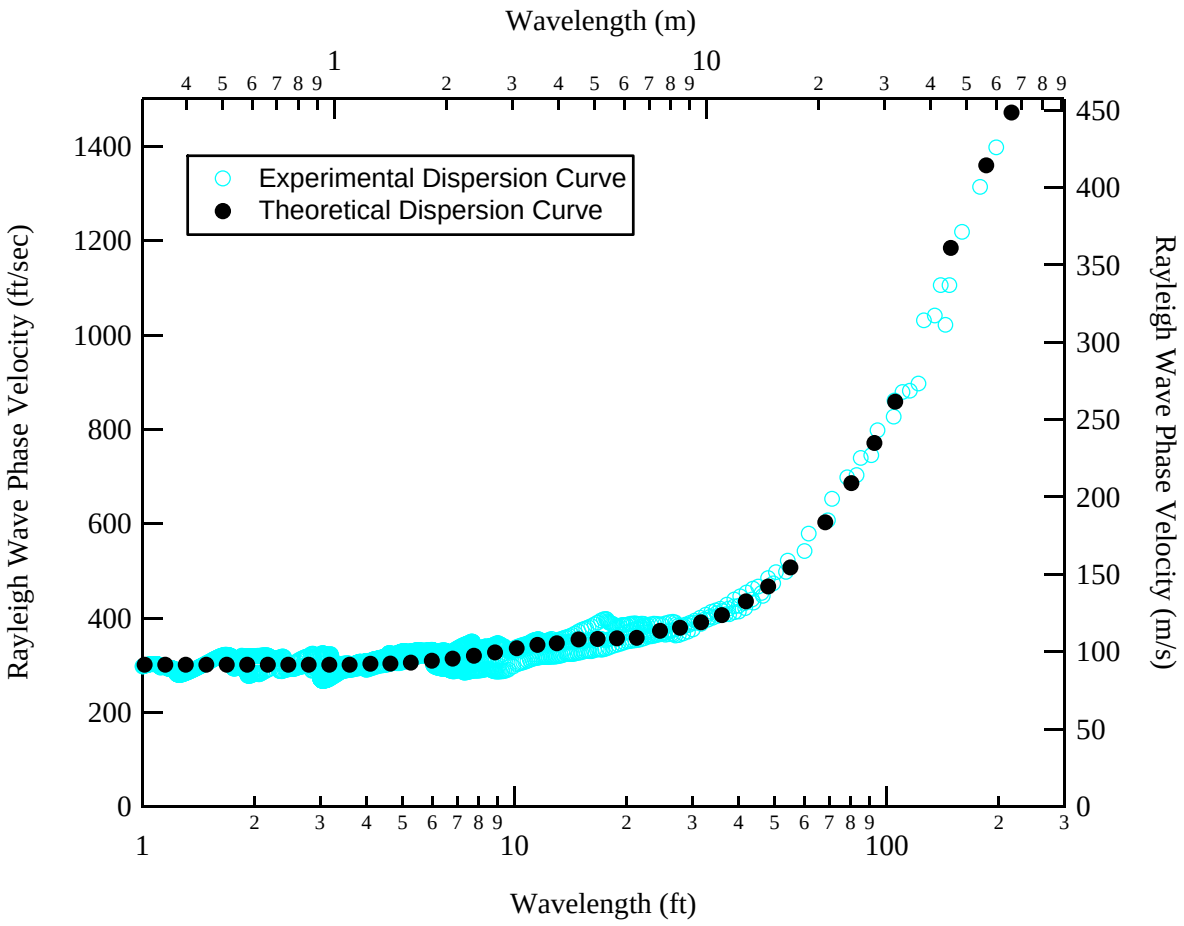


Figure 41 Experimental and theoretical dispersion data for Array #2 at Site 8 (CRREL).

Table 15 Final forward modeling soil profile for Array #2 at Site 8 (CRREL).

Layer No.	Thickness (m)	Depth to bottom (m)	P-wave velocity (m/s)	Shear wave velocity (m/s)	Poisson's Ratio	Unit Weight (kN/m^3)	Vs 30 Site Class (m/s)
1	1.2	1.2	180	100	0.30	16	296
2	5.2	6.4	230	120	0.30	17	
3	7.6	14.0	850	430	0.33	18	D
4	16.5	30.5	1090	550	0.33	19	

Note: maximum depth of profile is approximately equal to maximum experimental wavelength/two.

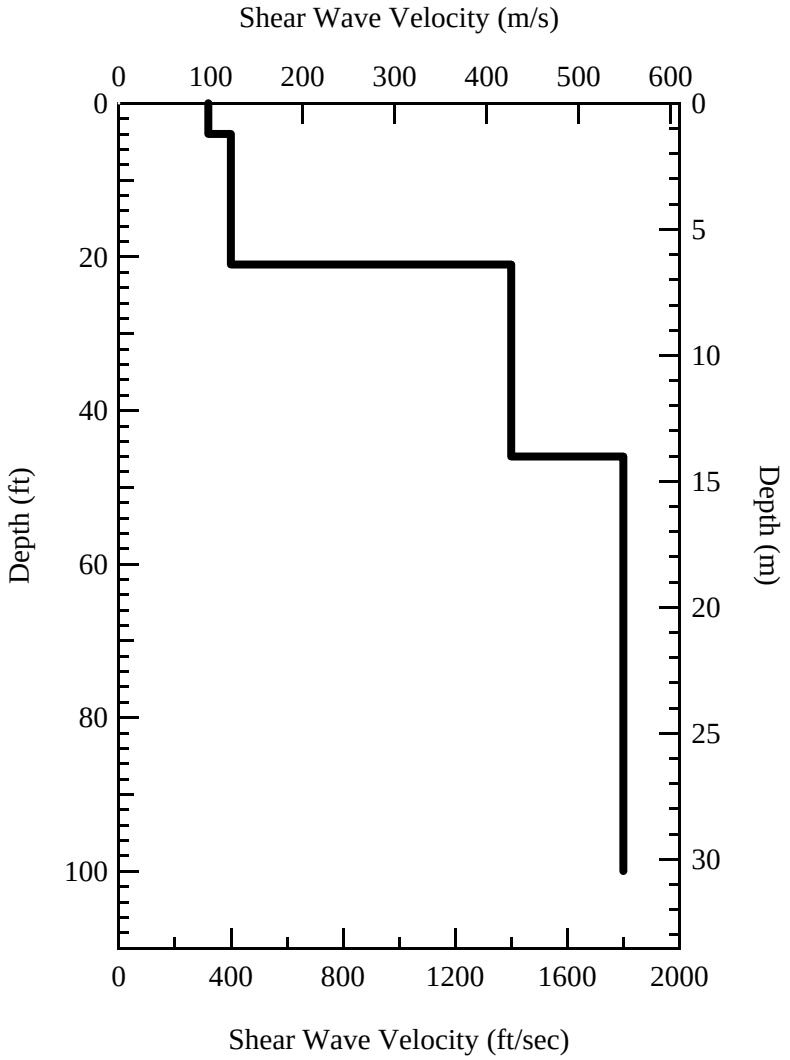


Figure 42 Shear wave velocity profile for Array #2 at Site 8 (CRREL).

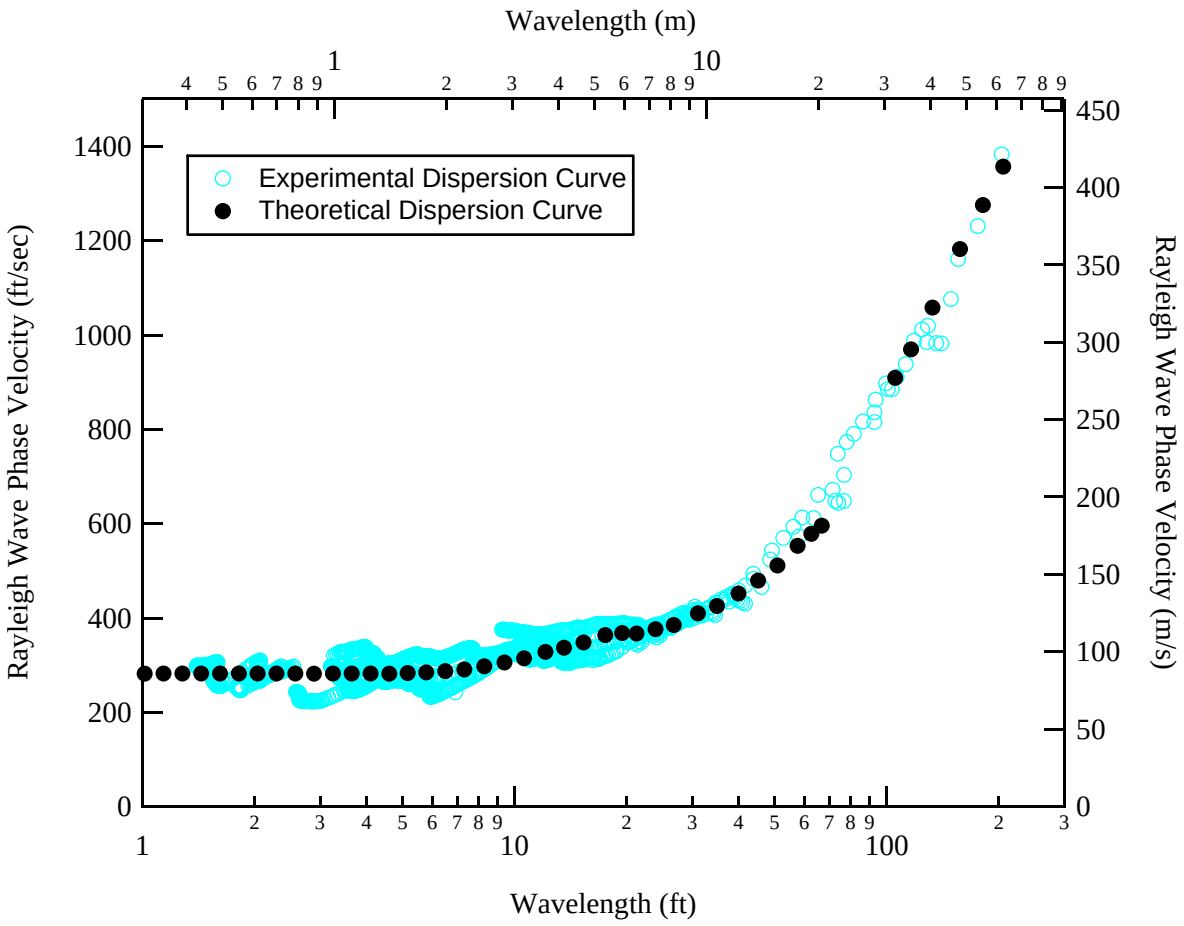


Figure 43 Experimental and theoretical dispersion data for Array #3 at Site 8 (CRREL).

Table 16 Final forward modeling soil profile for Array #3 at Site 8 (CRREL).

Layer No.	Thickness (m)	Depth to bottom (m)	P-wave velocity (m/s)	Shear wave velocity (m/s)	Poisson's Ratio	Unit Weight (kN/m^3)	Vs 30 Site Class (m/s)
1	1.5	1.5	170	90	0.30	16	280
2	4.6	6.1	240	130	0.30	17	
3	7.6	13.7	670	340	0.33	18	D
4	17.4	31.1	910	490	0.33	19	

Note: maximum depth of profile is approximately equal to maximum experimental wavelength/two.

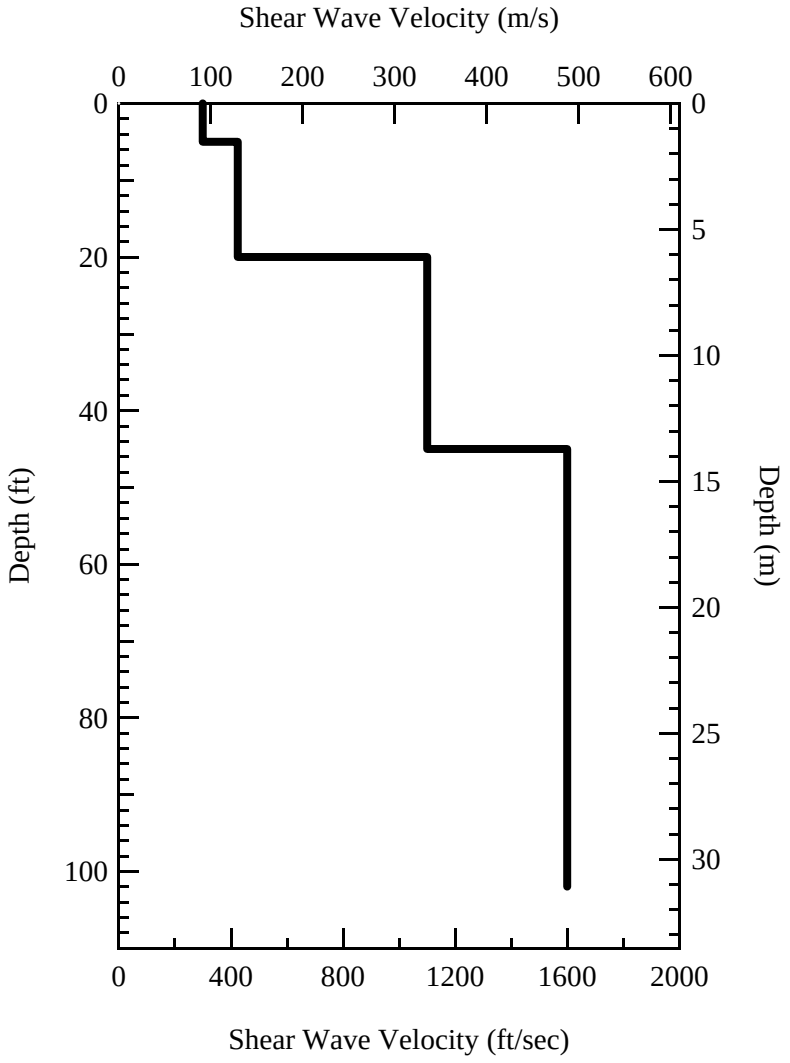


Figure 44 Shear wave velocity profile for Array #3 at Site 8 (CRREL).

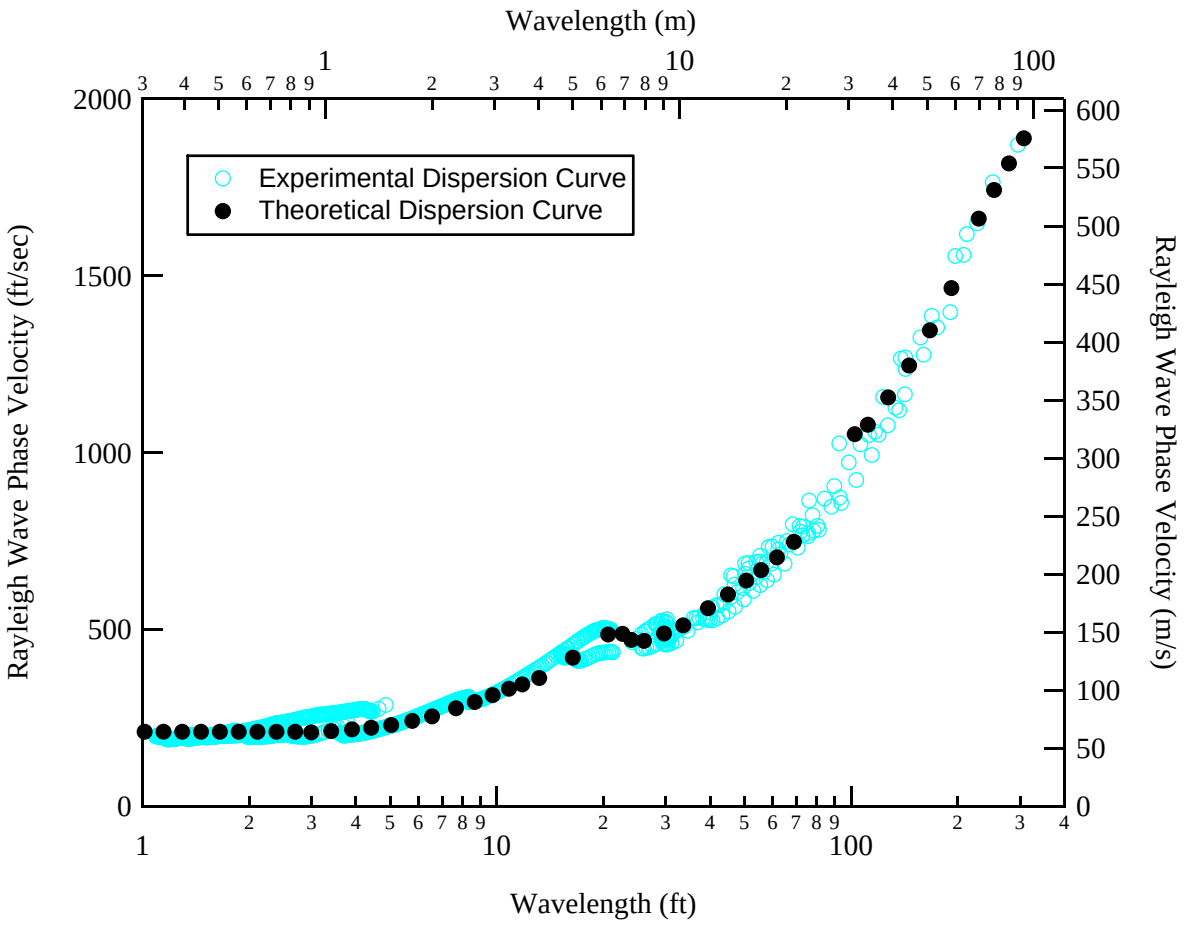


Figure 45 Experimental and theoretical dispersion data for Array #4 at Site 8 (CRREL).

Table 17 Final forward modeling soil profile for Array #4 at Site 8 (CRREL).

Layer No.	Thickness (m)	Depth to bottom (m)	P-wave velocity (m/s)	Shear wave velocity (m/s)	Poisson's Ratio	Unit Weight (kN/m^3)	Vs 30 Site Class (m/s)
1	0.9	0.9	130	70	0.30	16	310
2	4.6	5.5	300	160	0.30	17	
3	12.2	17.7	670	340	0.33	18	D
4	28.0	45.7	1270	640	0.33	19	

Note: maximum depth of profile is approximately equal to maximum experimental wavelength/two.

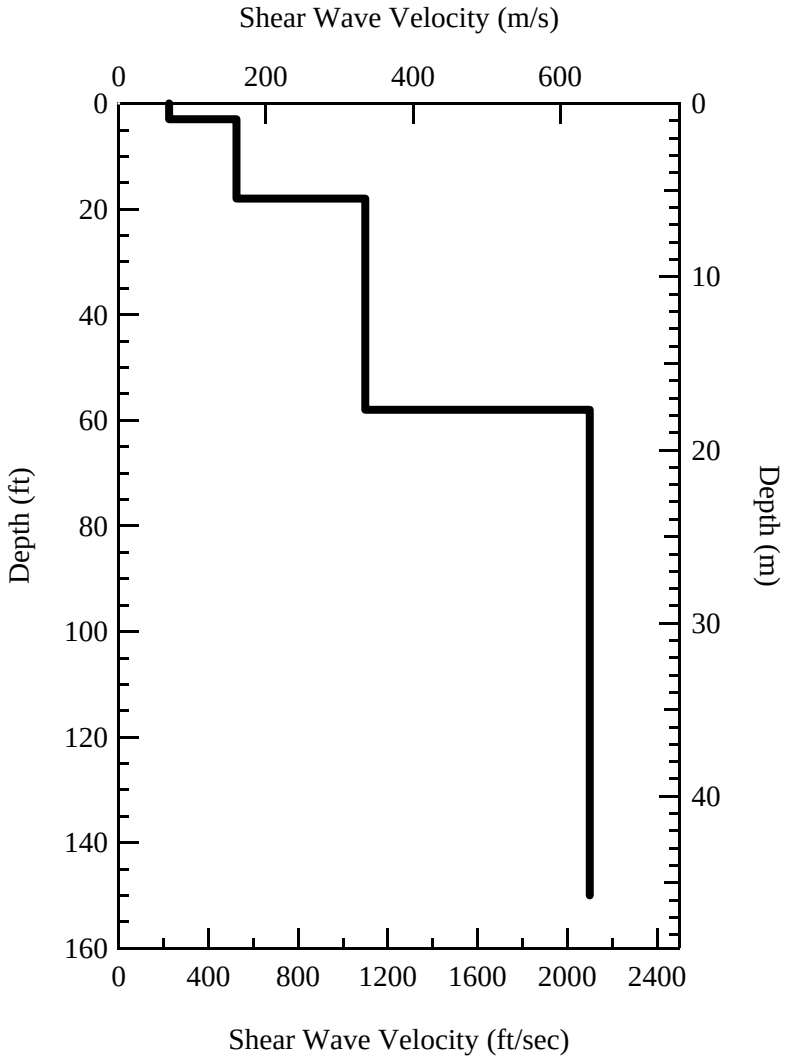


Figure 46 Shear wave velocity profile for Array #4 at Site 8 (CRREL).

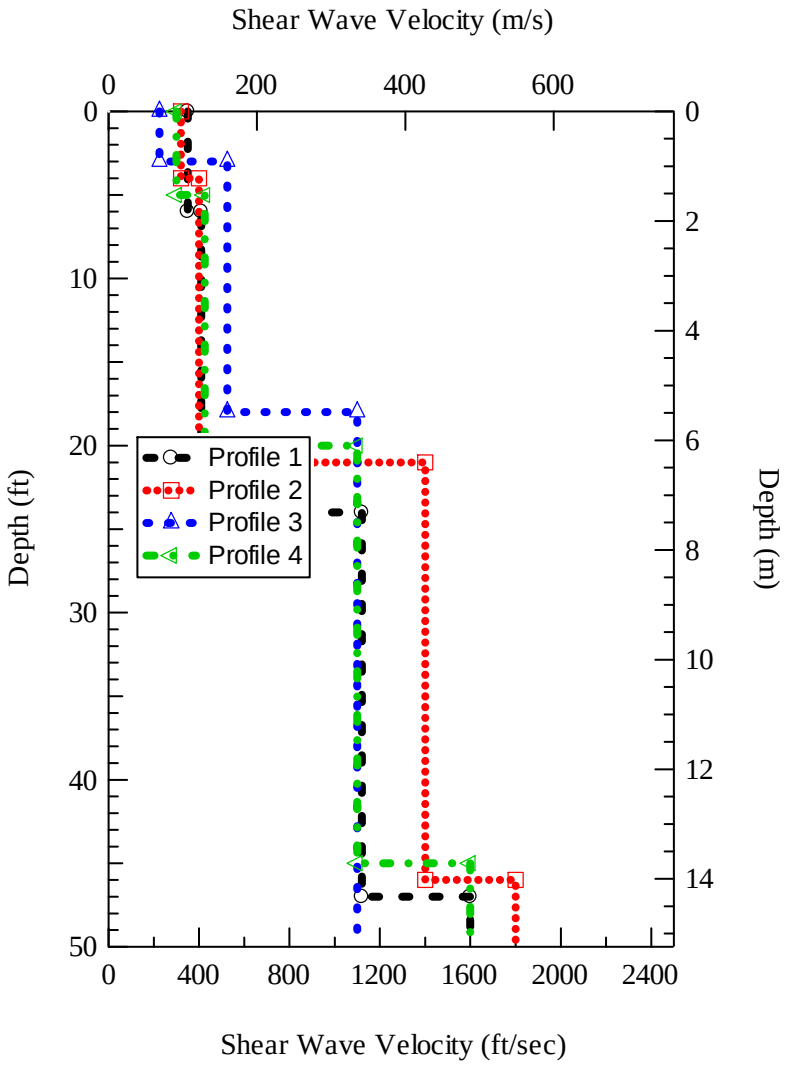


Figure 47 Shear wave velocity profile comparison for Site 8, 0-50ft. (CRREL).

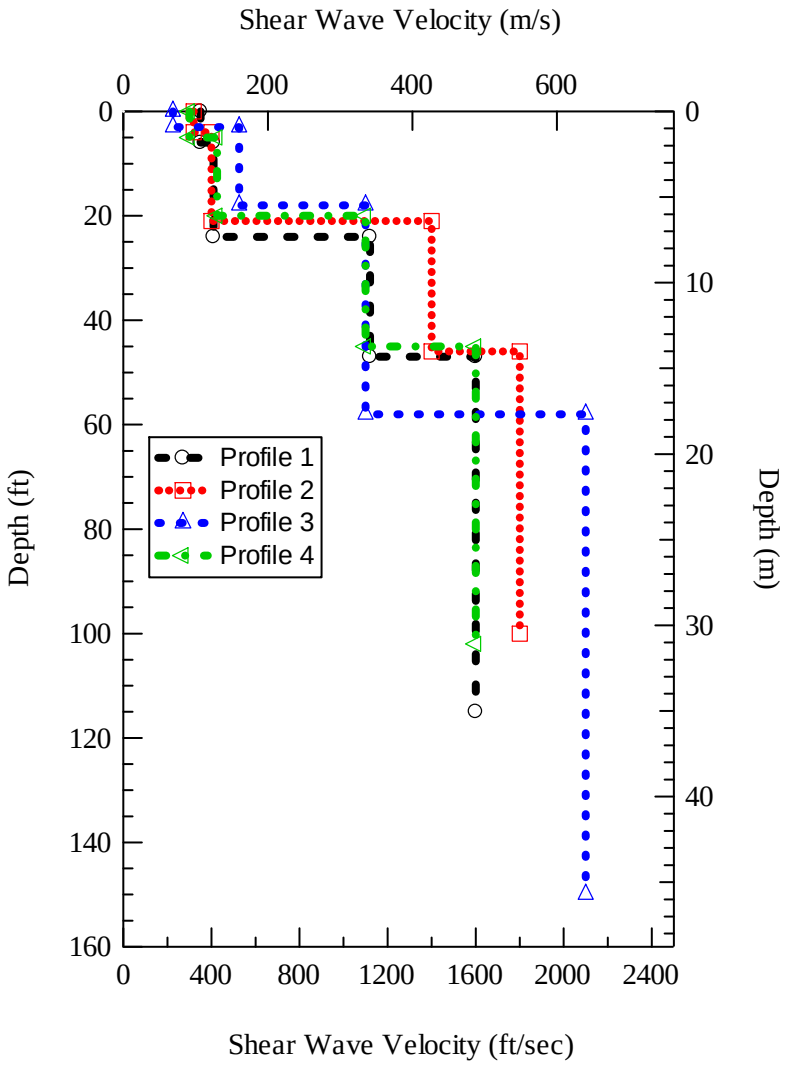


Figure 48 Shear wave velocity profile comparison for Site 8 (CRREL).

Site 9: Cushman & 17th Avenue

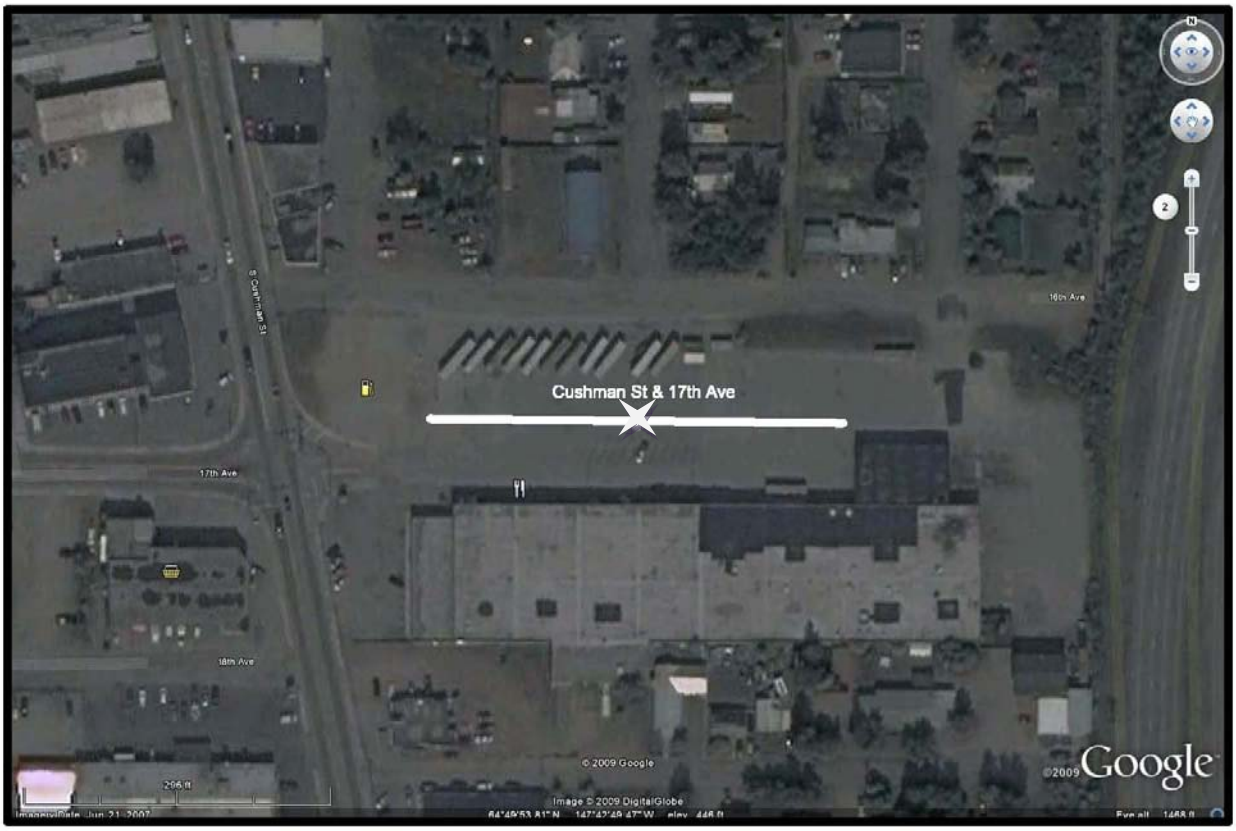


Figure 49 SASW Array location map for Site 9 (Cushman & 17th Avenue).

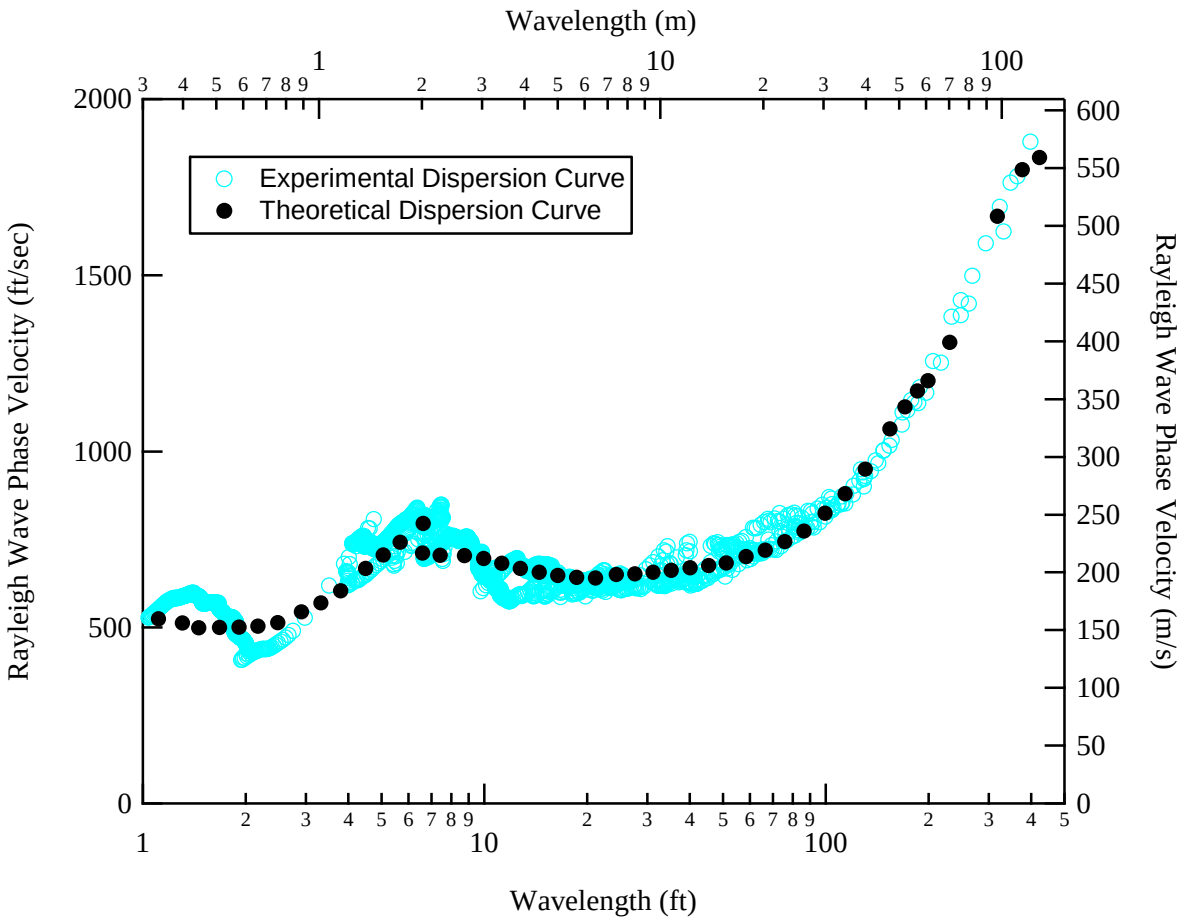


Figure 50 Experimental and theoretical dispersion data at Site 9 (Cushman & 17th Avenue).

Table 18 Final forward modeling soil profile for Site 9 (Cushman & 17th Avenue).

Layer No.	Thickness (m)	Depth to bottom (m)	P-wave velocity (m/s)	Shear wave velocity (m/s)	Poisson's Ratio	Unit Weight (kN/m^3)	Vs 30 Site Class (m/s)
1	0.4	0.4	240	130	0.30	16	325
2	1.2	1.6	540	290	0.30	18	
3	0.9	2.5	290	150	0.30	16	D
4	12.2	14.7	430	230	0.30	17	
5	46.3	61.0	1150	580	0.33	19	

Note: maximum depth of profile is approximately equal to maximum experimental wavelength/two.

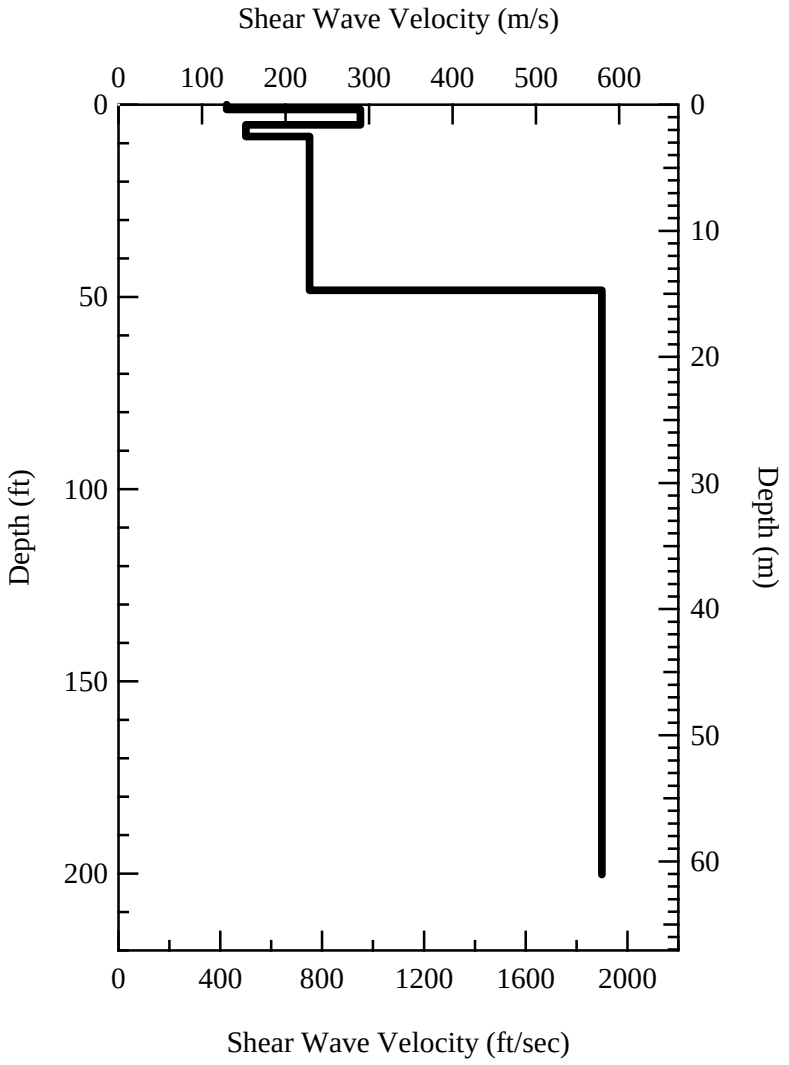


Figure 51 Shear wave velocity profile for Site 9 (Cushman & 17th Avenue).

Site 10: Fairbanks Airport

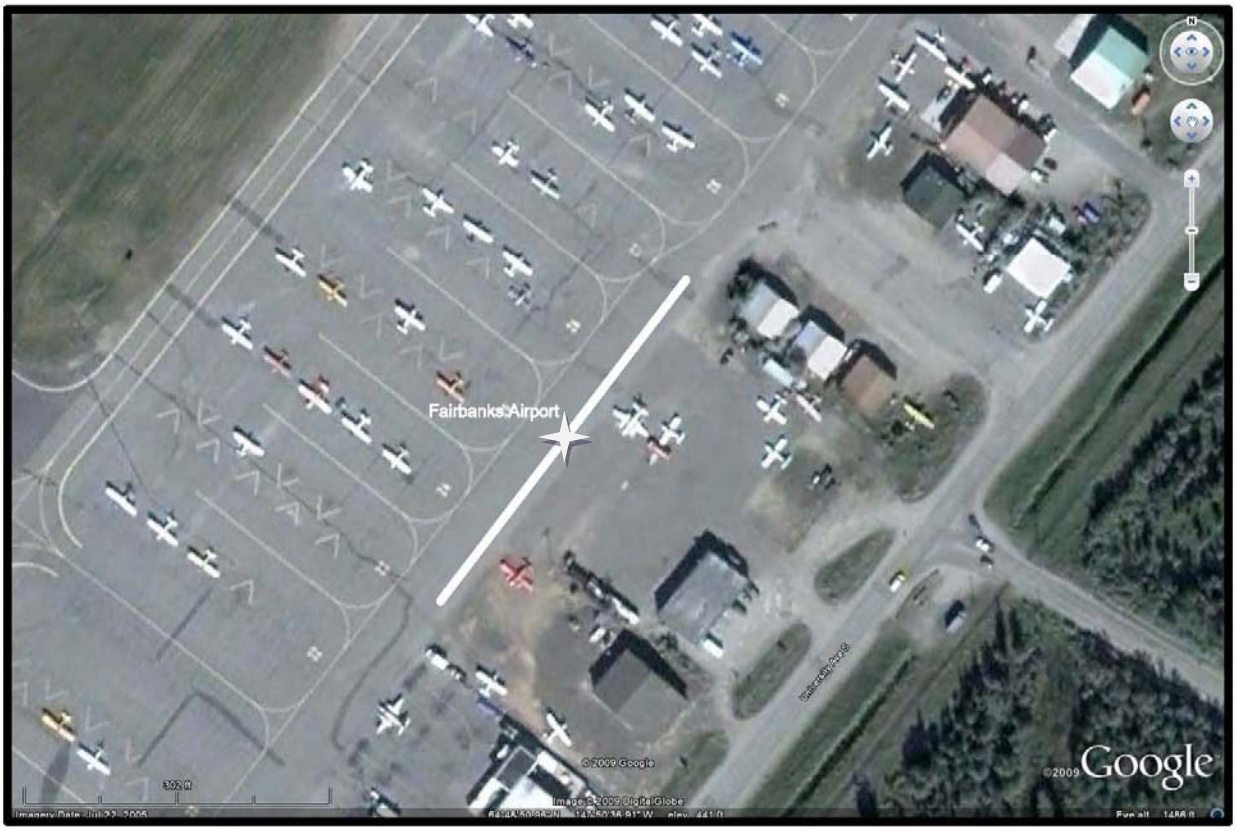


Figure 52 SASW Array location map for Site 10 (Fairbanks Airport).

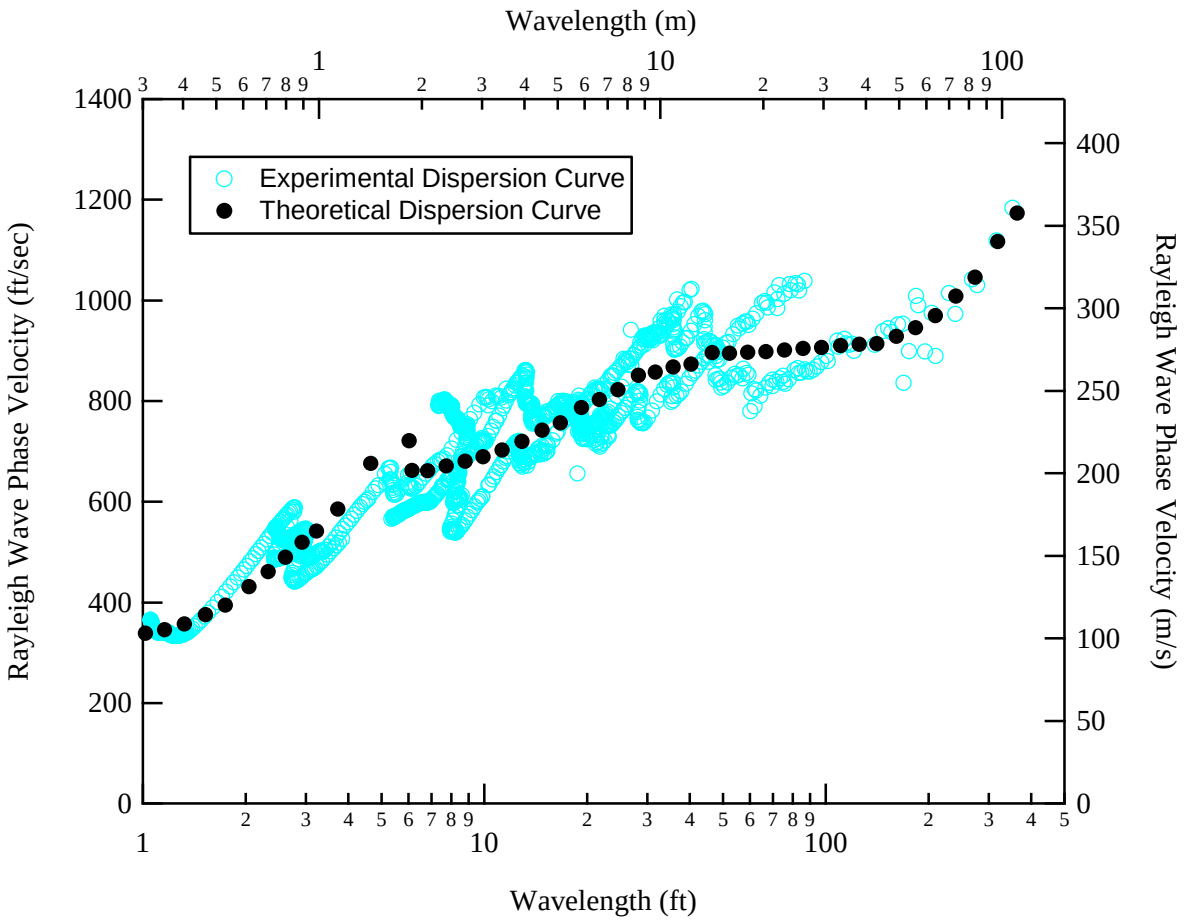


Figure 53 Experimental and theoretical dispersion data at Site 10 (Fairbanks Airport).

Table 19 Final forward modeling soil profile for Site 10 (Fairbanks Airport).

Layer No.	Thickness (m)	Depth to bottom (m)	P-wave velocity (m/s)	Shear wave velocity (m/s)	Poisson's Ratio	Unit Weight (kN/m^3)	Vs 30 Site Class (m/s)
1	0.2	0.2	230	110	0.30	16	295
2	2.4	2.6	460	240	0.30	17	
3	38.1	40.7	570	300	0.30	18	D
4	14.0	54.7	1000	500	0.33	19	

Note: maximum depth of profile is approximately equal to maximum experimental wavelength/two.

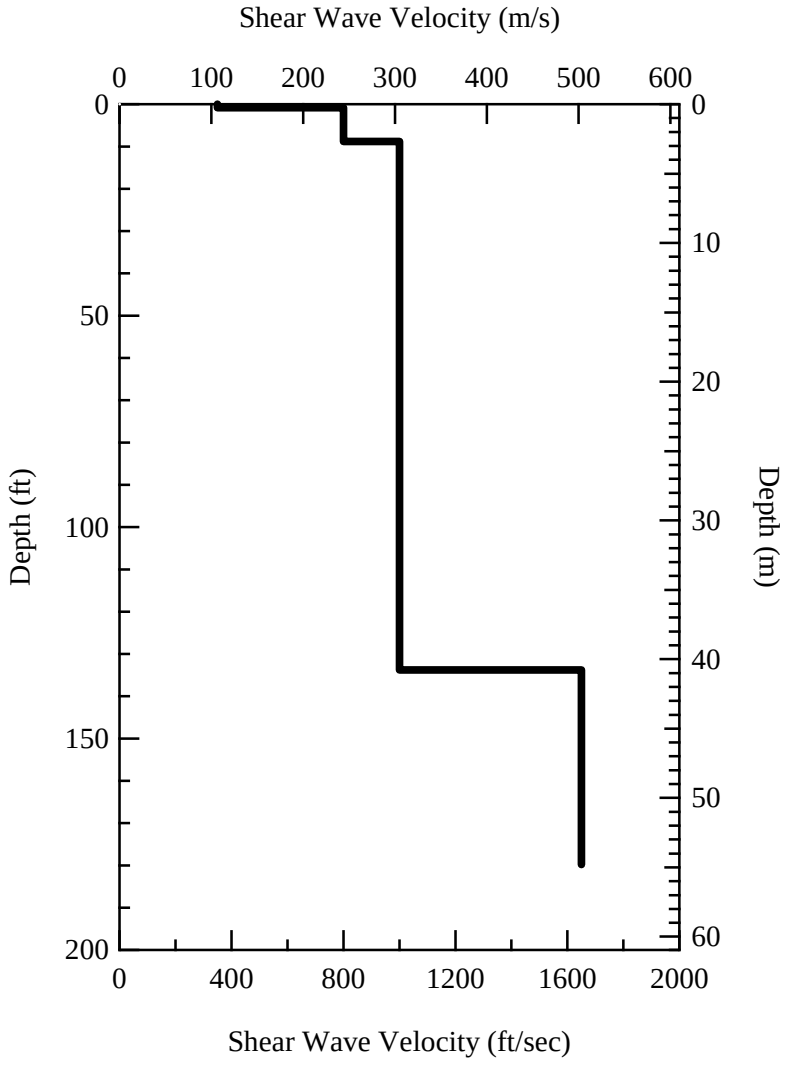


Figure 54 Shear wave velocity profile for Site 10 (Fairbanks Airport).

Site 11: Fairbanks Chevy

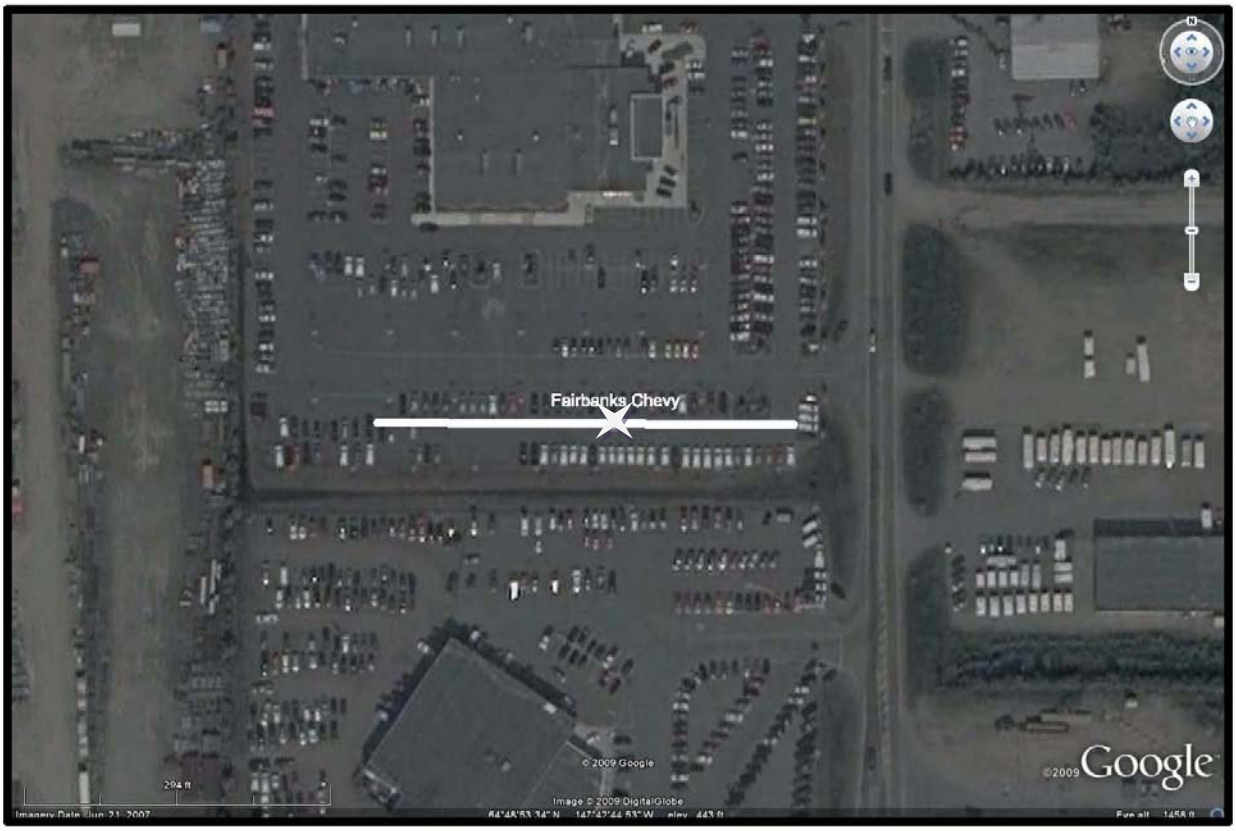


Figure 55 SASW Array location map for Site 11 (Fairbanks Chevy).

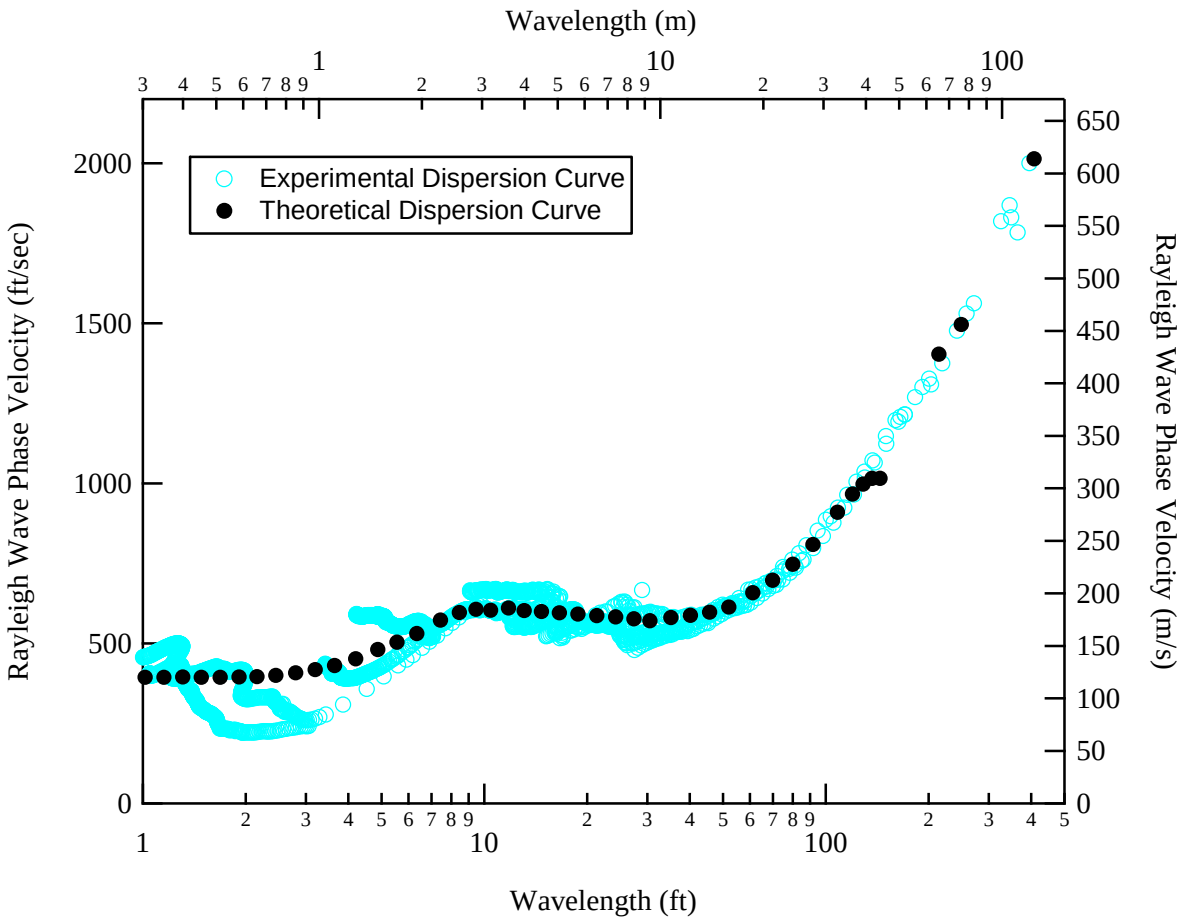


Figure 56 Experimental and theoretical dispersion data at Site 11 (Fairbanks Chevy).

Table 20 Final forward modeling soil profile for Site 11 (Fairbanks Chevy).

Layer No.	Thickness (m)	Depth to bottom (m)	P-wave velocity (m/s)	Shear wave velocity (m/s)	Poisson's Ratio	Unit Weight (kN/m^3)	Vs 30 Site Class (m/s)
1	0.6	0.6	240	130	0.30	16	323
2	3.0	3.6	400	210	0.30	17	
3	5.2	8.8	330	180	0.30	17	D
4	6.1	14.9	740	400	0.30	18	
5	46.0	60.9	1020	510	0.33	19	

Note: maximum depth of profile is approximately equal to maximum experimental wavelength/two.

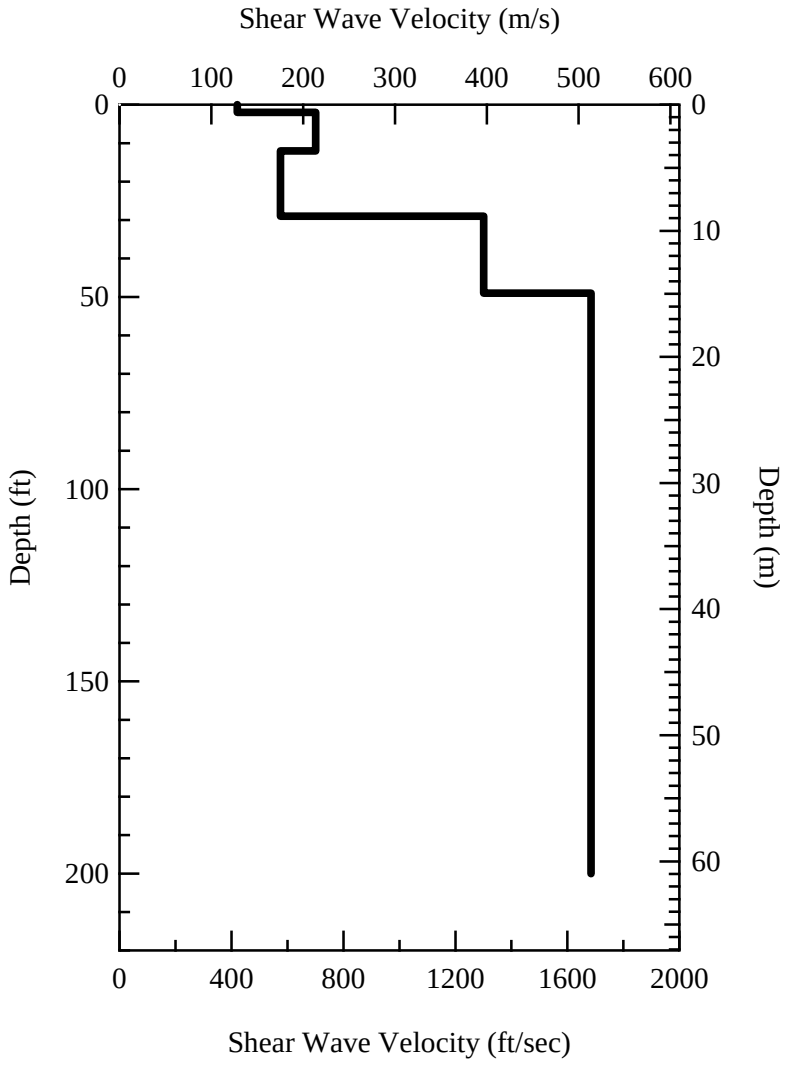


Figure 57 Shear wave velocity profile for Site 11 (Fairbanks Chevy).

Site 12: Frank Avenue

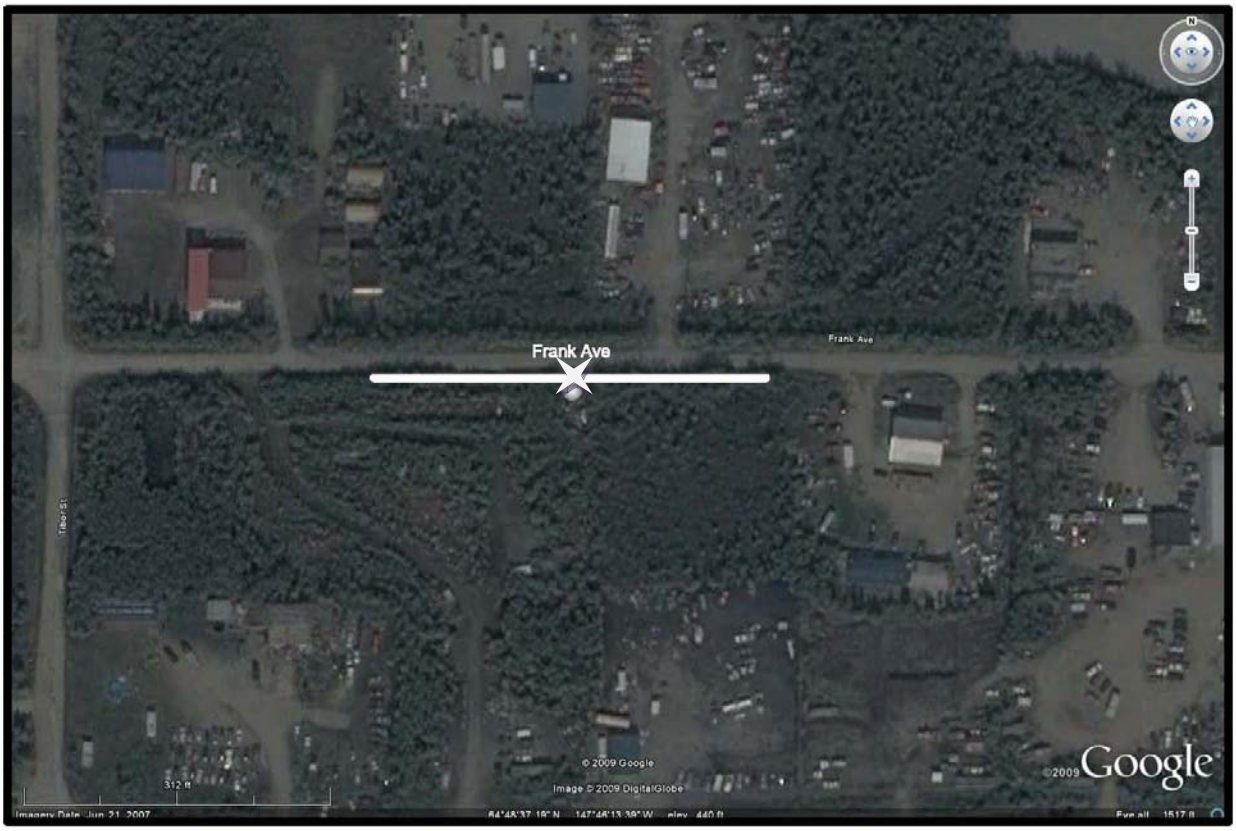


Figure 58 SASW Array location map for Site 12 (Frank Avenue).

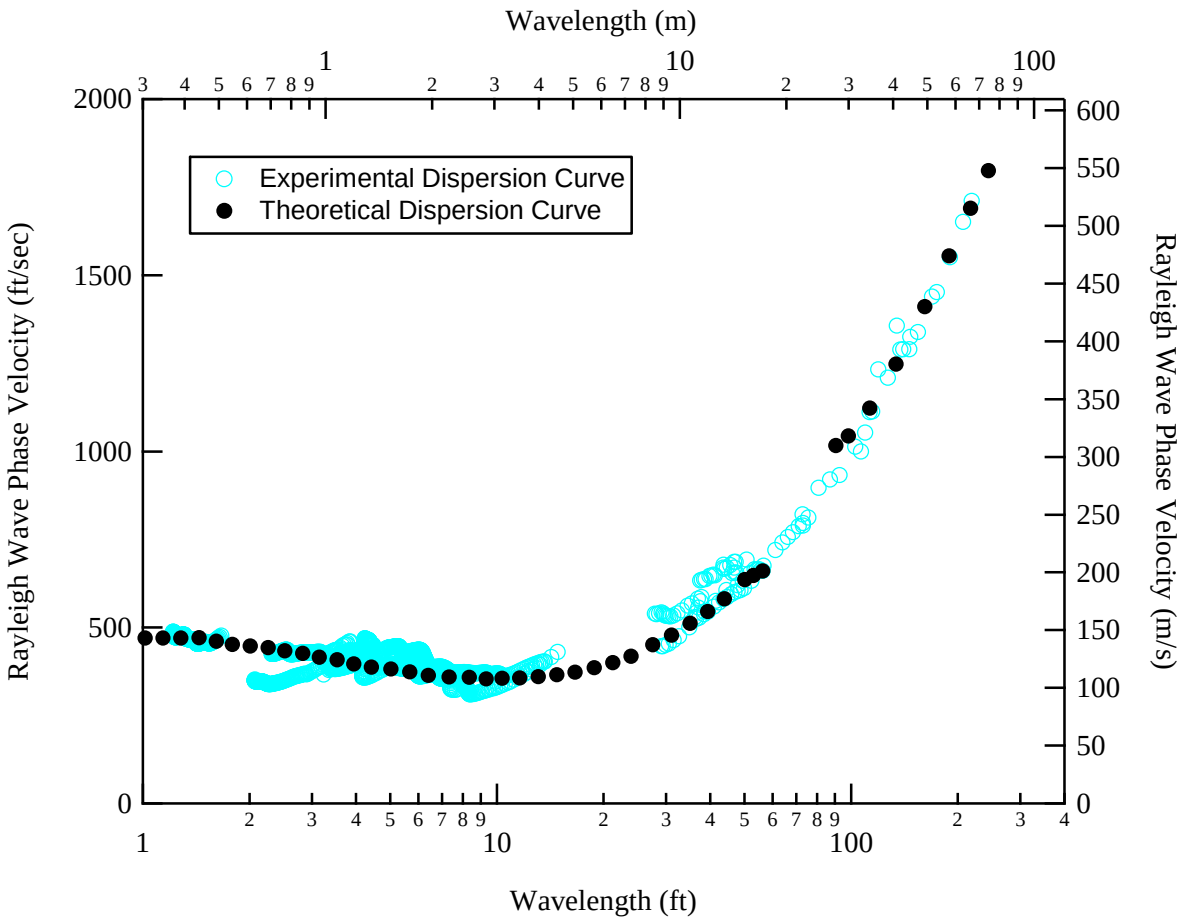


Figure 59 Experimental and theoretical dispersion data at Site 12 (Frank Avenue).

Table 21 Final forward modeling soil profile for Site 12 (Frank Avenue).

Layer No.	Thickness (m)	Depth to bottom (m)	P-wave velocity (m/s)	Shear wave velocity (m/s)	Poisson's Ratio	Unit Weight (kN/m^3)	Vs 30 Site Class (m/s)
1	0.5	0.5	290	150	0.30	16	334
2	2.4	2.9	200	110	0.30	16	
3	3.0	5.9	360	200	0.30	17	D
4	10.7	16.6	680	370	0.30	18	
5	17.1	33.7	1330	670	0.33	19	

Note: maximum depth of profile is approximately equal to maximum experimental wavelength/two.

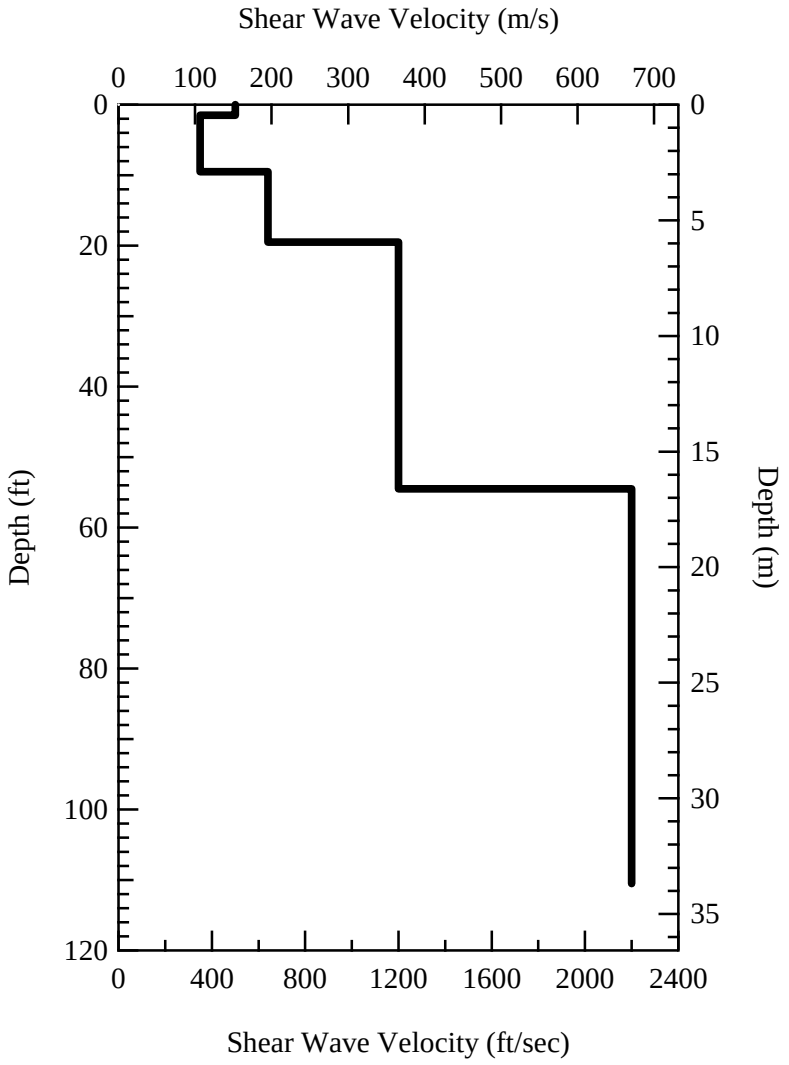


Figure 60 Shear wave velocity profile for Site 12 (Frank Avenue).

Site 13: Home Depot

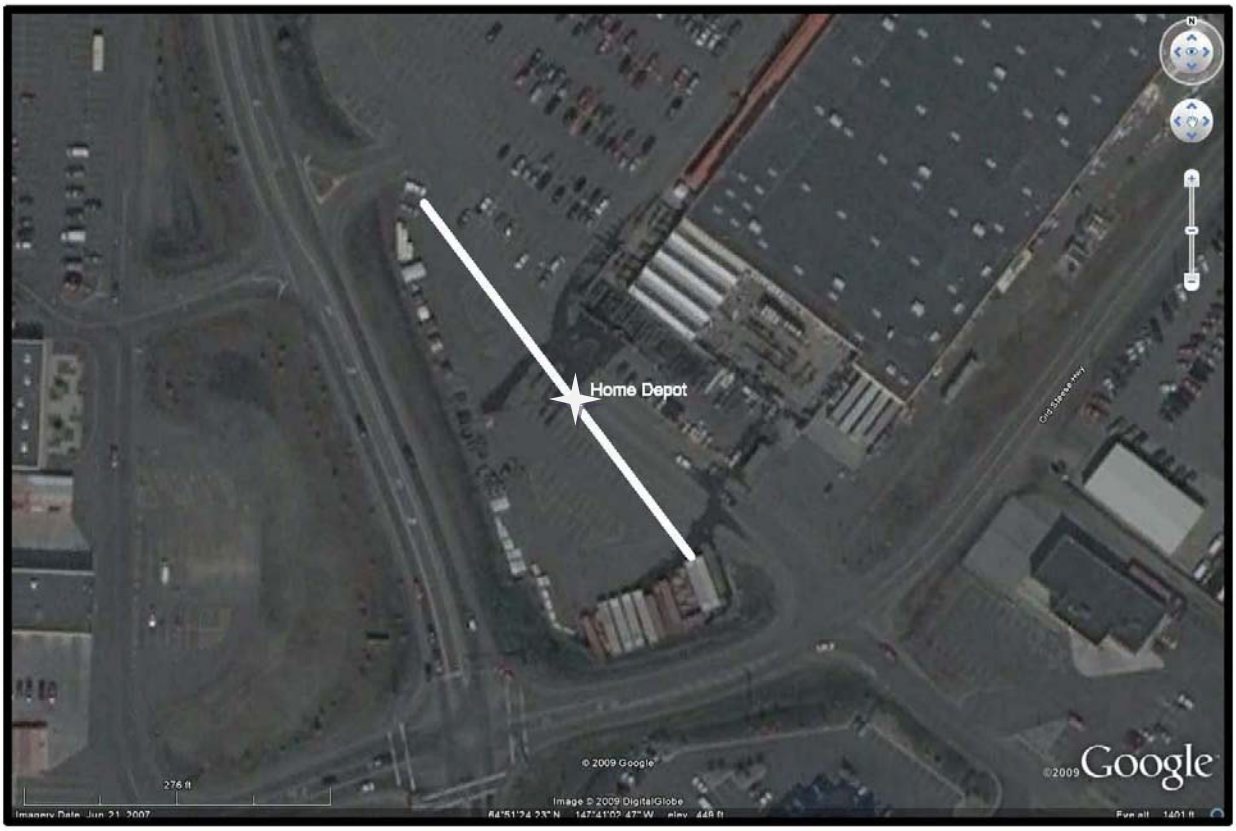


Figure 61 SASW Array location map for Site 13 (Home Depot).

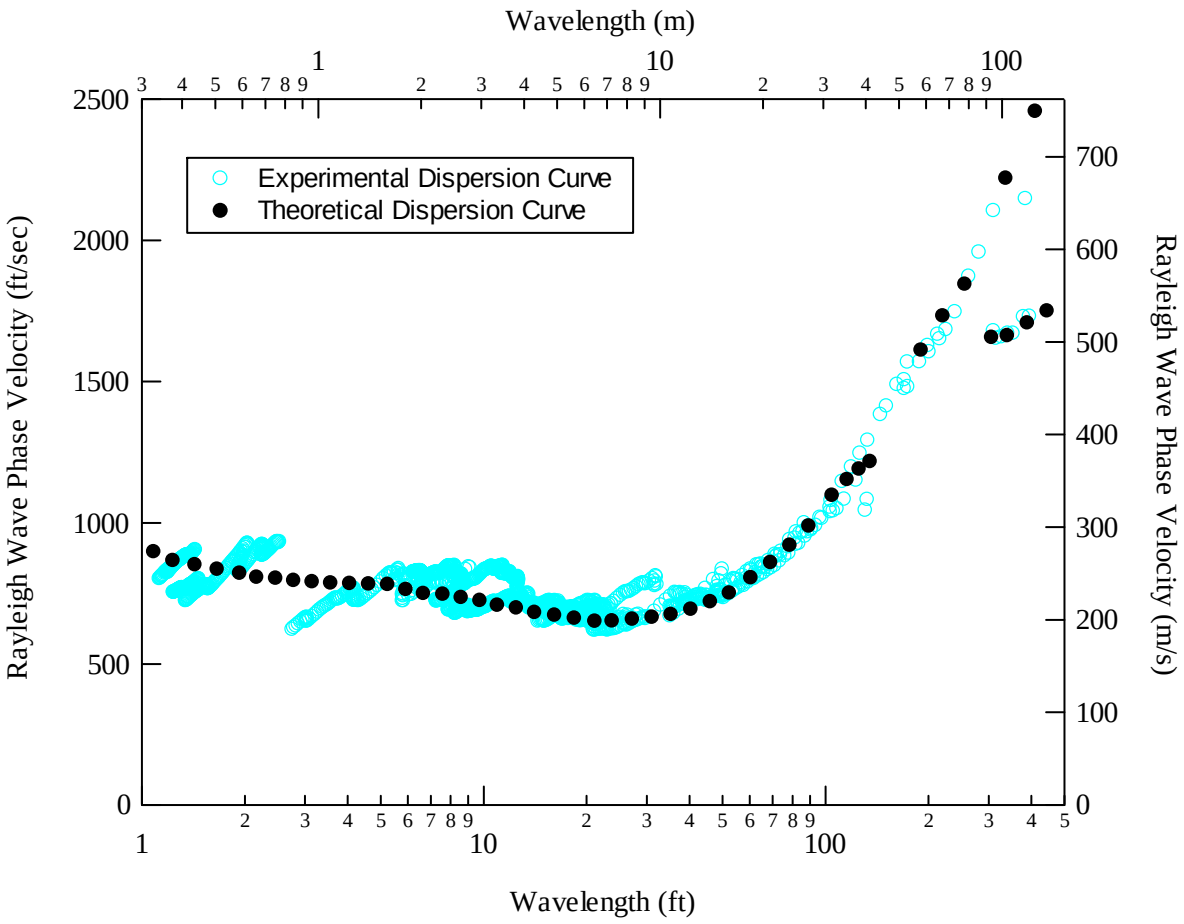


Figure 62 Experimental and theoretical dispersion data at Site 13 (Home Depot).

Table 22 Final forward modeling soil profile for Site 13 (Home Depot).

Layer No.	Thickness (m)	Depth to bottom (m)	P-wave velocity (m/s)	Shear wave velocity (m/s)	Poisson's Ratio	Unit Weight (kN/m^3)	Vs 30 Site Class (m/s)
1	1.6	1.6	460	240	0.30	17	383
2	4.9	6.5	360	190	0.30	16	
3	8.5	15.0	680	370	0.30	18	C
4	46.0	61.0	1260	630	0.33	19	

Note: maximum depth of profile is approximately equal to maximum experimental wavelength/two.

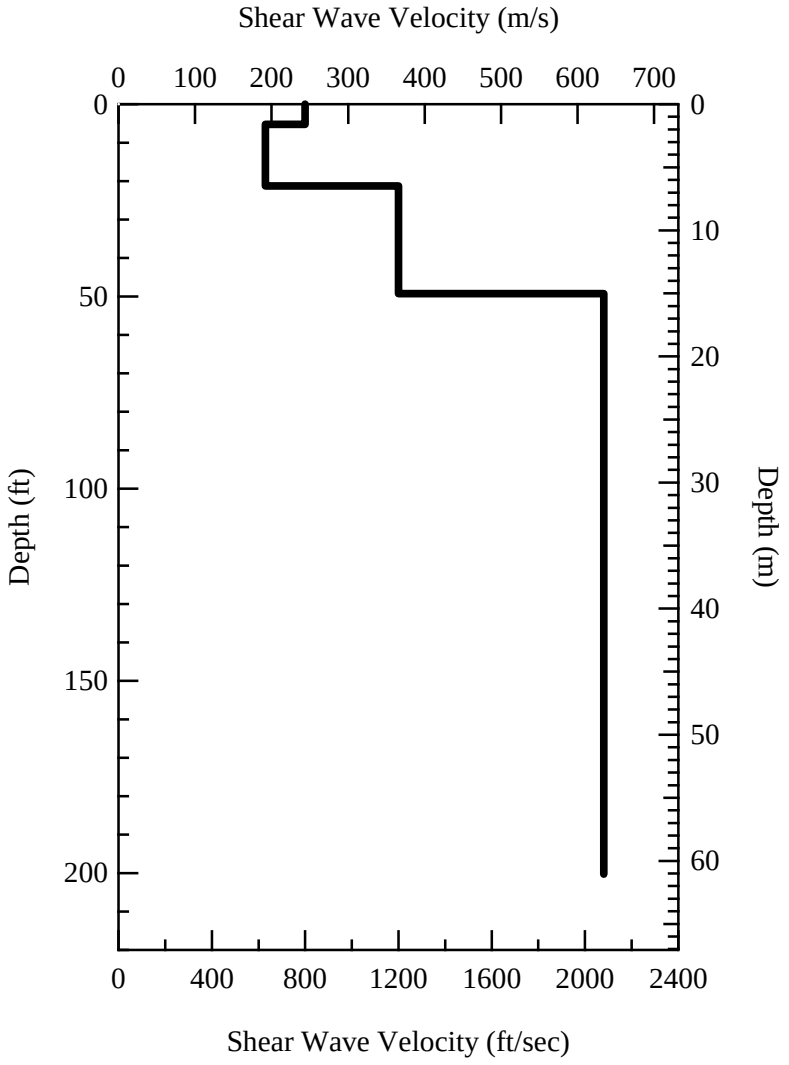


Figure 63 Shear wave velocity profile for Site 13 (Home Depot).

Site 14: Iniakuk Avenue

Figure 64 SASW Array location map for Site 14 (Iniakuk Avenue).

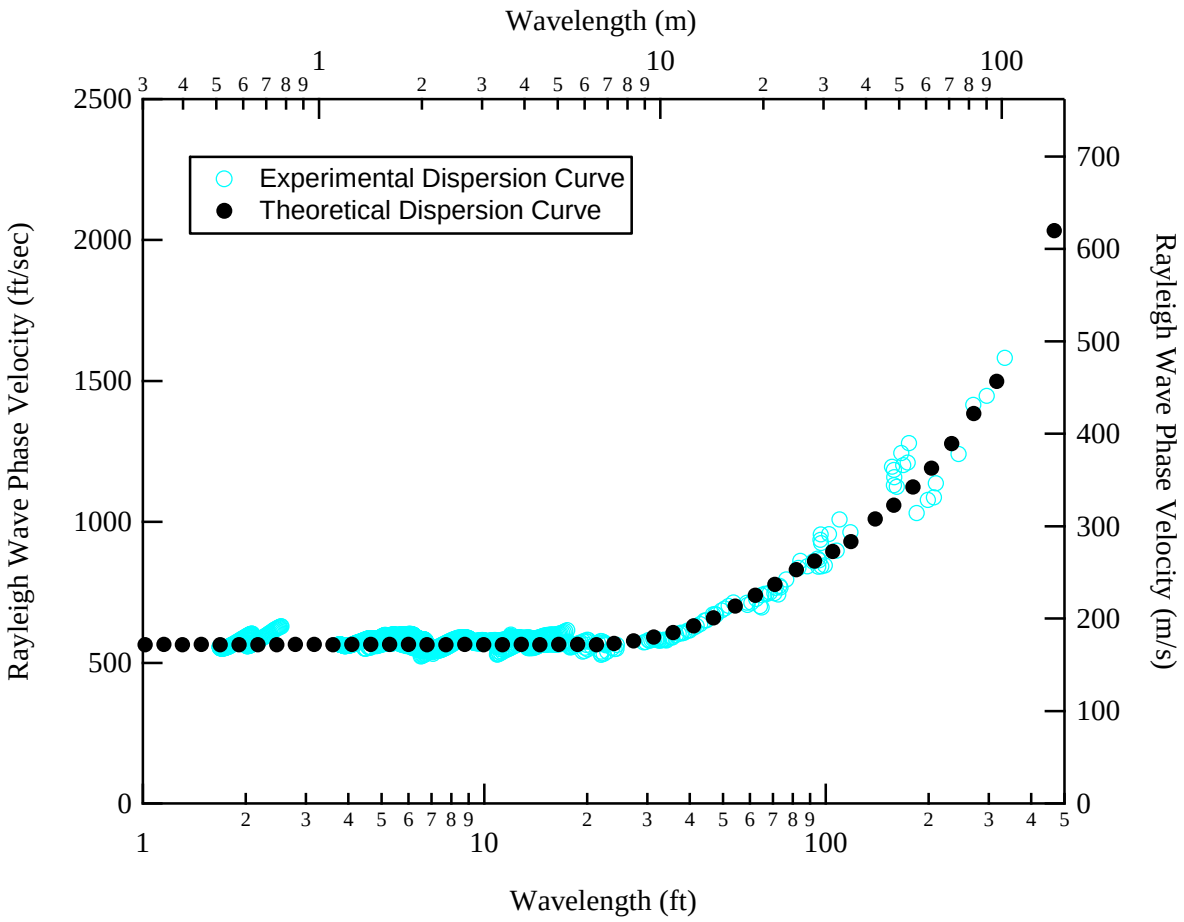


Figure 65 Experimental and theoretical dispersion data at Site 14 (Iniakuk Avenue).

Table 23 Final forward modeling soil profile for Site 14 (Iniakuk Avenue).

Layer No.	Thickness (m)	Depth to bottom (m)	P-wave velocity (m/s)	Shear wave velocity (m/s)	Poisson's Ratio	Unit Weight (kN/m^3)	Vs 30 Site Class (m/s)
1	6.4	6.4	340	180	0.30	17	302
2	15.2	21.6	570	300	0.30	18	
3	39.4	61.0	1090	550	0.33	19	D

Note: maximum depth of profile is approximately equal to maximum experimental wavelength/two.

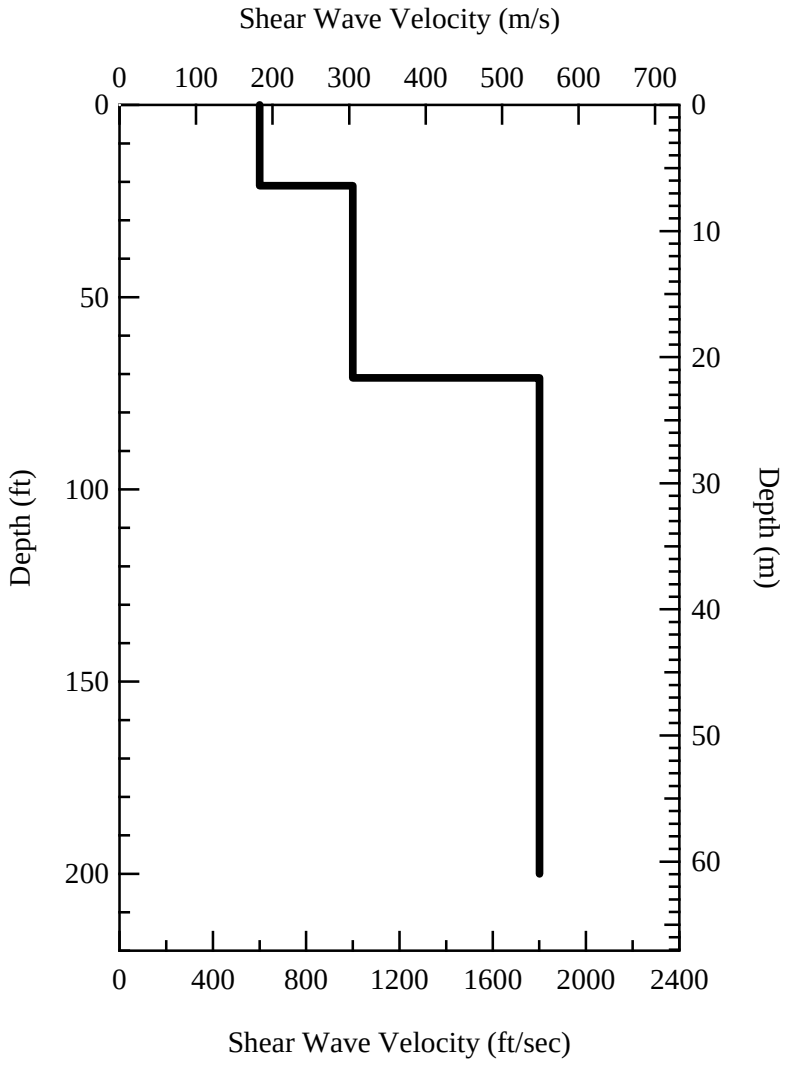


Figure 66 Shear wave velocity profile for Site 14 (Iniakuk Avenue).

Site 15: King Road

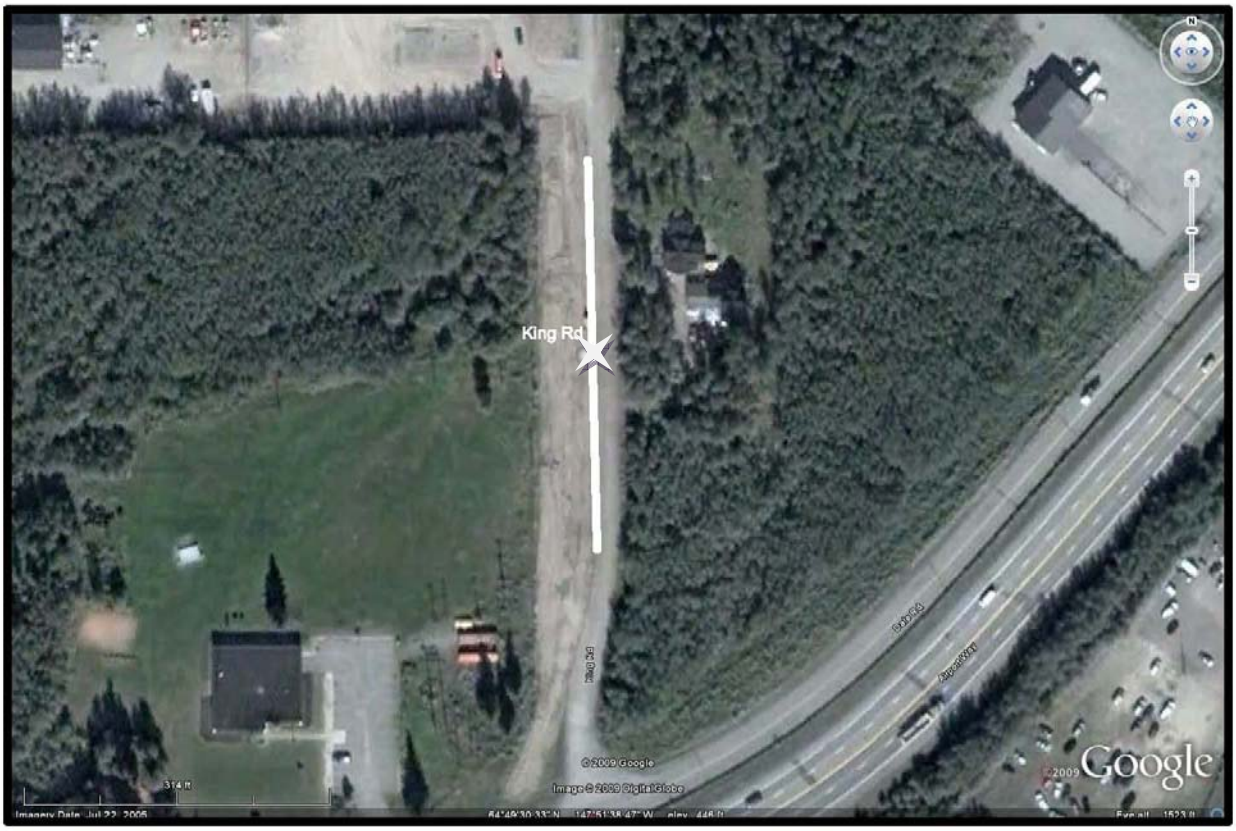


Figure 67 SASW Array location map for Site 15 (King Road).

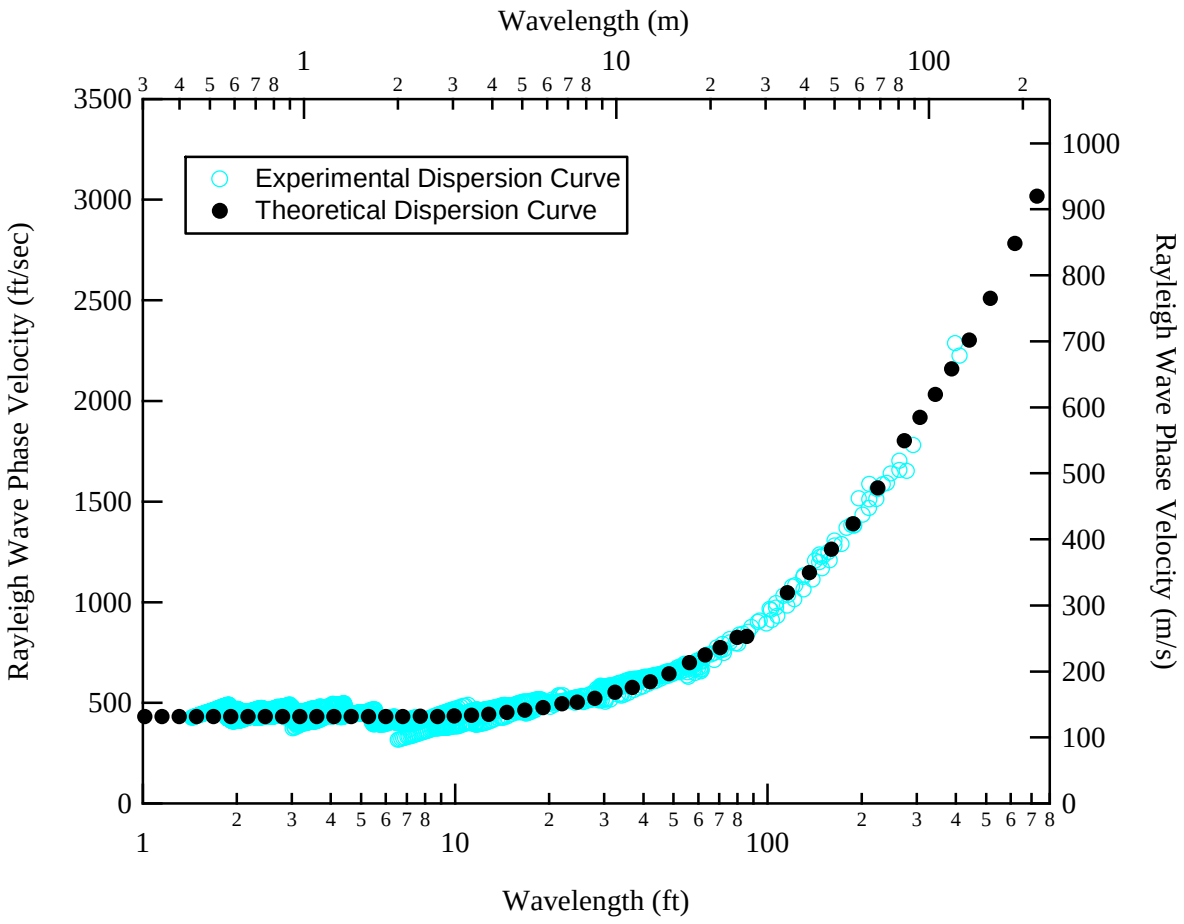


Figure 68 Experimental and theoretical dispersion data at Site 15 (King Road).

Table 24 Final forward modeling soil profile for Site 15 (King Road).

Layer No.	Thickness (m)	Depth to bottom (m)	P-wave velocity (m/s)	Shear wave velocity (m/s)	Poisson's Ratio	Unit Weight (kN/m^3)	Vs 30 Site Class (m/s)
1	2.7	2.7	260	140	0.30	16	326
2	4.3	7.0	360	190	0.30	16	
3	14.6	21.6	680	370	0.30	17	D
4	39.4	61.0	1510	760	0.33	18	

Note: maximum depth of profile is approximately equal to maximum experimental wavelength/two.

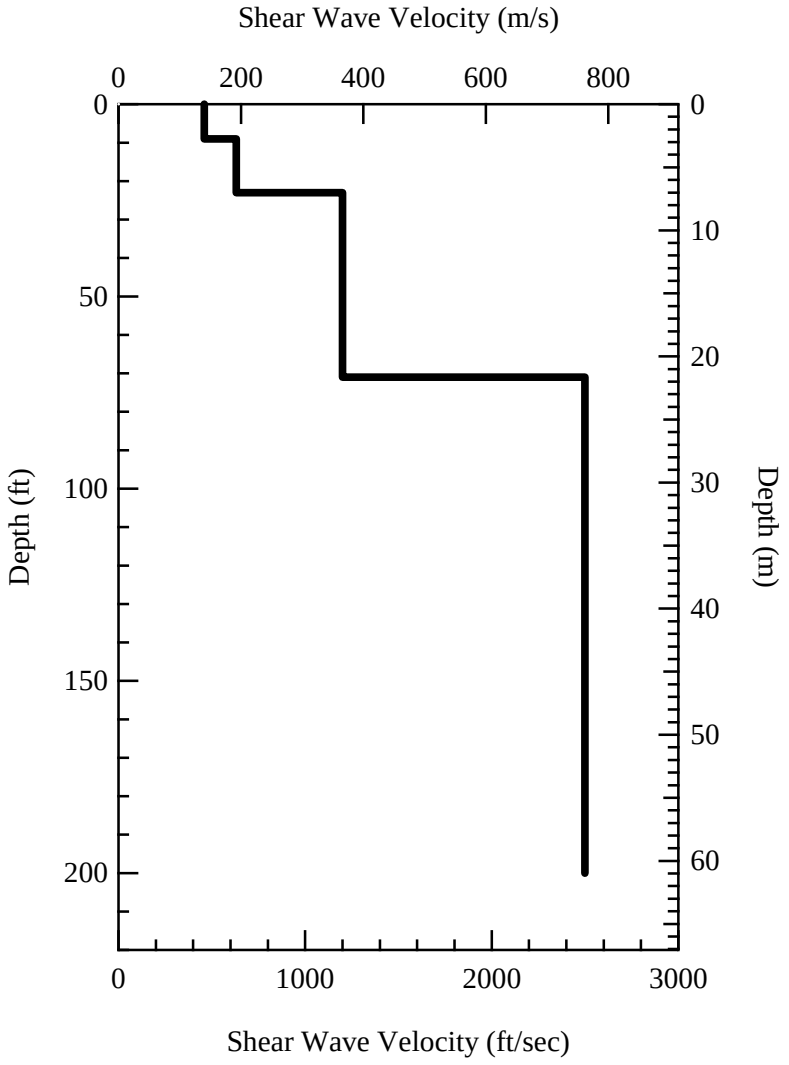


Figure 69 Shear wave velocity profile for Site 15 (King Road).

Site 16: Lathrop High School

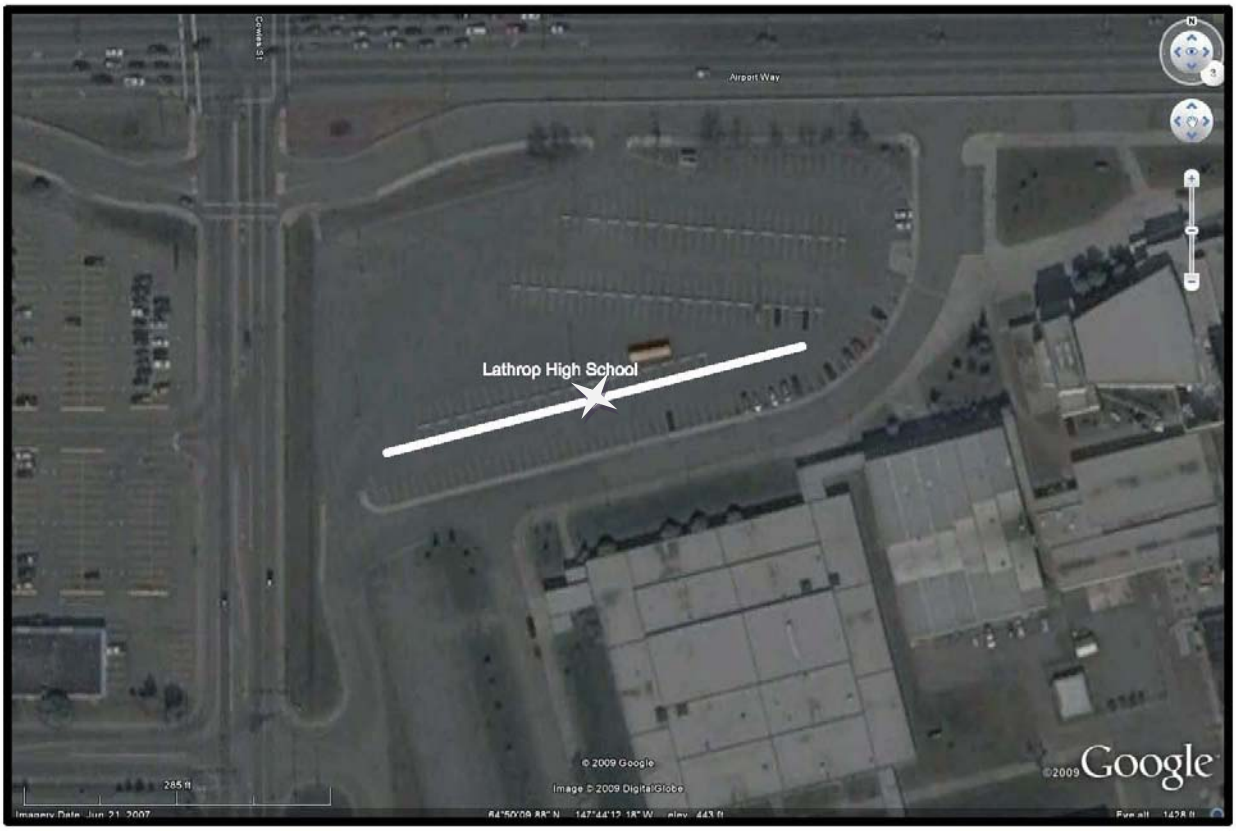


Figure 70 SASW Array location map for Site 16 (Lathrop High School).

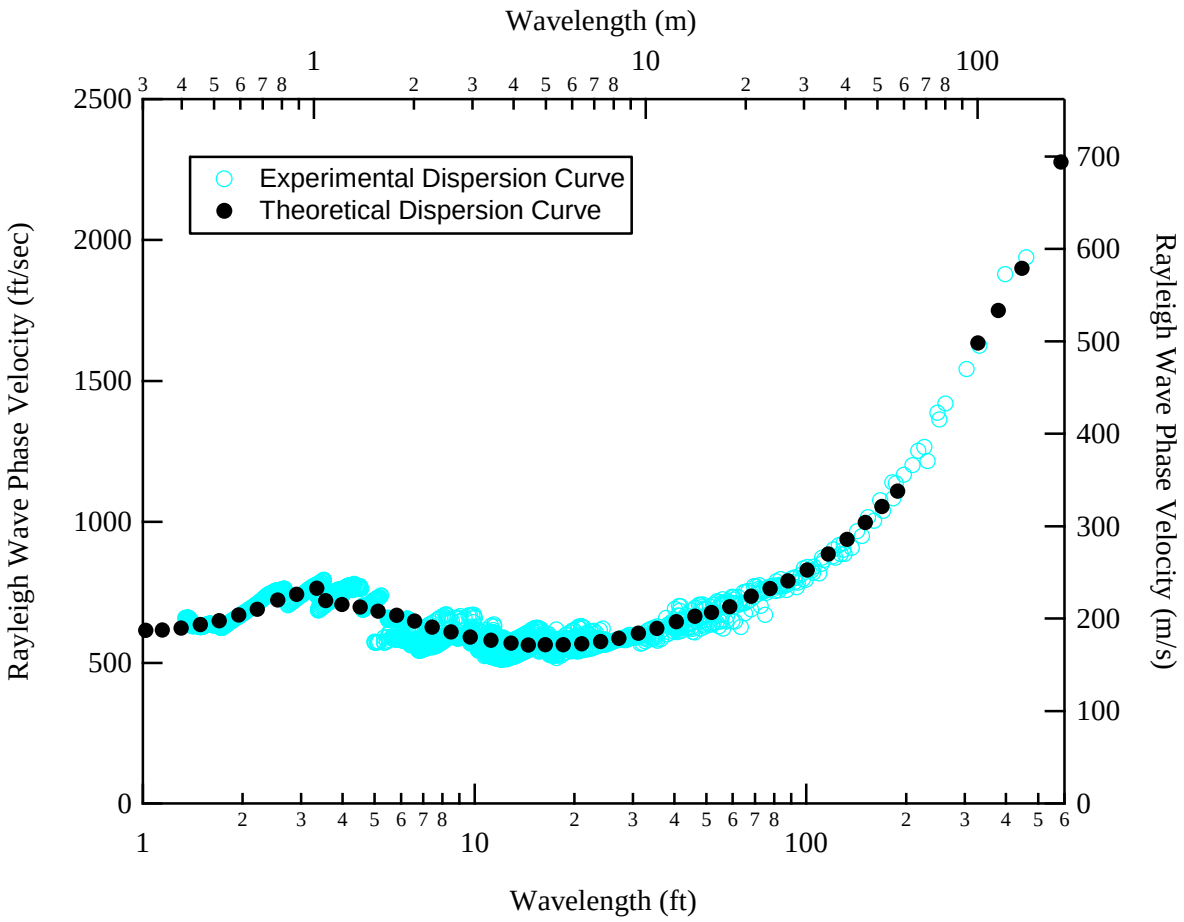


Figure 71 Experimental and theoretical dispersion data at Site 16 (Lathrop High School).

Table 25 Final forward modeling soil profile for Site 16 (Lathrop High School).

Layer No.	Thickness (m)	Depth to bottom (m)	P-wave velocity (m/s)	Shear wave velocity (m/s)	Poisson's Ratio	Unit Weight (kN/m^3)	Vs 30 Site Class (m/s)
1	0.3	0.3	370	200	0.30	17	297
2	0.5	0.8	540	290	0.30	17	
3	3.7	4.5	320	170	0.30	16	
4	9.8	14.3	460	240	0.30	17	D
5	10.7	25.0	680	370	0.30	18	
6	36.0	61.0	1270	640	0.33	19	

Note: maximum depth of profile is approximately equal to maximum experimental wavelength/two.

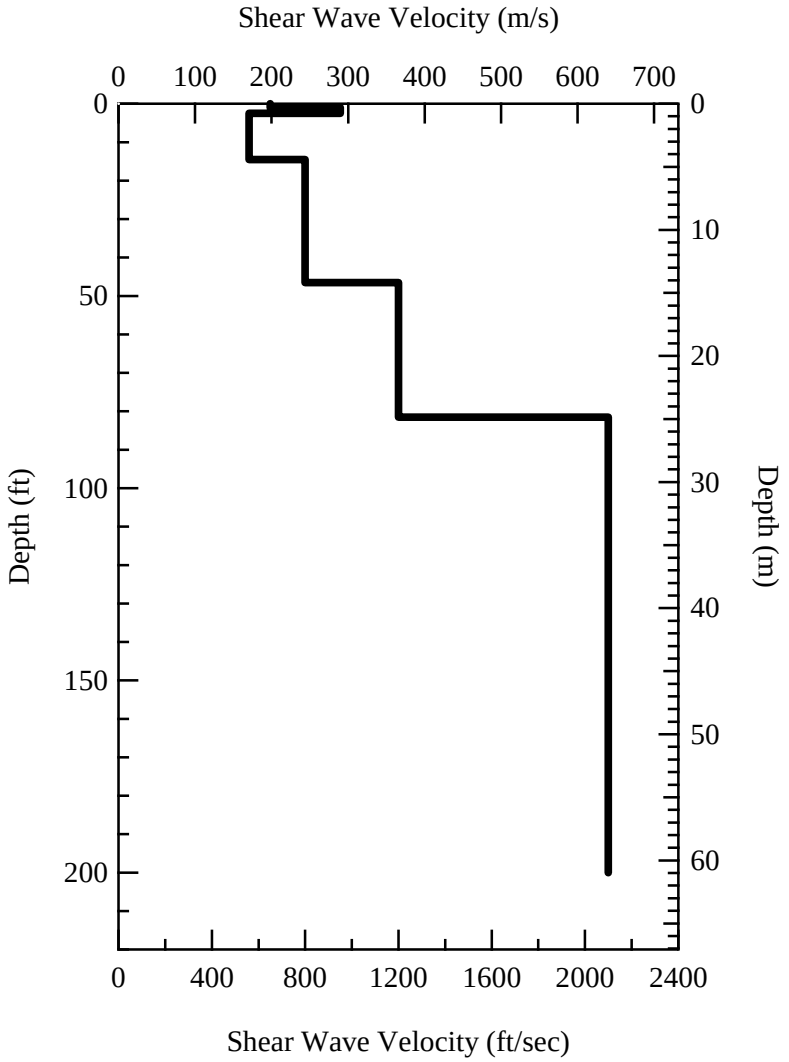


Figure 72 Shear wave velocity profile for Site 16 (Lathrop High School).

Site 17:Mail Trail Road

Figure 73 SASW Array location map for Site 17 (Mail Trail Road).

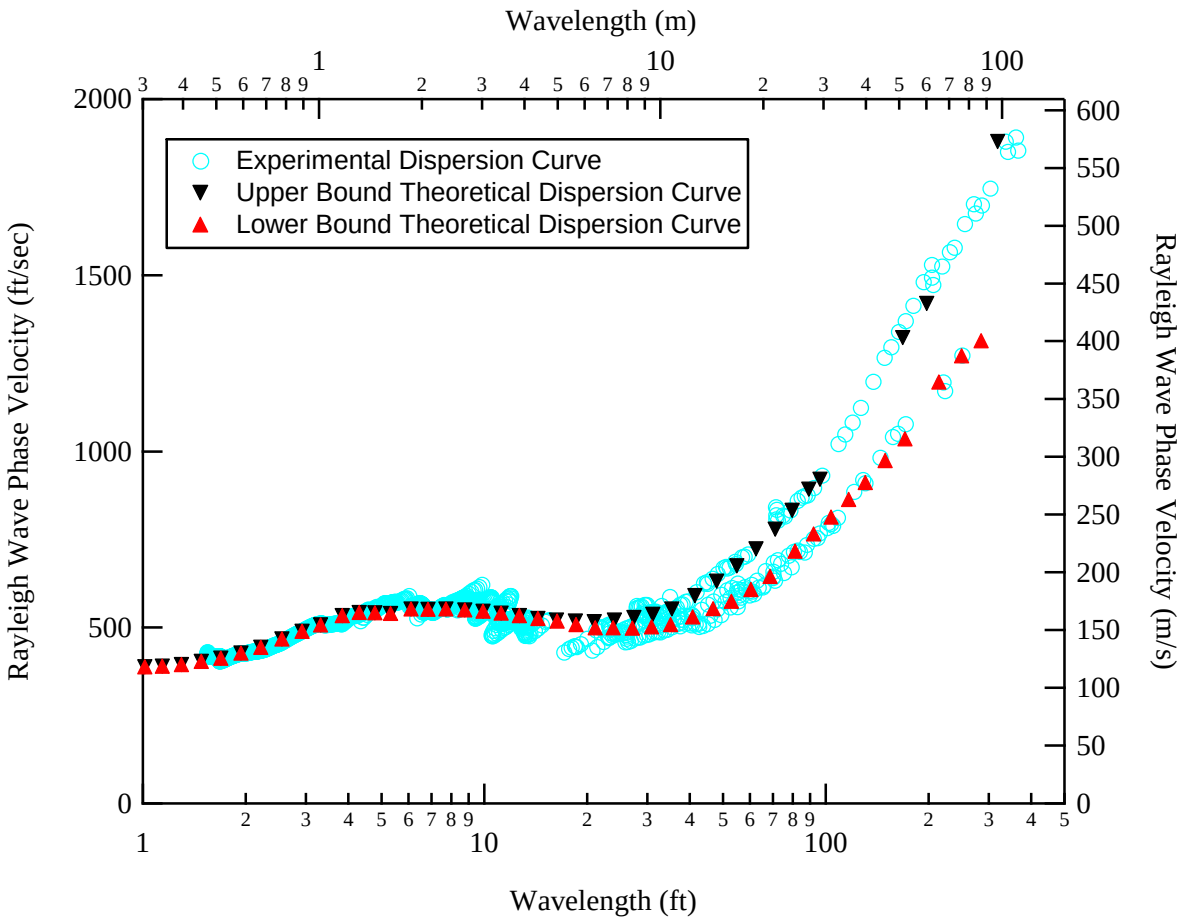


Figure 74 Experimental and theoretical dispersion data at Site 17 (Mail Trail Road).

Table 26 Final forward modeling soil profile for Site 17, Upper Bound (Mail Trail Road).

Layer No.	Thickness (m)	Depth to bottom (m)	P-wave velocity (m/s)	Shear wave velocity (m/s)	Poisson's Ratio	Unit Weight (kN/m^3)	Vs 30 Site Class (m/s)
1	0.3	0.3	230	120	0.30	16	328
2	2.1	2.4	360	190	0.30	17	
3	2.3	4.7	270	140	0.30	16	D
4	4.6	9.3	460	240	0.30	17	
5	42.7	52.0	940	470	0.33	18	

Note: maximum depth of profile is approximately equal to maximum experimental wavelength/two.

Table 27 Final forward modeling soil profile for Site 17, Lower Bound (Mail Trail Road).

Layer No.	Thickness (m)	Depth to bottom (m)	P-wave velocity (m/s)	Shear wave velocity (m/s)	Poisson's Ratio	Unit Weight (kN/m^3)	Vs 30 Site Class (m/s)
1	0.3	0.3	230	120	0.30	16	279
2	2.1	2.4	360	190	0.30	17	
3	4.0	6.4	270	140	0.30	16	D
4	8.8	15.2	510	270	0.30	18	
5	22.9	38.1	840	420	0.33	19	

Note: maximum depth of profile is approximately equal to maximum experimental wavelength/two.

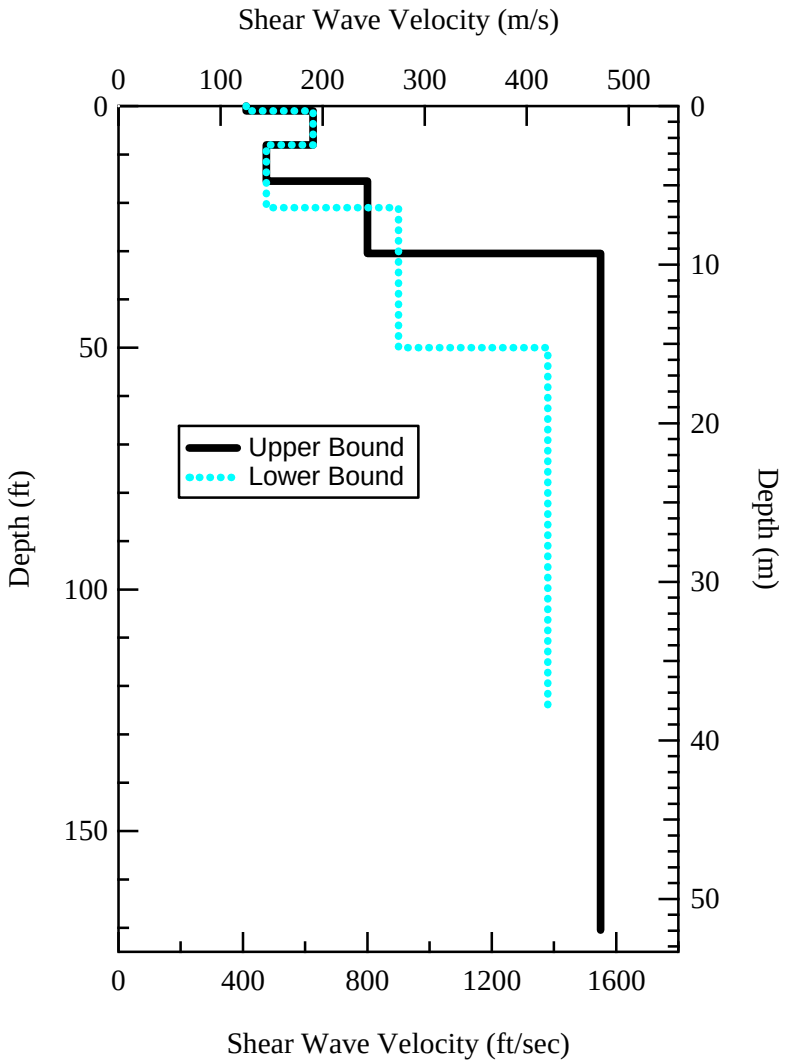


Figure 75 Shear wave velocity profile for Site 17 (Mail Trail Road).

Site 18: Monroe Catholic School

Figure 76 SASW Array location map for Site 18 (Monroe Catholic School).

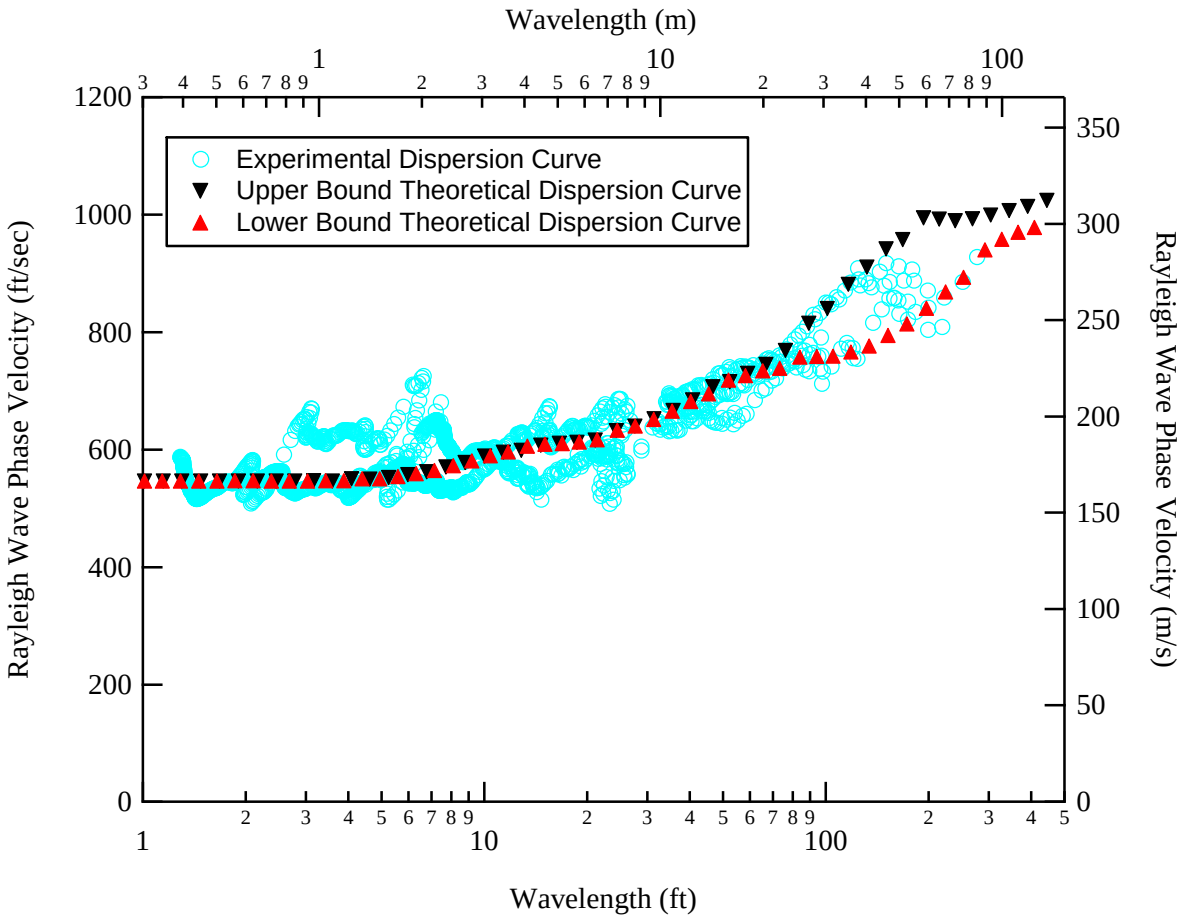


Figure 77 Experimental and theoretical dispersion data at Site 18 (Monroe Catholic School).

Table 28 Final forward modeling soil profile for Site 18, Upper Bound (Monroe Catholic School).

Layer No.	Thickness (m)	Depth to bottom (m)	P-wave velocity (m/s)	Shear wave velocity (m/s)	Poisson's Ratio	Unit Weight (kN/m^3)	Vs 30 Site Class (m/s)
1	1.2	1.2	330	180	0.30	16	245
2	4.3	5.5	380	200	0.30	17	
3	25.3	30.8	480	260	0.30	18	D
4	11.9	42.7	700	350	0.33	18	

Note: maximum depth of profile is approximately equal to maximum experimental wavelength/two.

Table 29 Final forward modeling soil profile for Site 18, Lower Bound (Monroe Catholic School).

Layer No.	Thickness (m)	Depth to bottom (m)	P-wave velocity (m/s)	Shear wave velocity (m/s)	Poisson's Ratio	Unit Weight (kN/m^3)	Vs 30 Site Class (m/s)
1	1.2	1.2	330	180	0.30	16	280
2	4.3	5.5	380	200	0.30	17	
3	9.8	15.3	480	260	0.30	18	D
4	9.1	24.4	700	350	0.33	18	

Note: maximum depth of profile is approximately equal to maximum experimental wavelength/two.

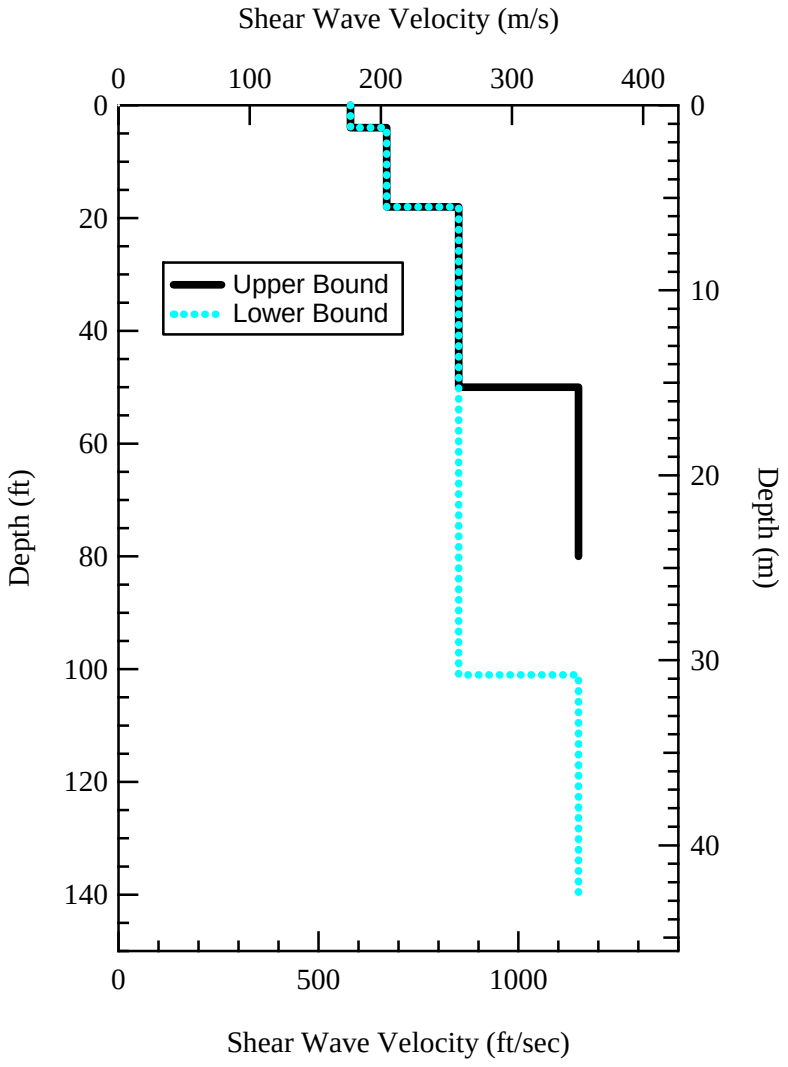


Figure 78 Shear wave velocity profile for Site 18 (Monroe Catholic School).

Site 19: North Peger Road

Figure 79 SASW Array location map for Site 19 (North Peger Road).

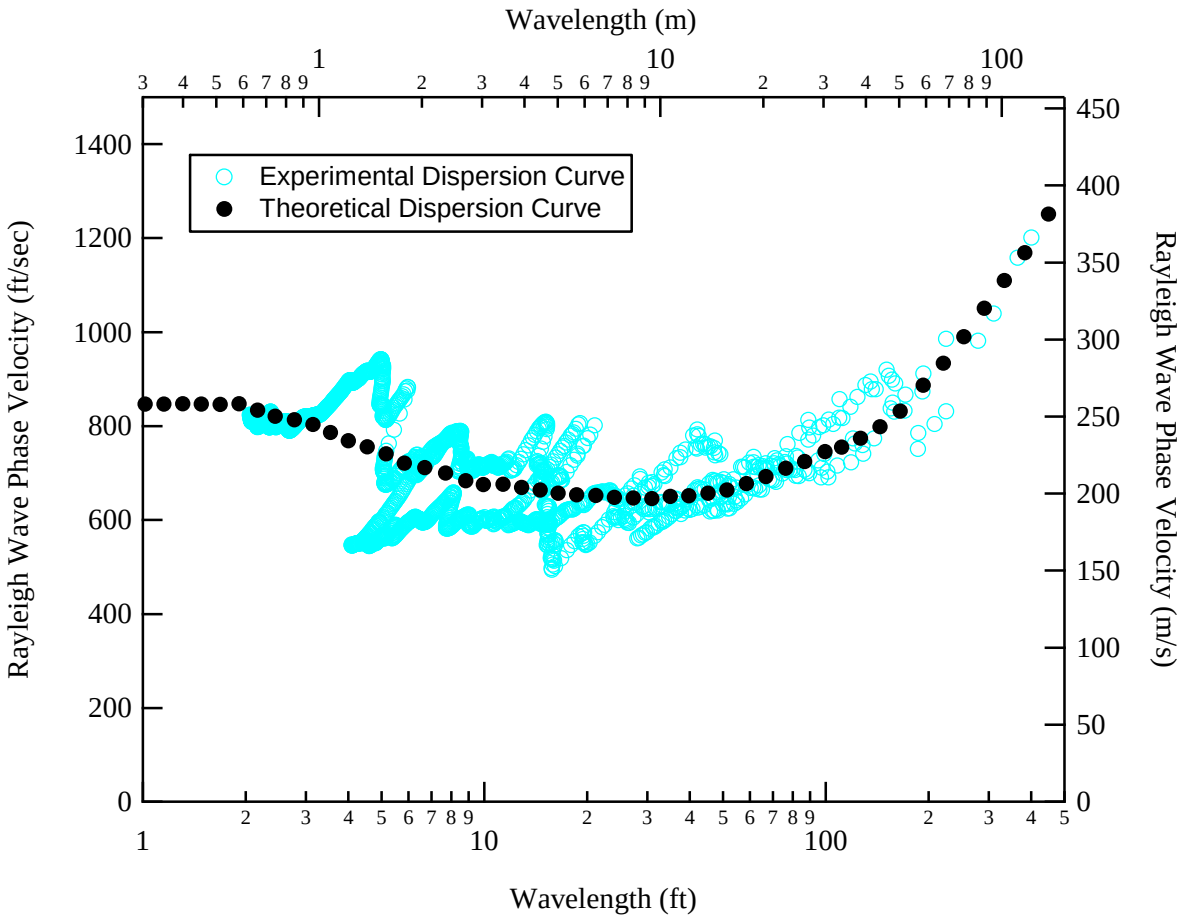


Figure 80 Experimental and theoretical dispersion data at Site 19 (North Peger Road).

Table 30 Final forward modeling soil profile for Site 19 (North Peger Road).

Layer No.	Thickness (m)	Depth to bottom (m)	P-wave velocity (m/s)	Shear wave velocity (m/s)	Poisson's Ratio	Unit Weight (kN/m^3)	Vs 30 Site Class (m/s)
1	0.6	0.6	460	270	0.30	17	244
2	9.1	9.7	370	200	0.30	16	
3	19.8	29.5	570	260	0.30	17	D
4	31.5	61.0	790	430	0.33	18	

Note: maximum depth of profile is approximately equal to maximum experimental wavelength/two.

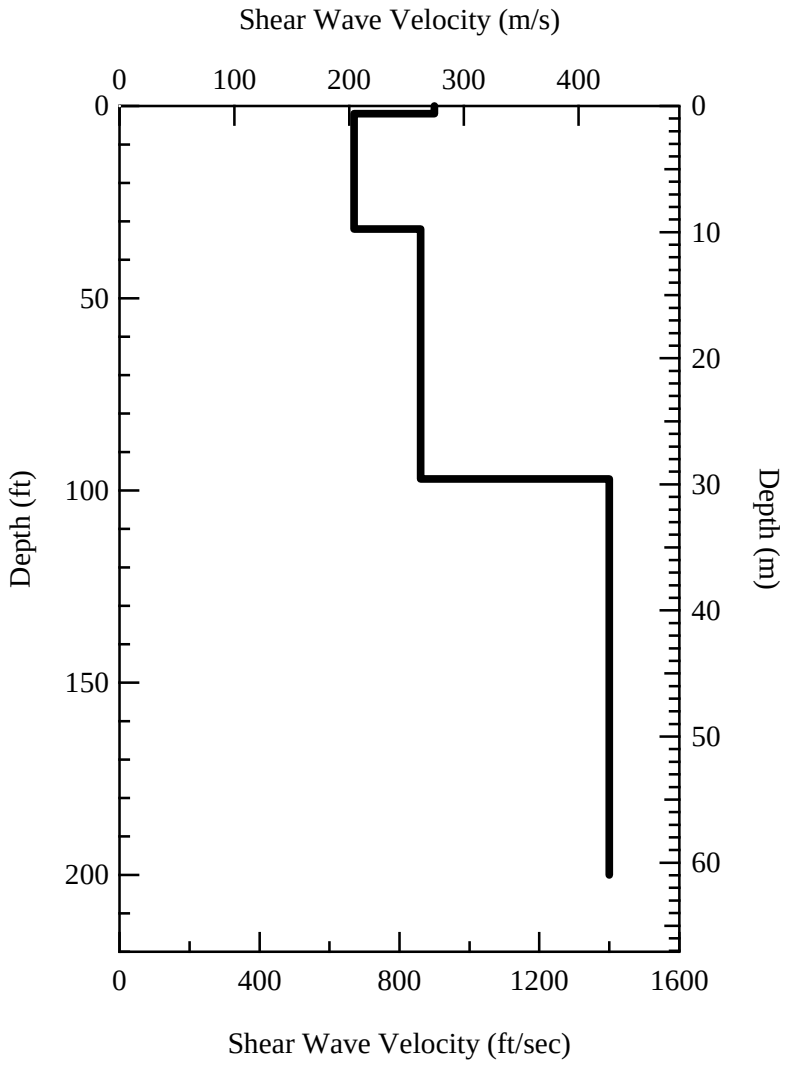


Figure 81 Shear wave velocity profile for Site 19 (North Peger Road).

Site 20: Old Pioneer Way

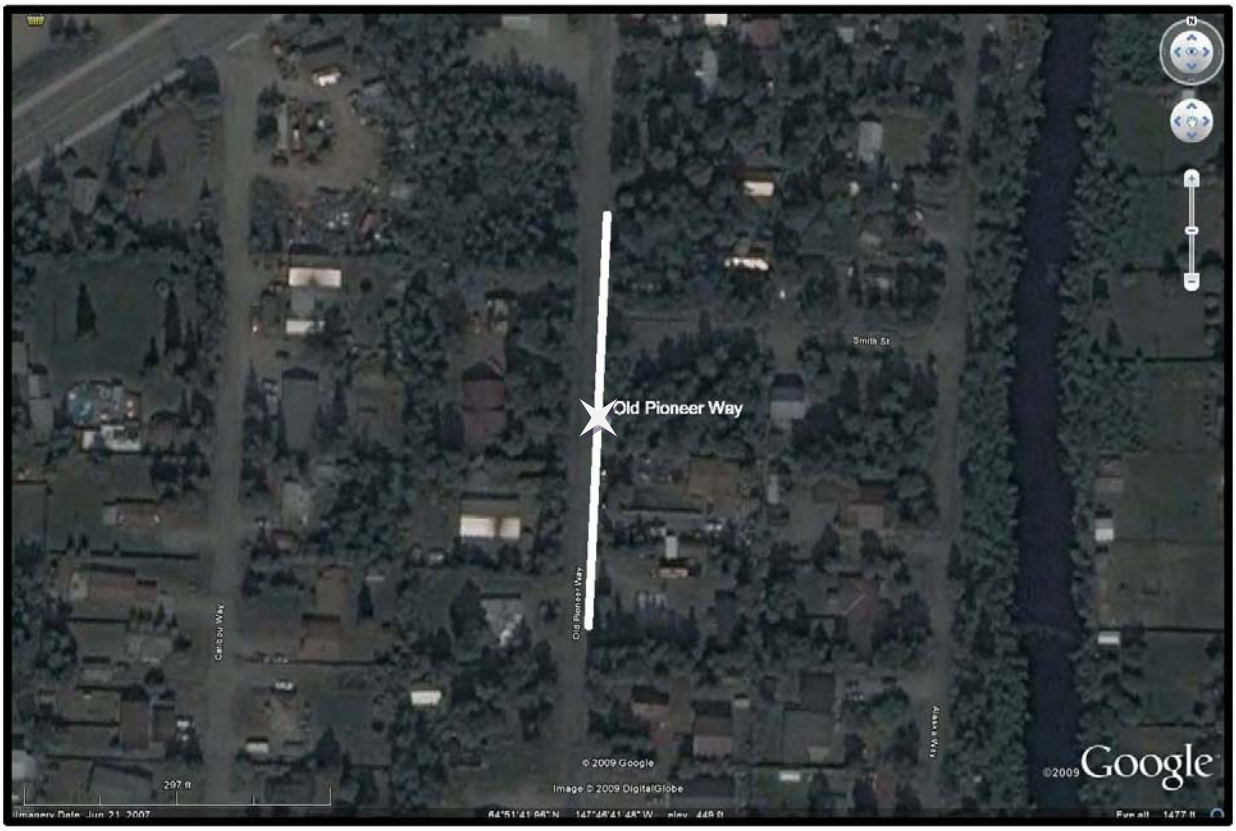


Figure 82 SASW Array location map for Site 20 (Old Pioneer Way).

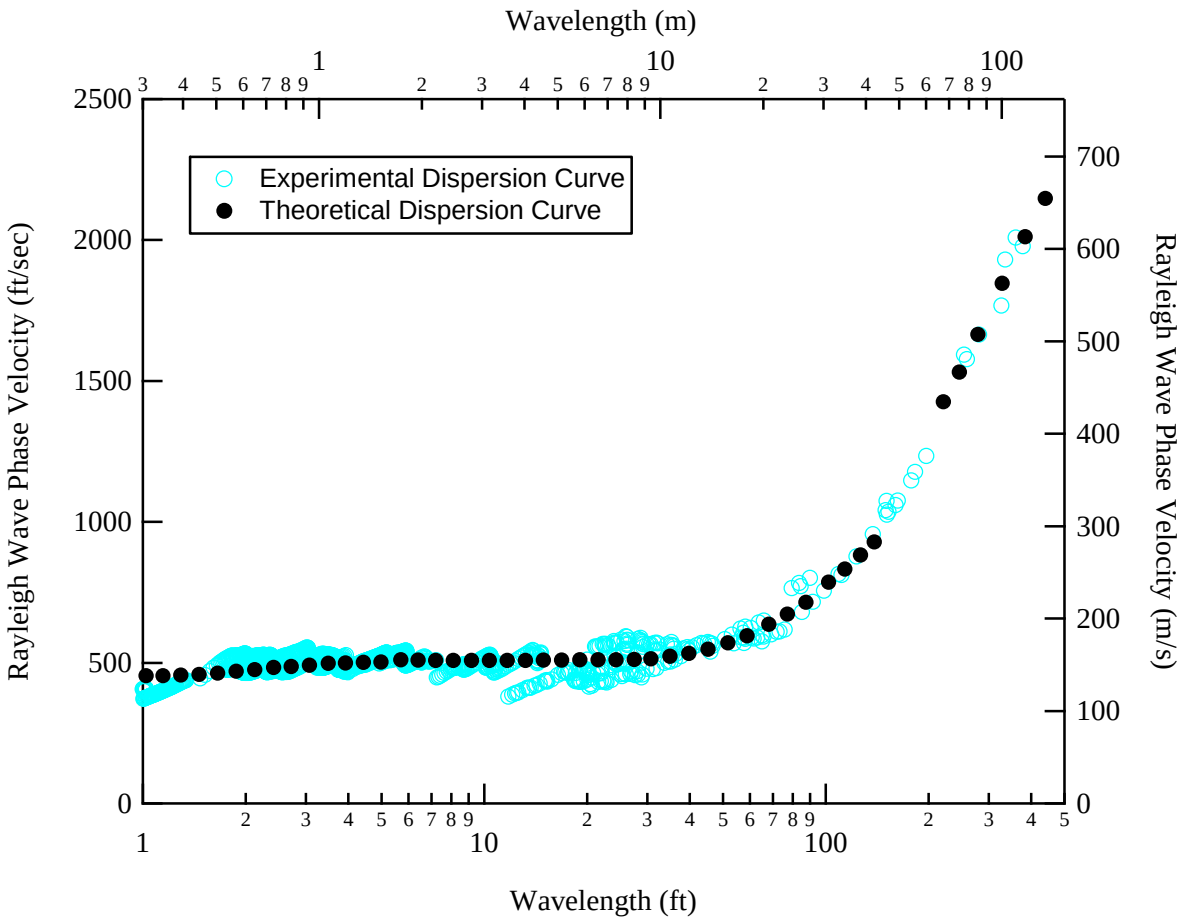


Figure 83 Experimental and theoretical dispersion data at Site 20 (Old Pioneer Way).

Table 31 Final forward modeling soil profile for Site 20 (Old Pioneer Way).

Layer No.	Thickness (m)	Depth to bottom (m)	P-wave velocity (m/s)	Shear wave velocity (m/s)	Poisson's Ratio	Unit Weight (kN/m^3)	Vs 30 Site Class (m/s)
1	0.3	0.3	270	150	0.30	16	302
2	8.2	8.5	310	170	0.30	16	
3	10.7	19.2	570	300	0.30	17	D
4	38.7	57.9	1510	760	0.33	19	

Note: maximum depth of profile is approximately equal to maximum experimental wavelength/two.

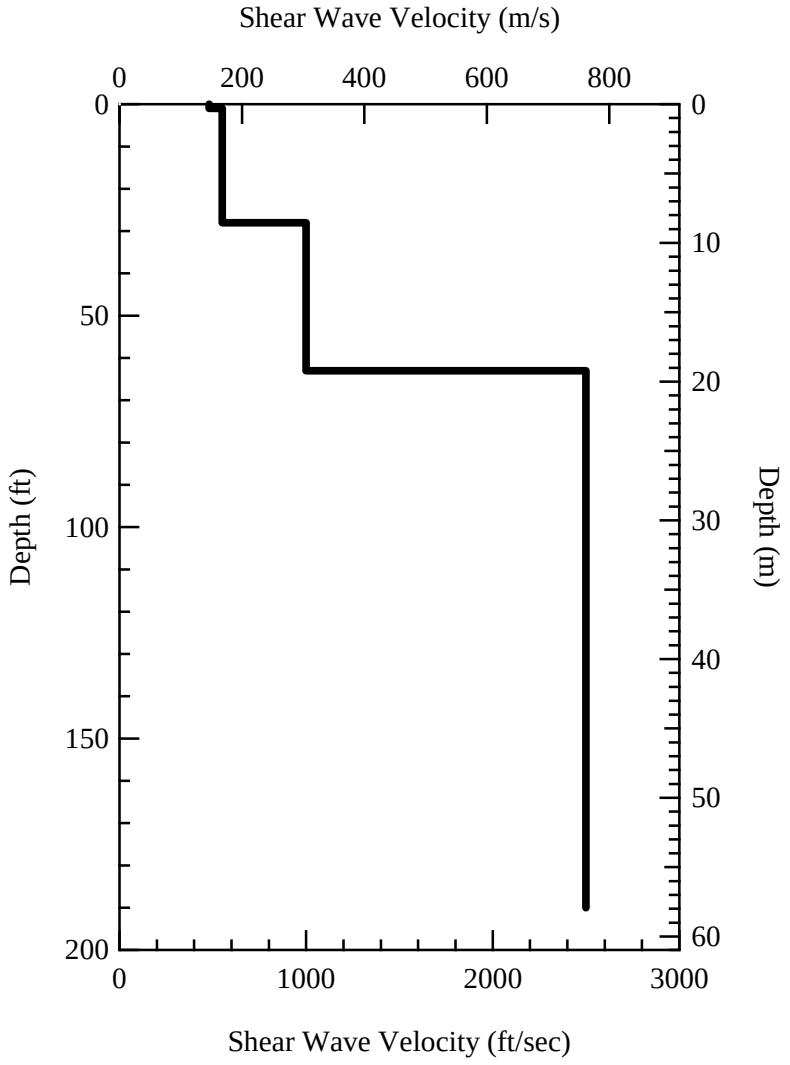


Figure 84 Shear wave velocity profile for Site 20 (Old Pioneer Way).

Site 21: Pioneer Park

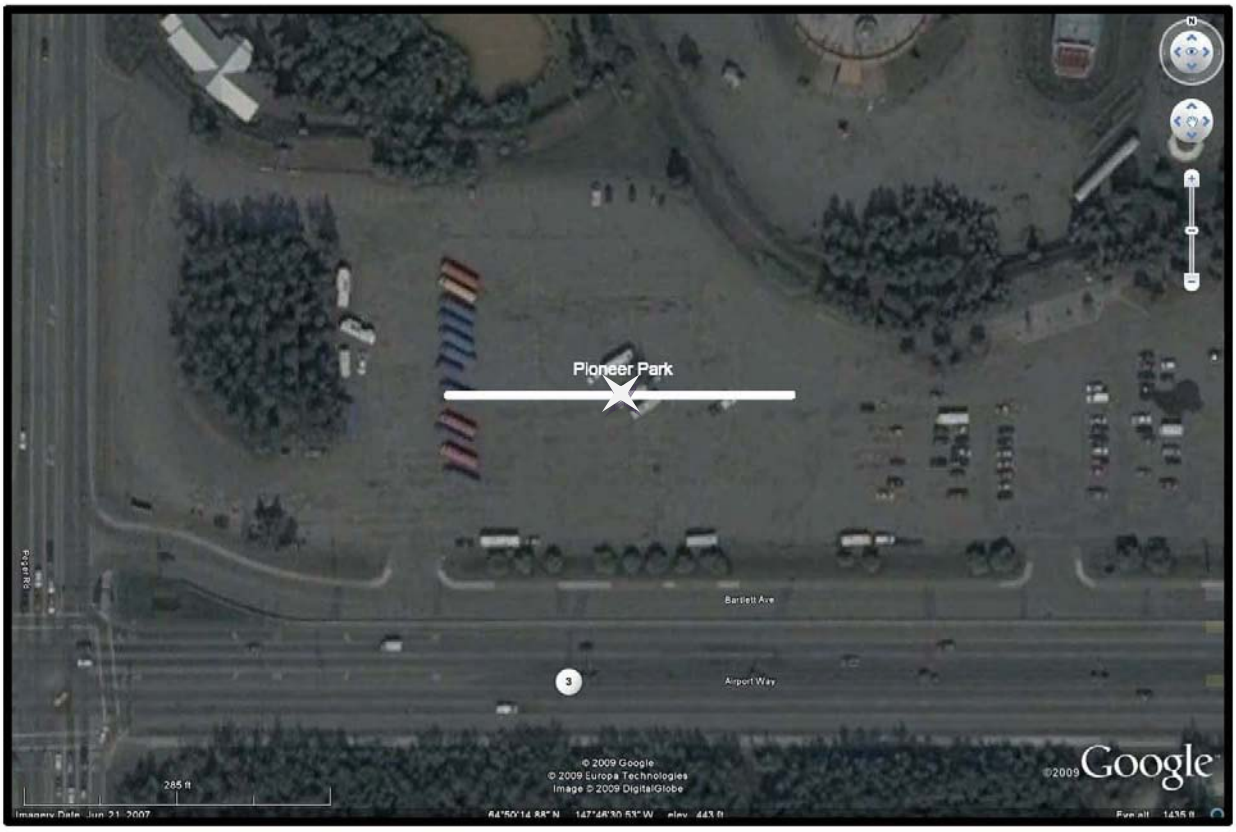


Figure 85 SASW Array location map for Site 21 (Pioneer Park).

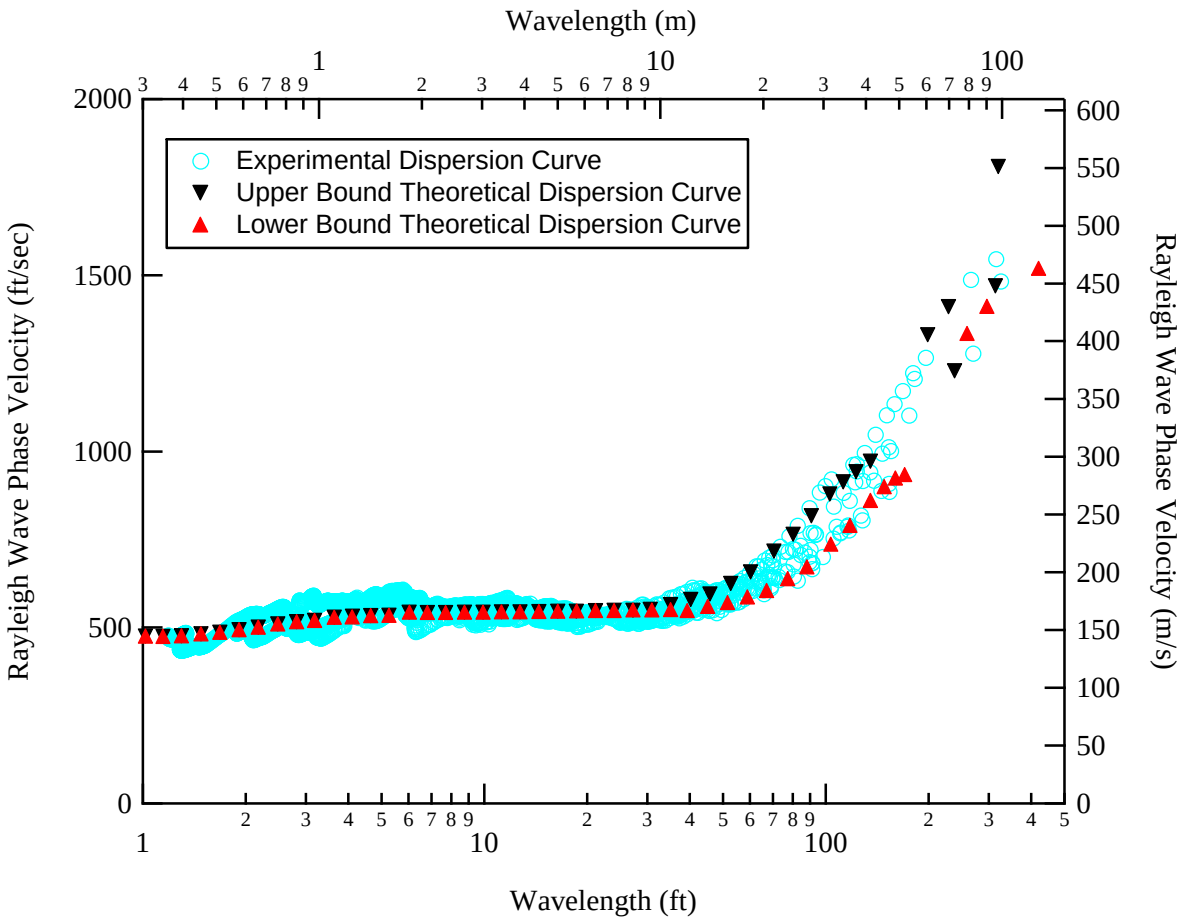


Figure 86 Experimental and theoretical dispersion data at Site 21 (Pioneer Park).

Table 31 Final forward modeling soil profile for Site 21 Upper Bound (Pioneer Park).

Layer No.	Thickness (m)	Depth to bottom (m)	P-wave velocity (m/s)	Shear wave velocity (m/s)	Poisson's Ratio	Unit Weight (kN/m^3)	Vs 30 Site Class (m/s)
1	0.3	0.3	1030	150	0.30	16	309
2	8.2	8.5	290	180	0.30	16	
3	12.2	20.7	260	400	0.30	17	D
4	28.0	48.7	970	490	0.33	18	

Note: maximum depth of profile is approximately equal to maximum experimental wavelength/two.

Table 32 Final forward modeling soil profile for Site 21 Lower Bound (Pioneer Park).

Layer No.	Thickness (m)	Depth to bottom (m)	P-wave velocity (m/s)	Shear wave velocity (m/s)	Poisson's Ratio	Unit Weight (kN/m^3)	Vs 30 Site Class (m/s)
1	0.3	0.3	290	150	0.30	16	276
2	11.6	11.9	340	180	0.30	16	
3	12.2	24.1	740	400	0.30	17	D
4	24.7	48.8	970	490	0.33	18	

Note: maximum depth of profile is approximately equal to maximum experimental wavelength/two.

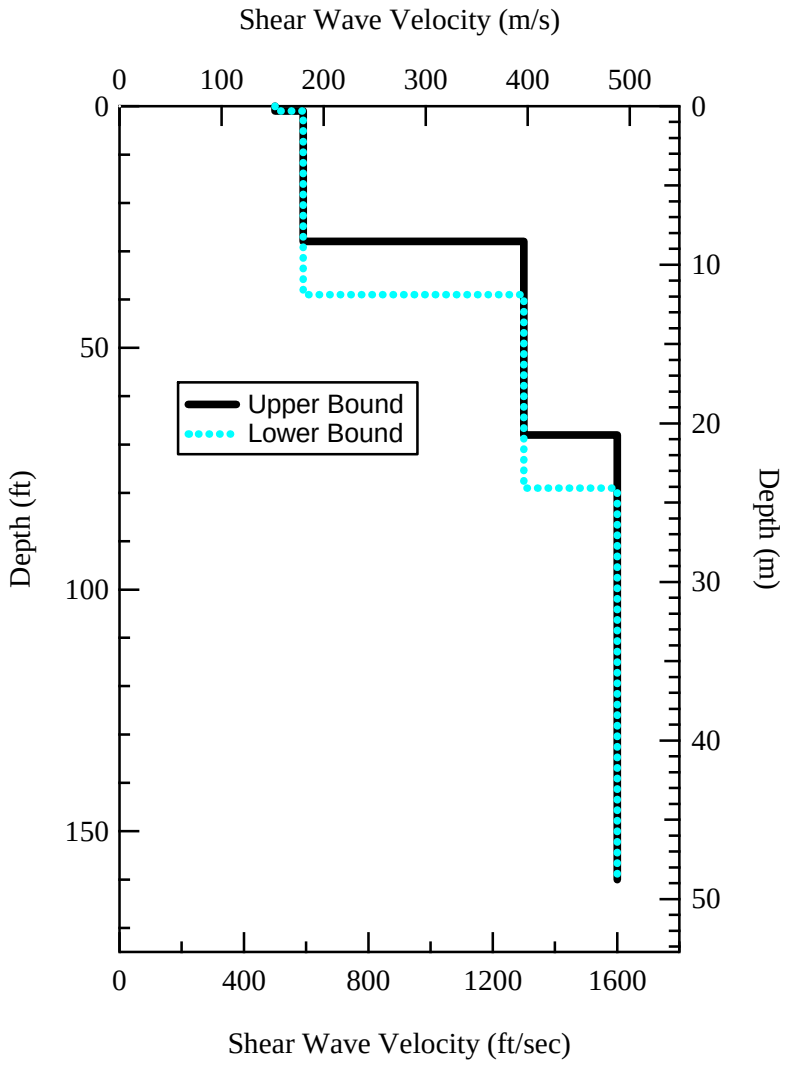


Figure 87 Shear wave velocity profile for Site 21 (Pioneer Park).

Site 22: Sadlers

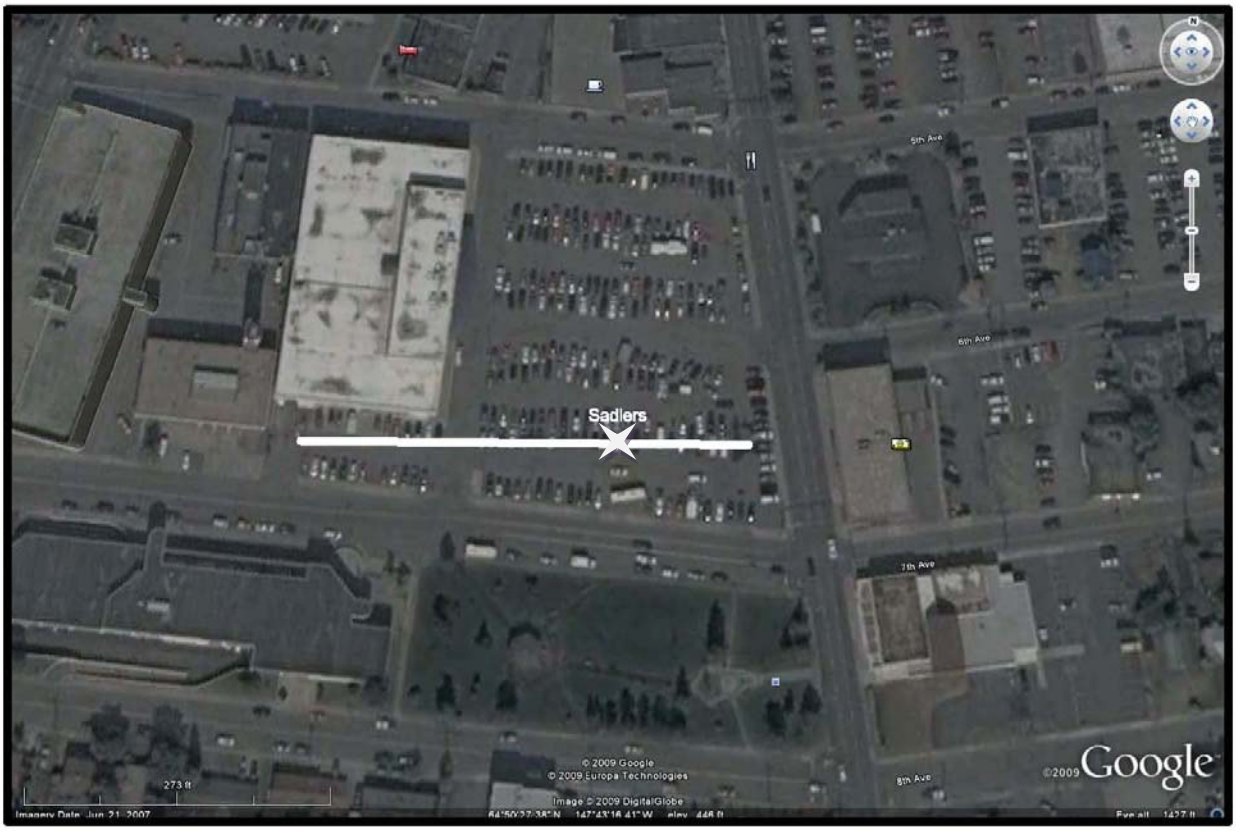


Figure 88 SASW Array location map for Site 22 (Sadlers).

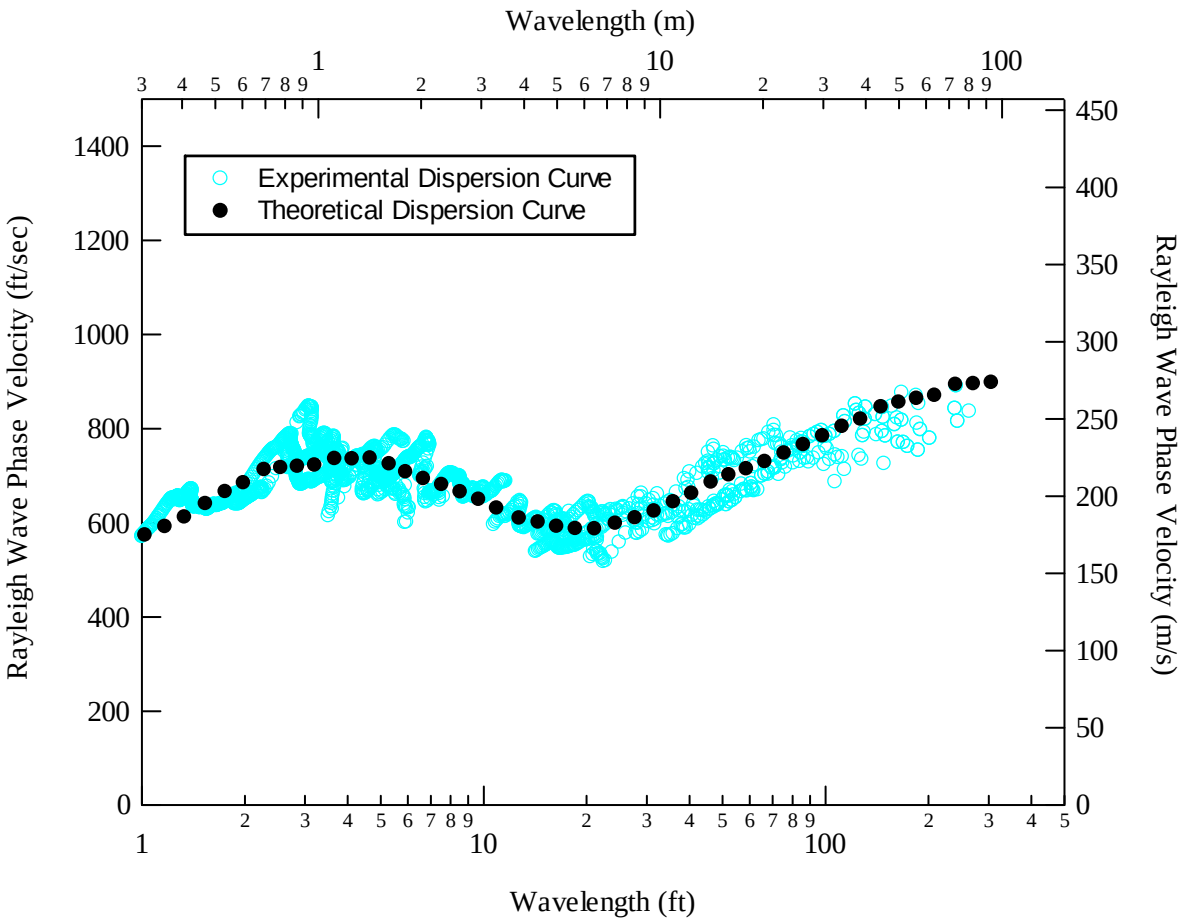


Figure 89 Experimental and theoretical dispersion data at Site 22 (Sadlers).

Table 33 Final forward modeling soil profile for Site 22 (Sadlers).

Layer No.	Thickness (m)	Depth to bottom (m)	P-wave velocity (m/s)	Shear wave velocity (m/s)	Poisson's Ratio	Unit Weight (kN/m^3)	Vs 30 Site Class (m/s)
1	0.2	0.2	330	180	0.30	16	263
2	1.2	1.4	470	250	0.30	17	
3	2.4	3.8	300	160	0.30	16	D
4	12.2	16.0	470	250	0.30	17	
5	21.0	37.0	580	310	0.30	17	

Note: maximum depth of profile is approximately equal to maximum experimental wavelength/two.

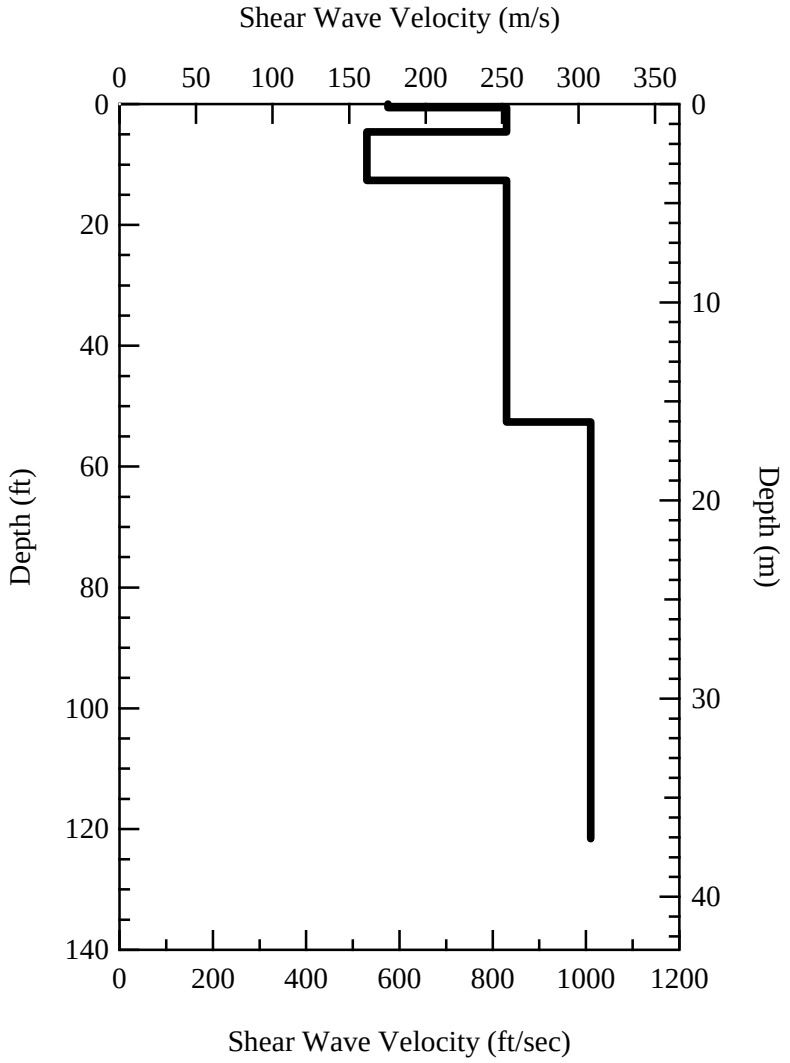


Figure 90 Shear wave velocity profile for Site 22 (Sadlers).

Site 23: Sam's Club

Figure 91 SASW Array location map for Site 23 (Sam's Club).

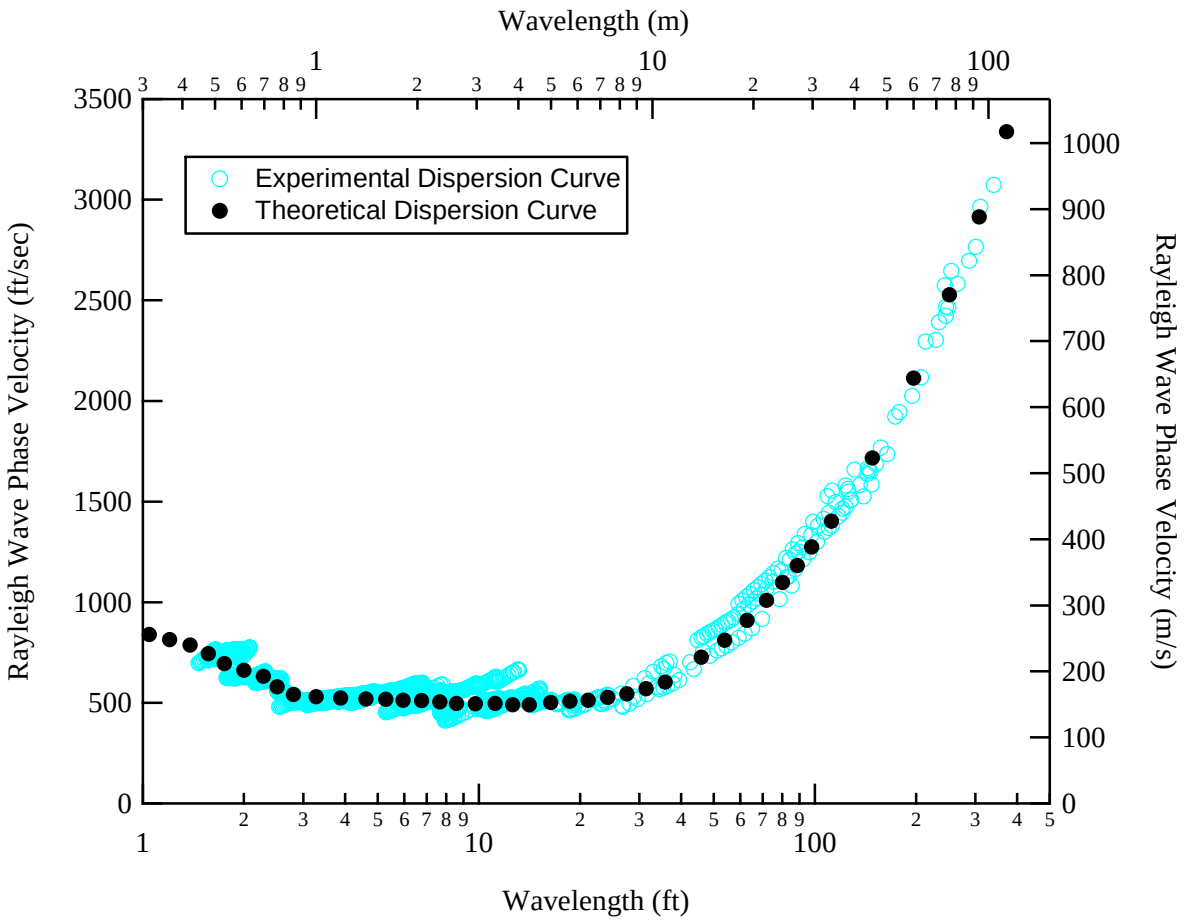


Figure 92 Experimental and theoretical dispersion data at Site 23 Interpretation 1 (Sam's Club).

Table 34 Final forward modeling soil profile for Site 23 Interpretation 1 (Sam's Club).

Layer No.	Thickness (m)	Depth to bottom (m)	P-wave velocity (m/s)	Shear wave velocity (m/s)	Poisson's Ratio	Unit Weight (kN/m^3)	Vs 30 Site Class (m/s)
1	2.1	2.1	290	160	0.30	16	454
2	2.1	4.2	260	140	0.30	16	
3	17.4	21.6	1030	550	0.30	18	C
4	30.5	52.1	2720	1340	0.33	19	

Note: maximum depth of profile is approximately equal to maximum experimental wavelength/two.

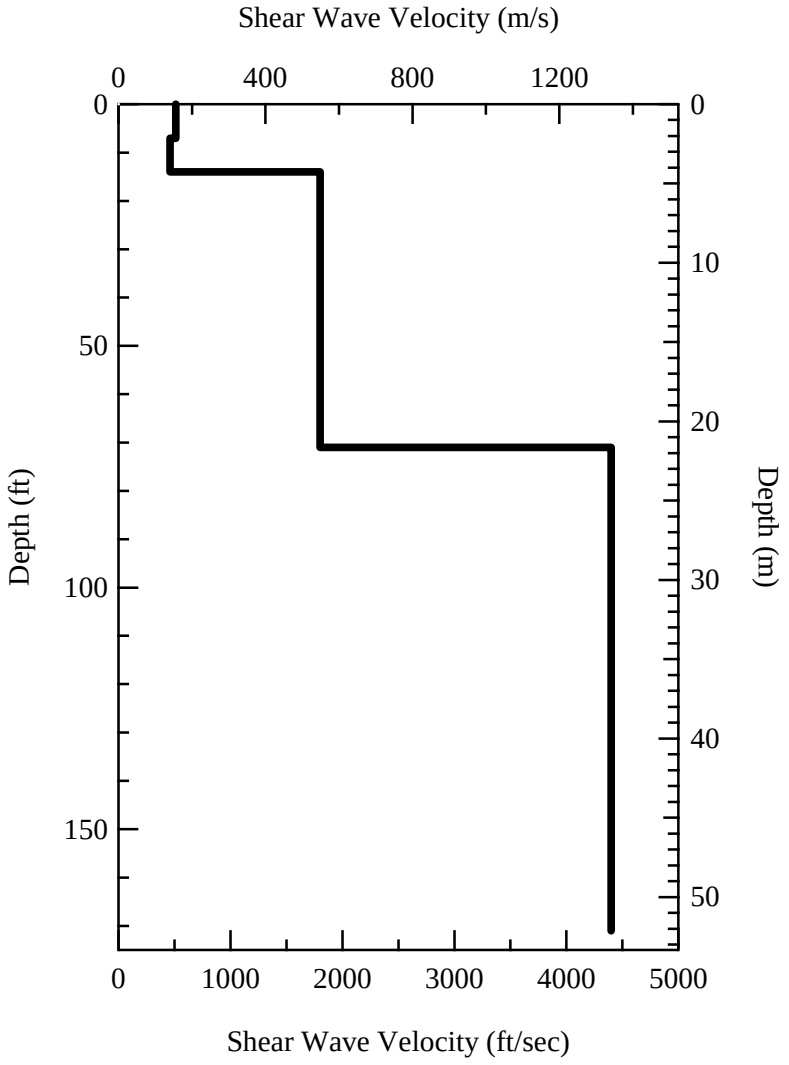


Figure 93 Shear wave velocity profile for Site 23, Interpretation 1 (Sam's Club).

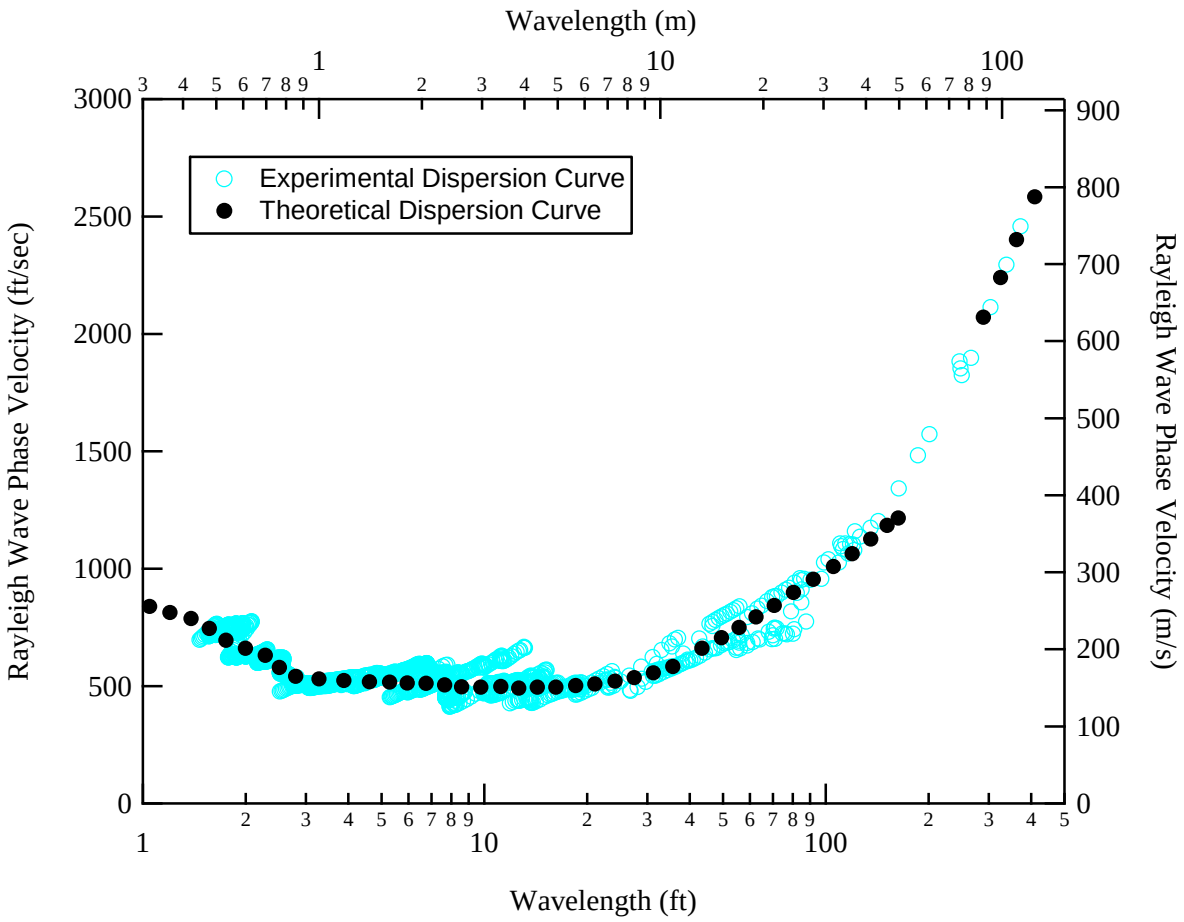


Figure 94 Experimental and theoretical dispersion data at Site 23 Interpretation 2 (Sam's Club).

Table 35 Final forward modeling soil profile for Site 23 Interpretation 2 (Sam's Club).

Layer No.	Thickness (m)	Depth to bottom (m)	P-wave velocity (m/s)	Shear wave velocity (m/s)	Poisson's Ratio	Unit Weight (kN/m^3)	Vs 30 Site Class (m/s)
1	2.1	2.1	290	160	0.30	16	354
2	2.1	4.2	260	140	0.30	16	
3	15.8	20.0	630	340	0.30	17	D
4	36.6	56.6	2060	1040	0.33	19	

Note: maximum depth of profile is approximately equal to maximum experimental wavelength/two.

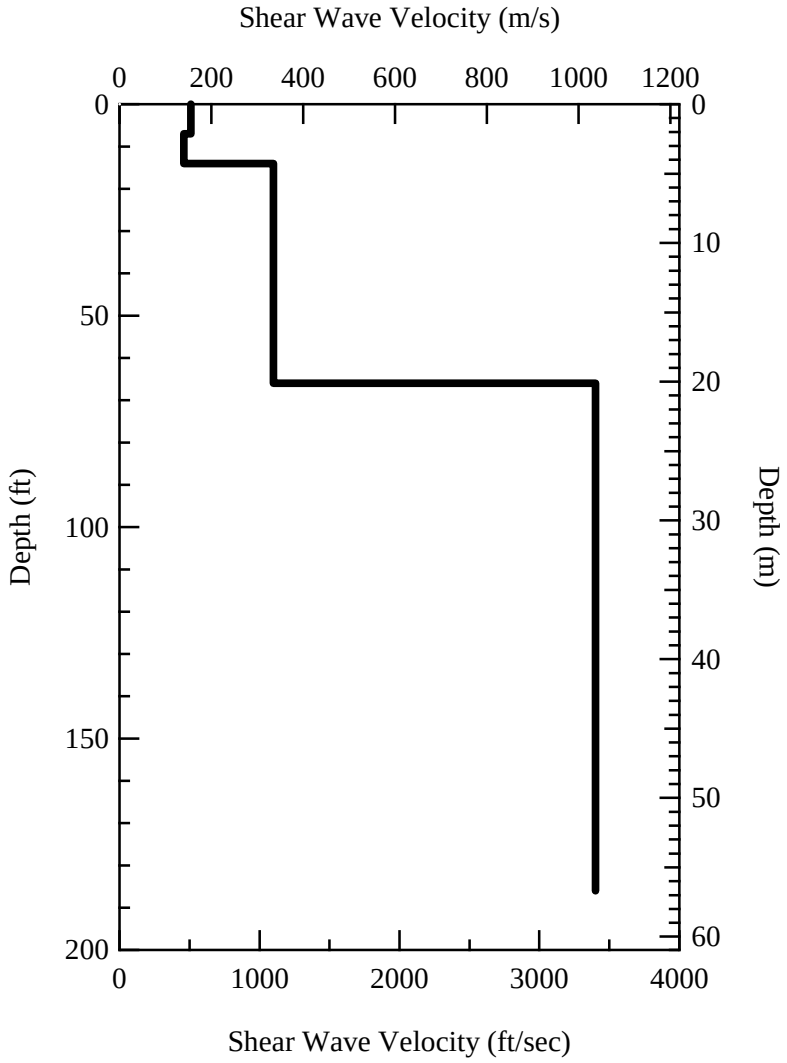


Figure 95 Shear wave velocity profile for Site 23 Interpretation 2 (Sam's Club).

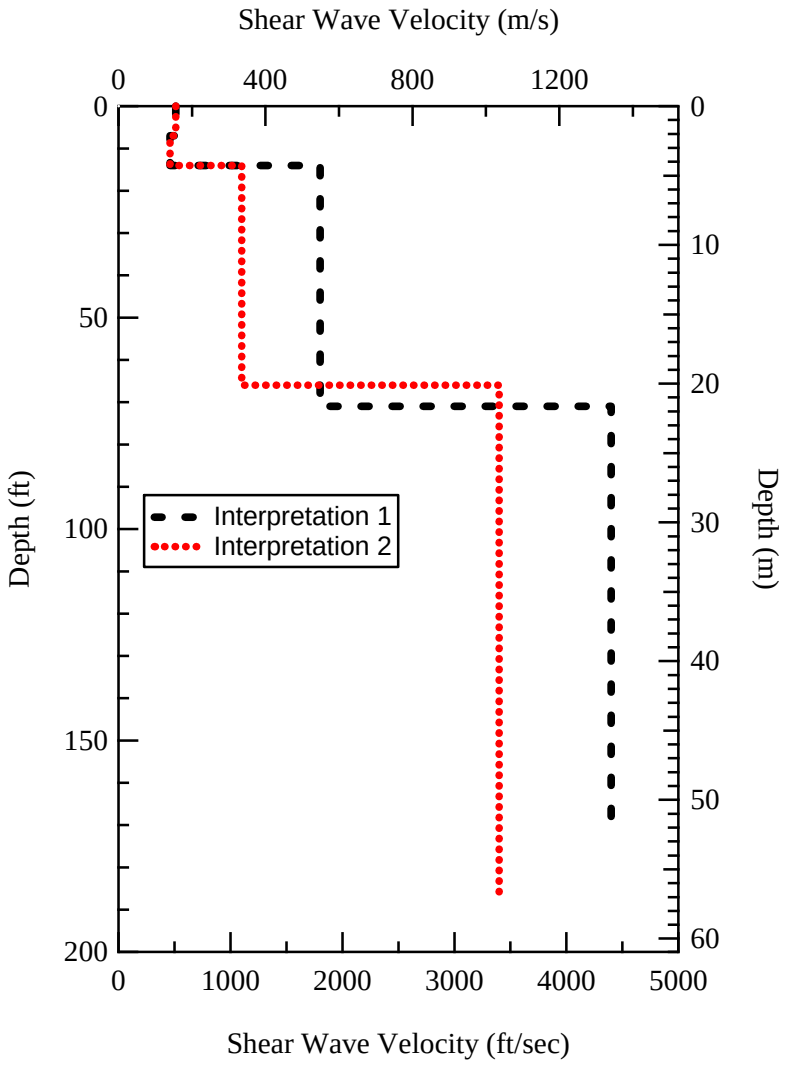


Figure 96 Comparison of shear wave velocity profiles at Site 23 (Sam's Club)

Site 24: Sears

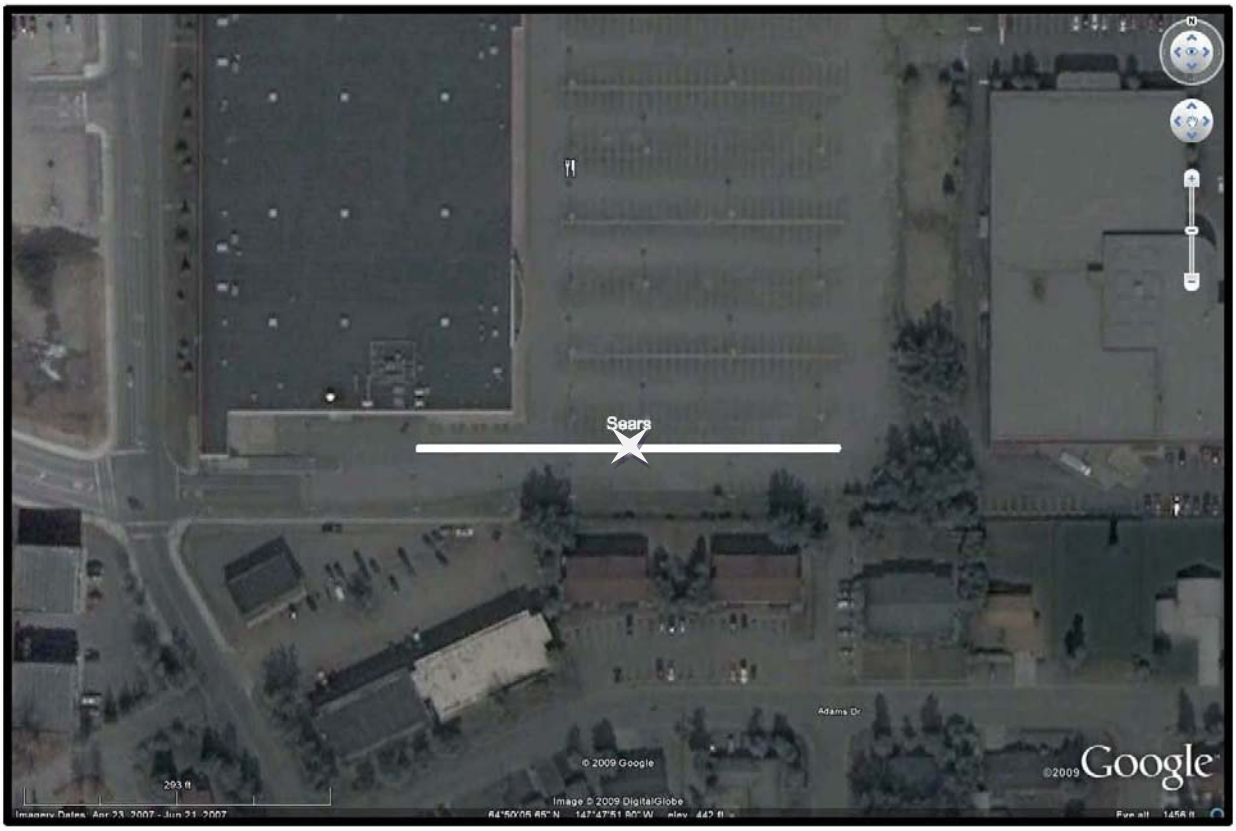


Figure 97 SASW Array location map for Site 24 (Sears).

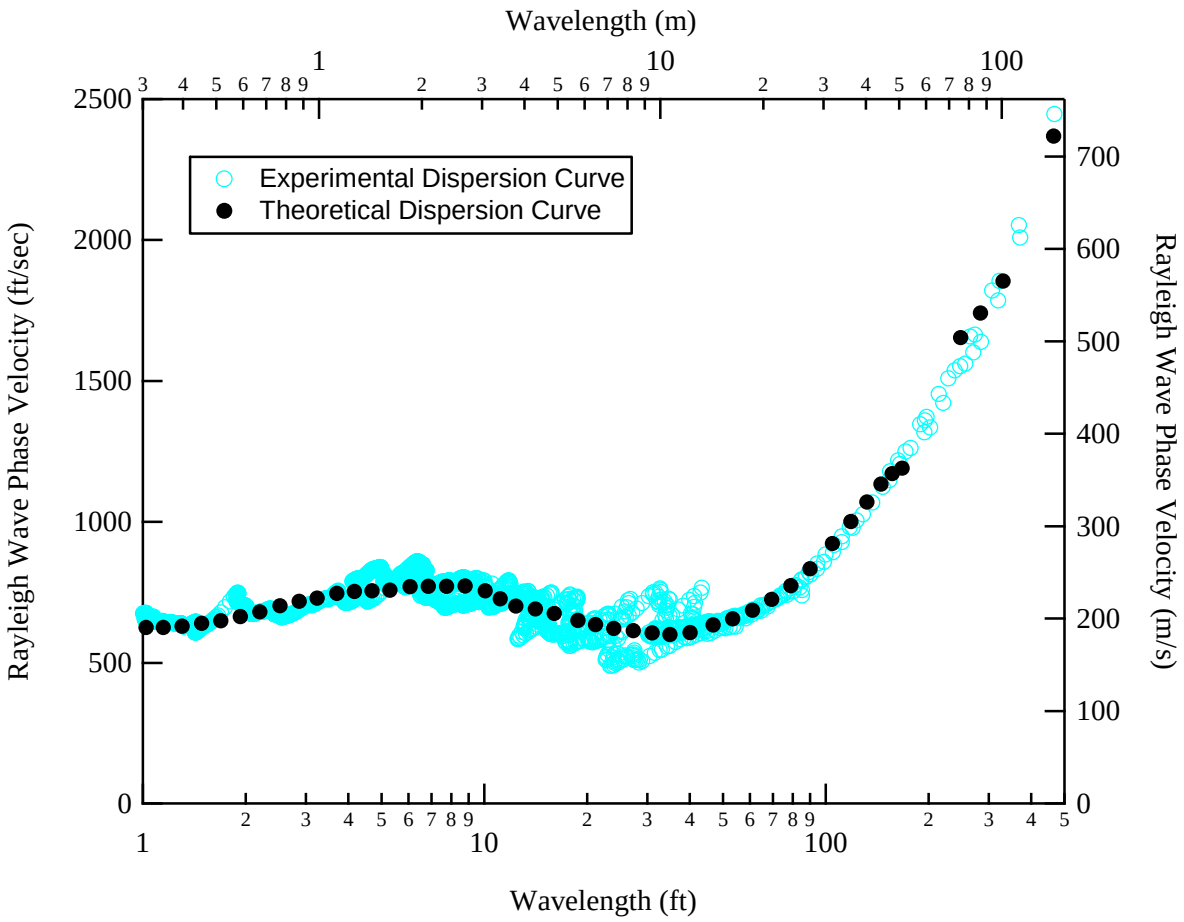


Figure 98 Experimental and theoretical dispersion data at Site 24 (Sears).

Table 36 Final forward modeling soil profile for Site 24 (Sears).

Layer No.	Thickness (m)	Depth to bottom (m)	P-wave velocity (m/s)	Shear wave velocity (m/s)	Poisson's Ratio	Unit Weight (kN/m^3)	Vs 30 Site Class (m/s)
1	0.3	0.3	380	200	0.30	16	344
2	2.4	2.7	480	260	0.30	17	
3	2.4	5.1	260	140	0.30	16	
4	4.9	10.0	440	230	0.30	17	D
5	9.1	19.1	800	430	0.30	18	
6	41.8	60.9	1230	620	0.33	19	

Note: maximum depth of profile is approximately equal to maximum experimental wavelength/two.

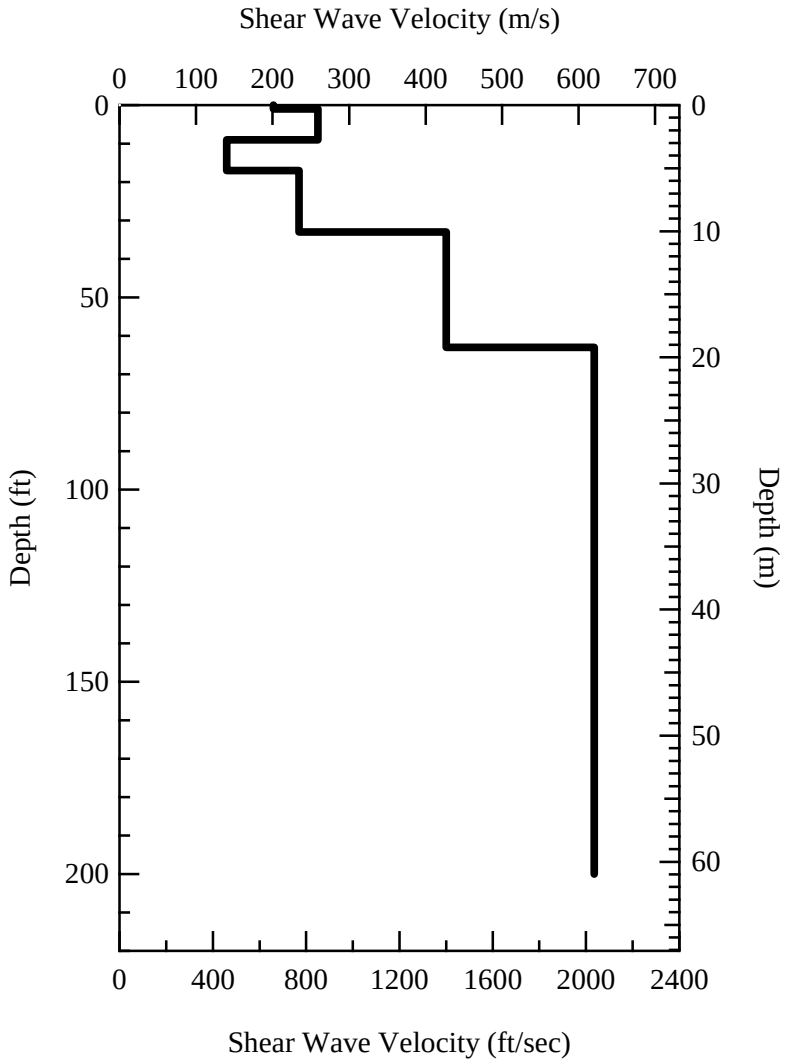


Figure 99 Shear wave velocity profile for Site 24 (Sears).

Site 25: Shell Street

Figure 100 SASW Array location map for Site 25 (Shell Street).

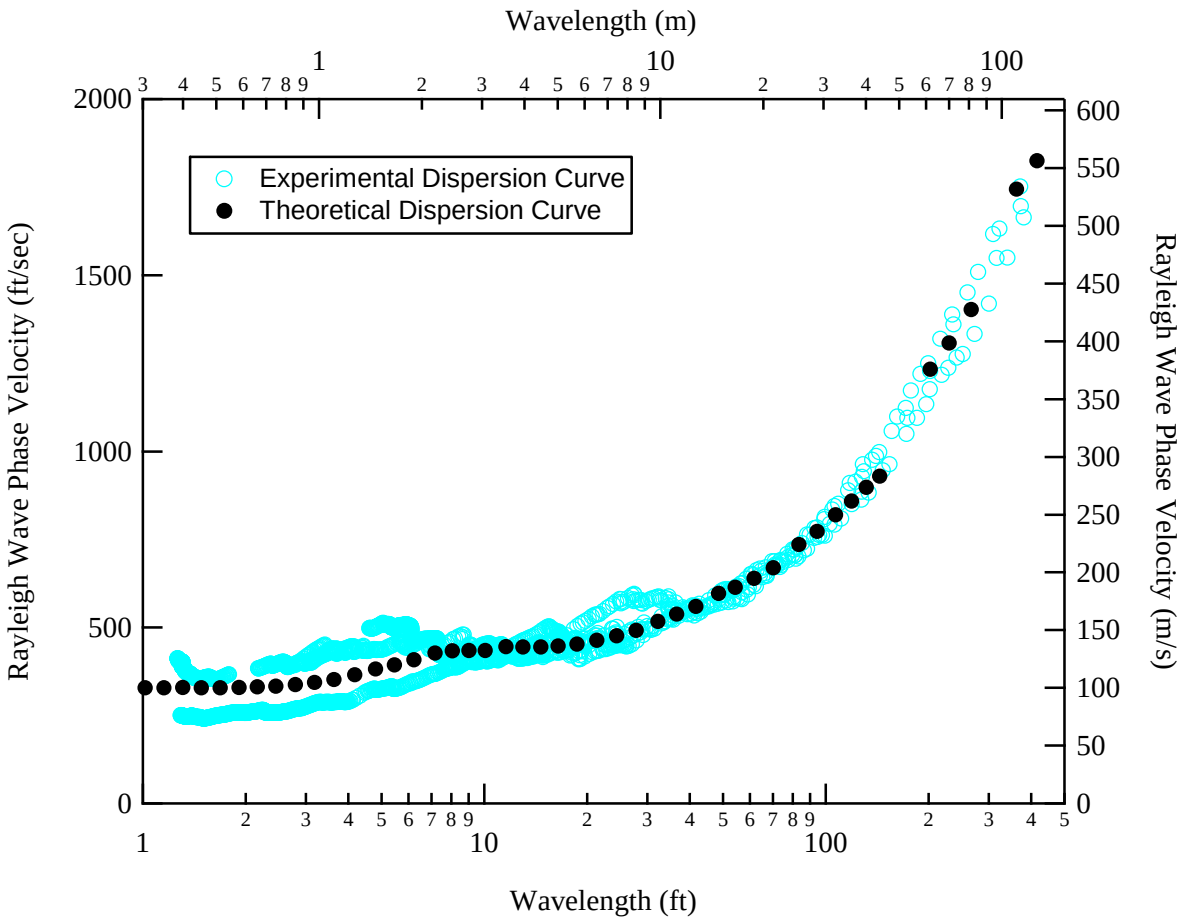


Figure 101 Experimental and theoretical dispersion data at Site 25 (Shell Street).

Table 37 Final forward modeling soil profile for Site 25 (Shell Street).

Layer No.	Thickness (m)	Depth to bottom (m)	P-wave velocity (m/s)	Shear wave velocity (m/s)	Poisson's Ratio	Unit Weight (kN/m^3)	Vs 30 Site Class (m/s)
1	0.6	0.6	200	110	0.30	16	284
2	4.0	4.6	290	150	0.30	17	
3	9.1	13.7	430	230	0.30	17	D
4	42.7	56.4	940	470	0.33	18	

Note: maximum depth of profile is approximately equal to maximum experimental wavelength/two.

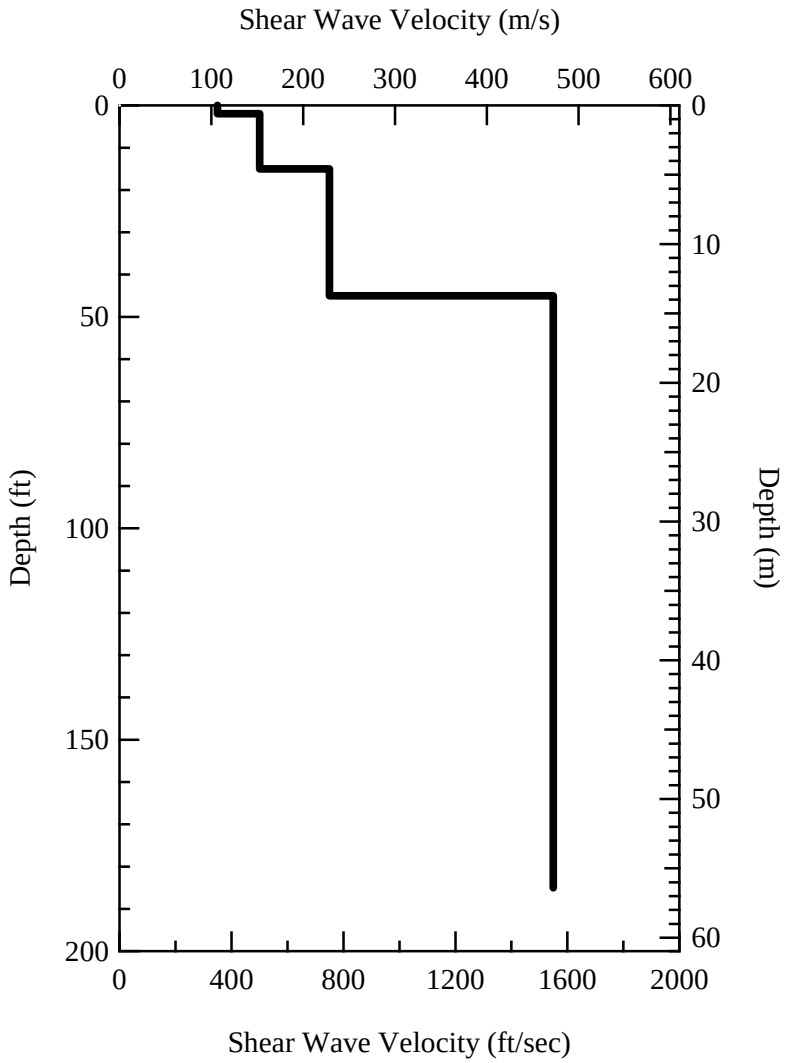


Figure 102 Shear wave velocity profile for Site 25 (Shell Street).

Site 26: Tanana Middle School

Figure 103 SASW Array location map for Site 26 (Tanana Middle School).

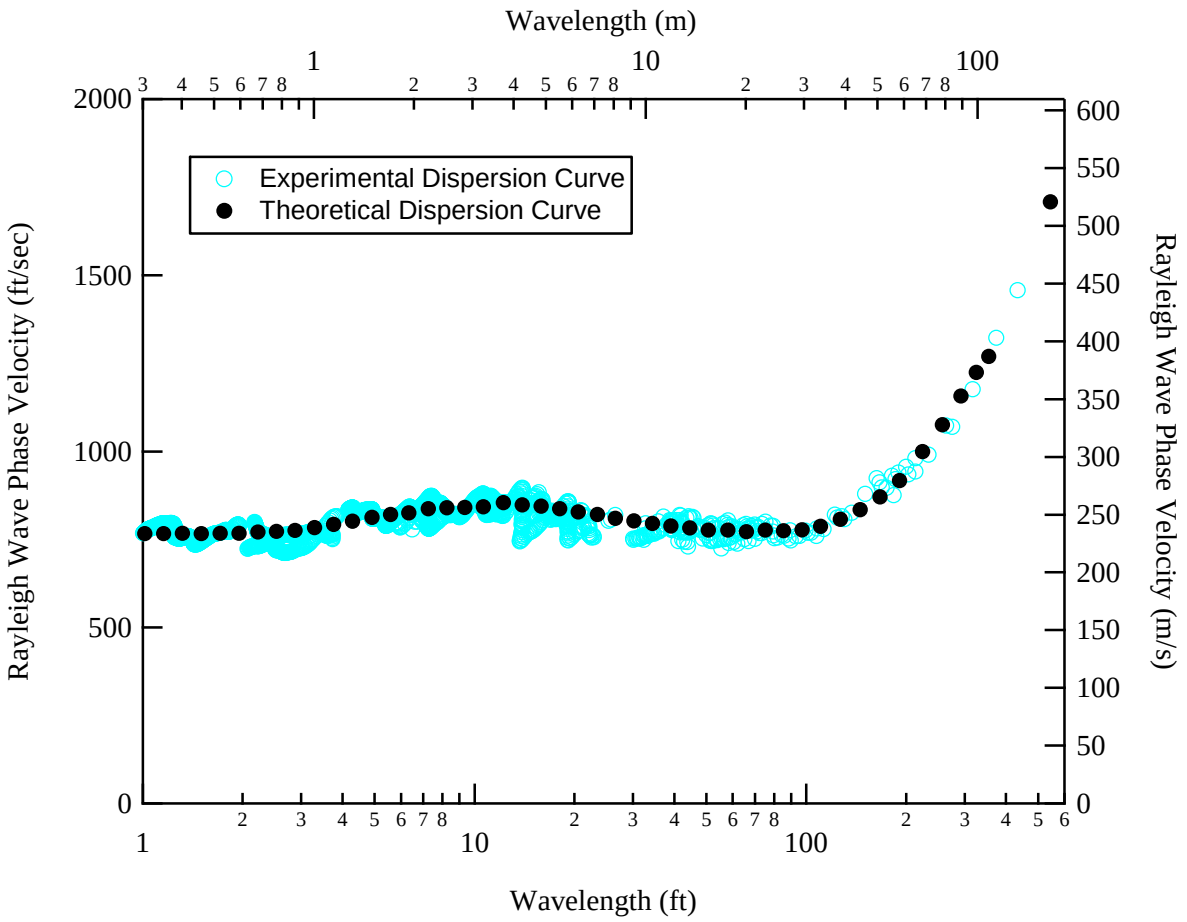


Figure 104 Experimental and theoretical dispersion data at Site 26 (Tanana Middle School).

Table 38 Final forward modeling soil profile for Site 26 (Tanana Middle School).

Layer No.	Thickness (m)	Depth to bottom (m)	P-wave velocity (m/s)	Shear wave velocity (m/s)	Poisson's Ratio	Unit Weight (kN/m^3)	Vs 30 Site Class (m/s)
1	0.6	0.6	460	250	0.30	17	262
2	3.0	3.6	530	280	0.30	17	
3	18.3	21.9	460	240	0.30	17	D
4	9.1	31.0	590	300	0.32	18	
5	39.1	61.0	1210	610	0.33	19	

Note: maximum depth of profile is approximately equal to maximum experimental wavelength/two.

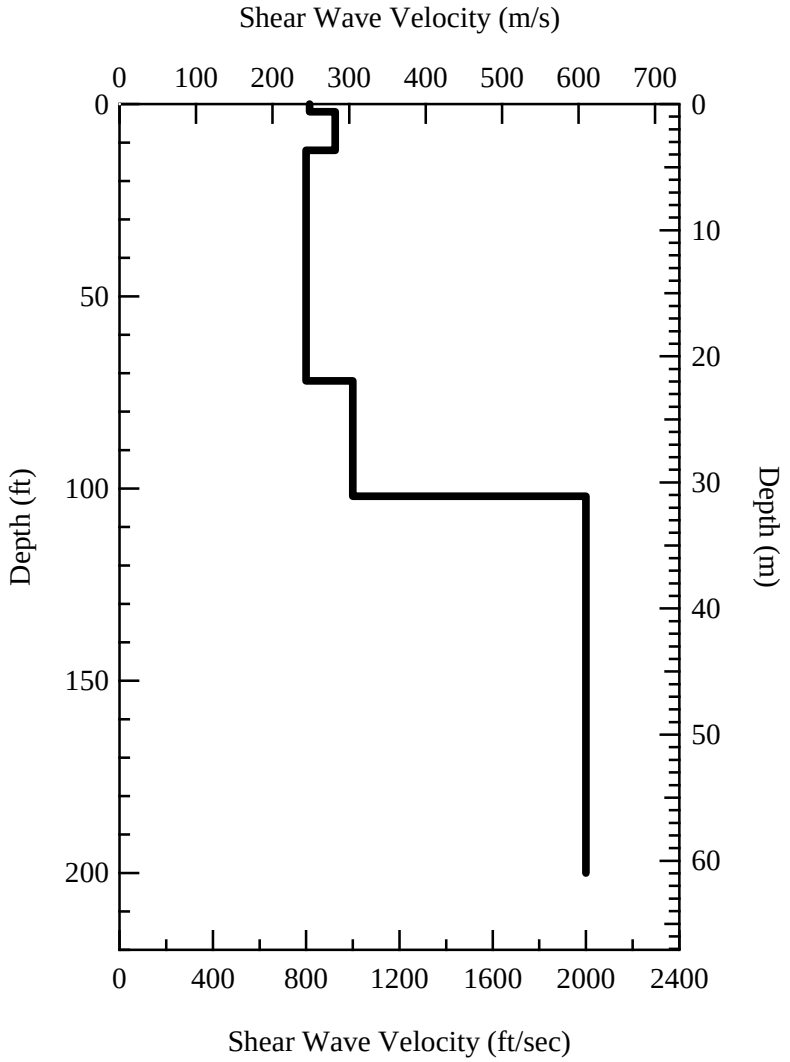


Figure 105 Shear wave velocity profile for Site 26 (Tanana Middle School).

Site 27: UAF Farm

Figure 106 SASW Array location map for Site 27 (UAF Farm).

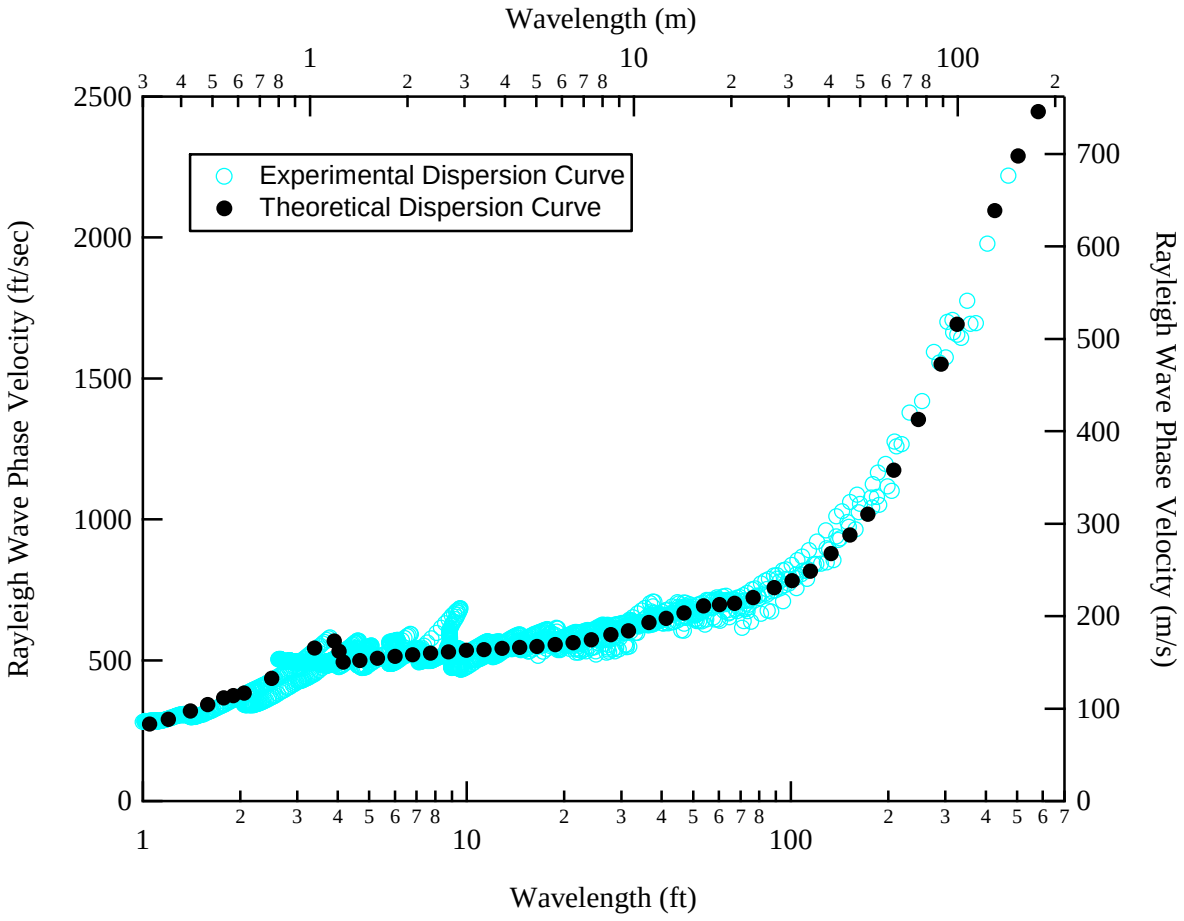


Figure 107 Experimental and theoretical dispersion data at Site 27 (UAF Farm).

Table 39 Final forward modeling soil profile for Site 27 (UAF Farm).

Layer No.	Thickness (m)	Depth to bottom (m)	P-wave velocity (m/s)	Shear wave velocity (m/s)	Poisson's Ratio	Unit Weight (kN/m^3)	Vs 30 Site Class (m/s)
1	0.2	0.2	140	70	0.30	16	302
2	4.6	4.8	340	180	0.30	17	
3	15.2	20.0	460	250	0.30	18	D
4	41.0	61.0	1690	850	0.33	19	

Note: maximum depth of profile is approximately equal to maximum experimental wavelength/two.

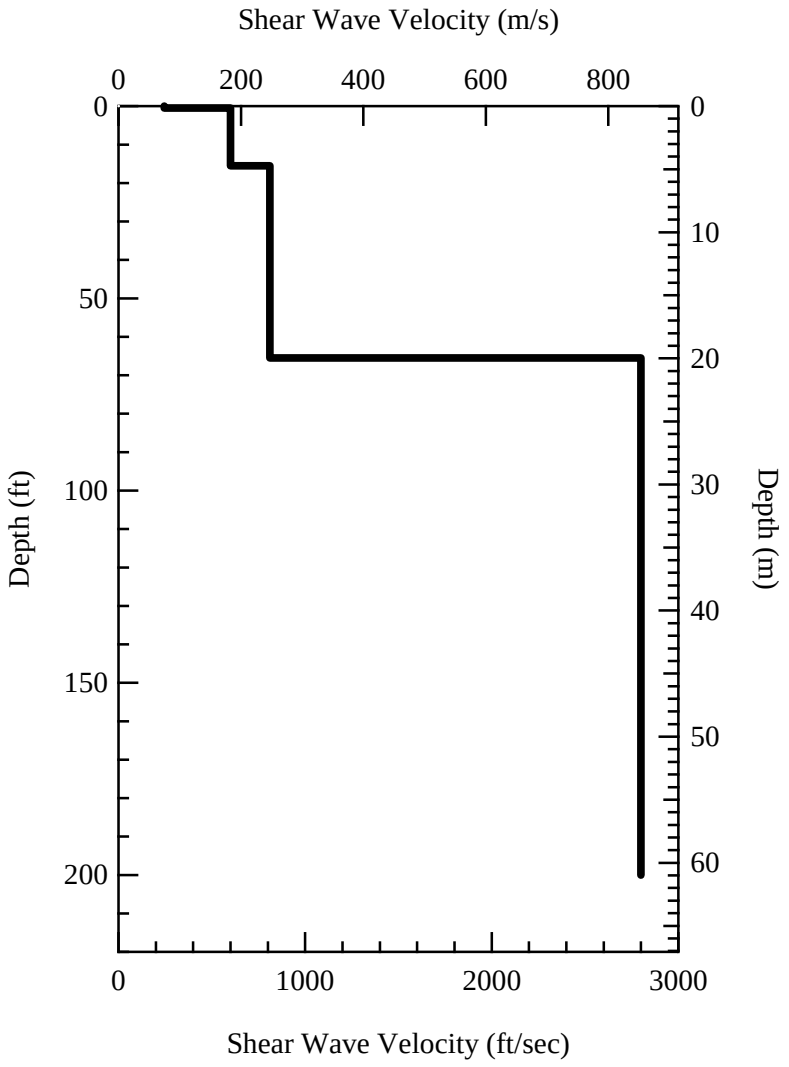


Figure 108 Shear wave velocity profile for Site 27 (UAF Farm).

Site 28: WestValley High School

Figure 109 SASW Array location map for Site 28 (West Valley High School).

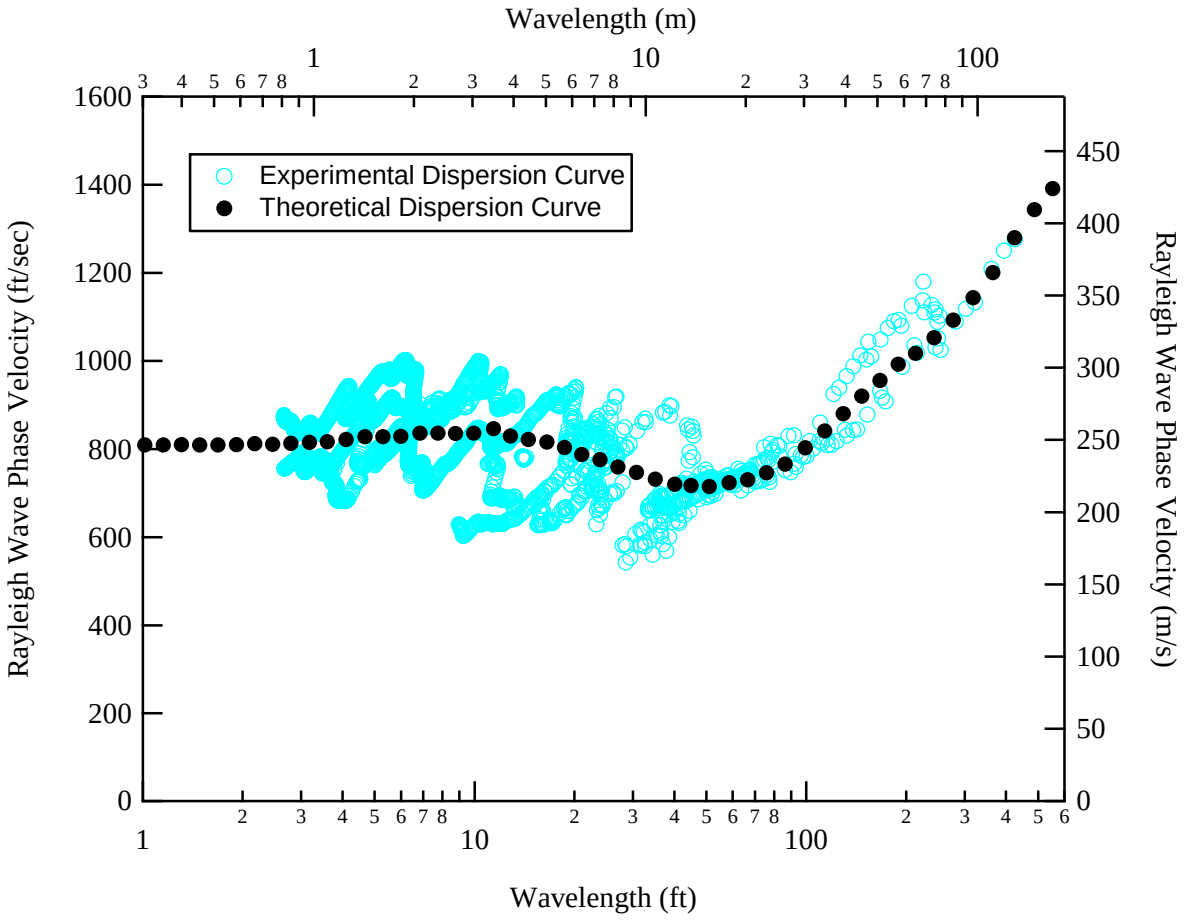


Figure 110 Experimental and theoretical dispersion data at Site 28 (West Valley High School).

Table 40 Final forward modeling soil profile for Site 28 (West Valley High School).

Layer No.	Thickness (m)	Depth to bottom (m)	P-wave velocity (m/s)	Shear wave velocity (m/s)	Poisson's Ratio	Unit Weight (kN/m^3)	Vs 30 Site Class (m/s)
1	0.6	0.6	490	260	0.30	17	286
2	3.0	3.6	510	270	0.30	17	
3	9.1	12.7	400	210	0.30	16	D
4	36.6	49.3	680	350	0.32	18	
5	11.7	61.0	1000	500	0.33	19	

Note: maximum depth of profile is approximately equal to maximum experimental wavelength/two.

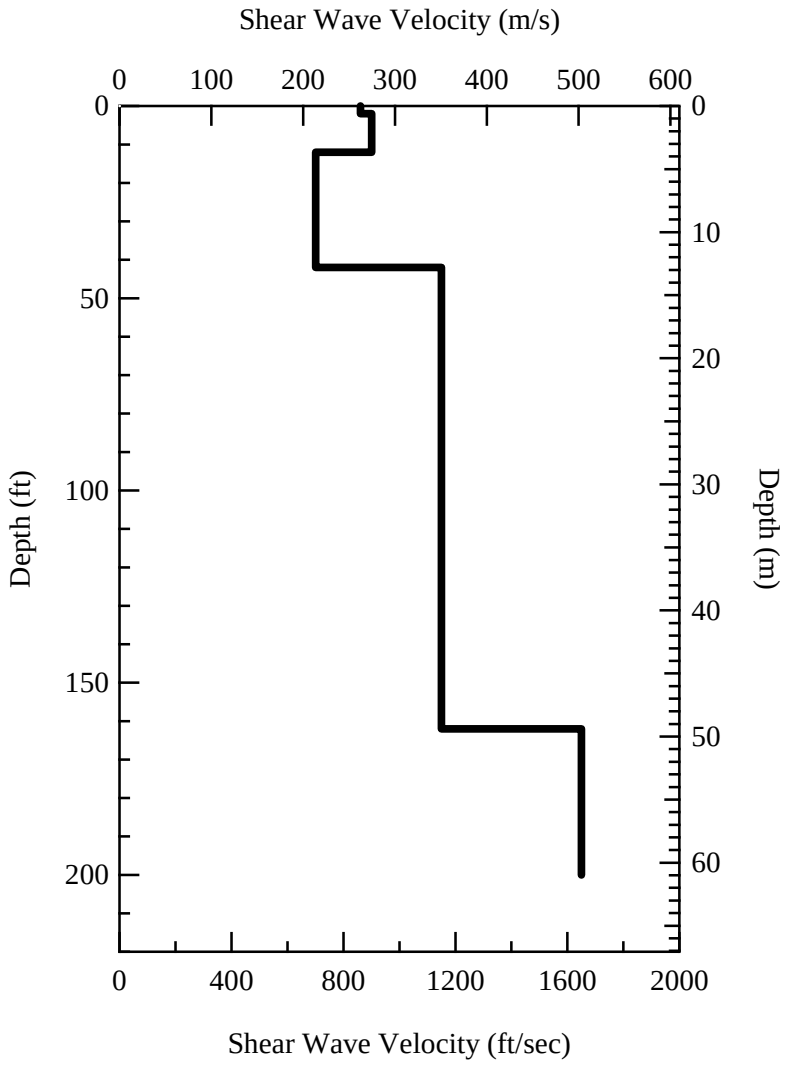


Figure 111 Shear wave velocity profile for Site 28 (West Valley High School).

Site 29: WRRC (West Ridge Research Center)

Figure 112 SASW Array location map for Site 29 (WRRC).

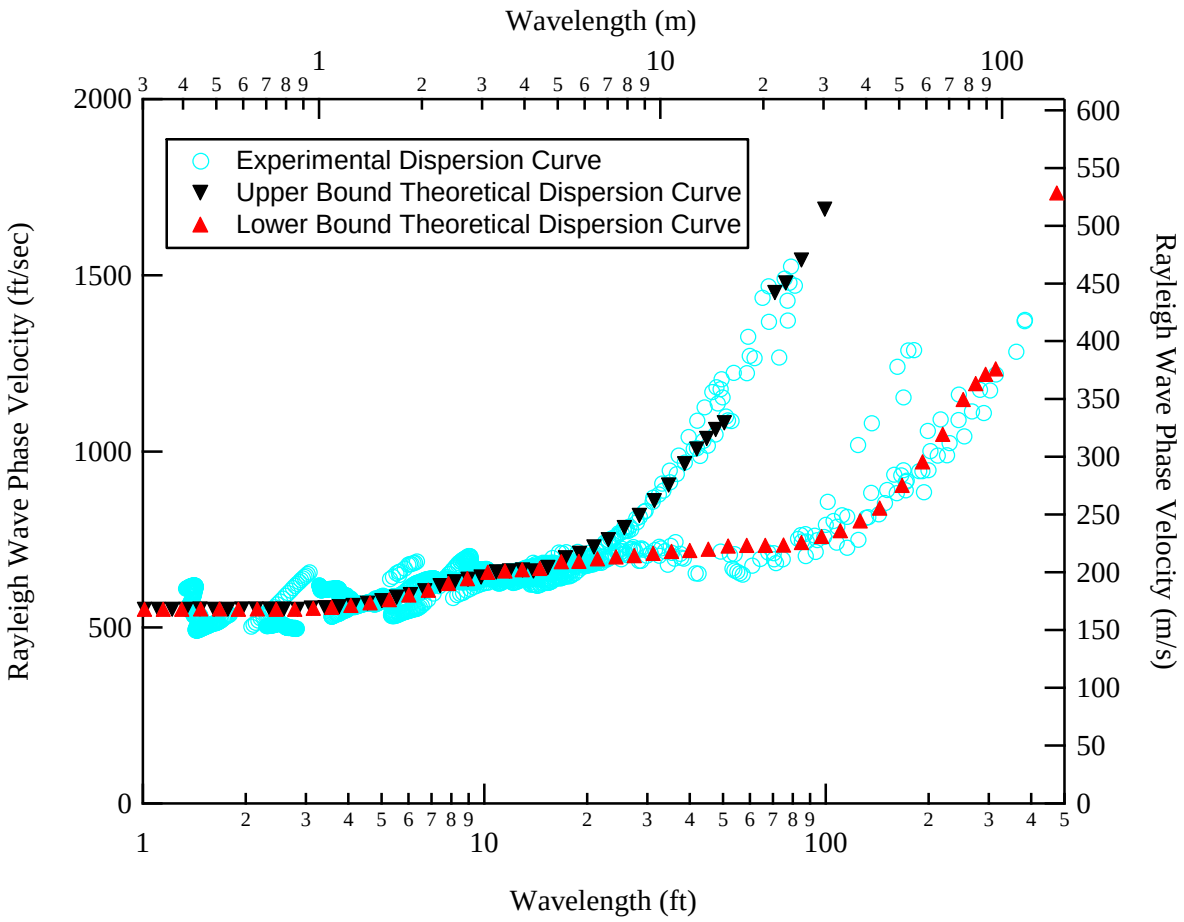


Figure 113 Experimental and theoretical dispersion data for Array #1 at Site 29 (WRRC).

Table 41 Final forward modeling soil profile for Array #1, Site 29 Upper Bound (WRRC).

Layer No.	Thickness (m)	Depth to bottom (m)	P-wave velocity (m/s)	Shear wave velocity (m/s)	Poisson's Ratio	Unit Weight (kN/m^3)	Vs 30 Site Class (m/s)
1	0.9	0.9	330	180	0.30	16	435
2	3.2	4.1	420	230	0.30	17	
3	8.2	12.3	1030	520	0.33	19	C

Note: maximum depth of profile is approximately equal to maximum experimental wavelength/two.

Table 42 Final forward modeling soil profile for Array #1, Site 29 Lower Bound (WRRC).

Layer No.	Thickness (m)	Depth to bottom (m)	P-wave velocity (m/s)	Shear wave velocity (m/s)	Poisson's Ratio	Unit Weight (kN/m^3)	Vs 30 Site Class (m/s)
1	0.9	0.9	330	180	0.30	16	269
2	2.7	3.6	420	230	0.30	17	
3	19.8	23.4	460	240	0.30	18	D
4	34.4	57.8	940	470	0.33	19	

Note: maximum depth of profile is approximately equal to maximum experimental wavelength/two.

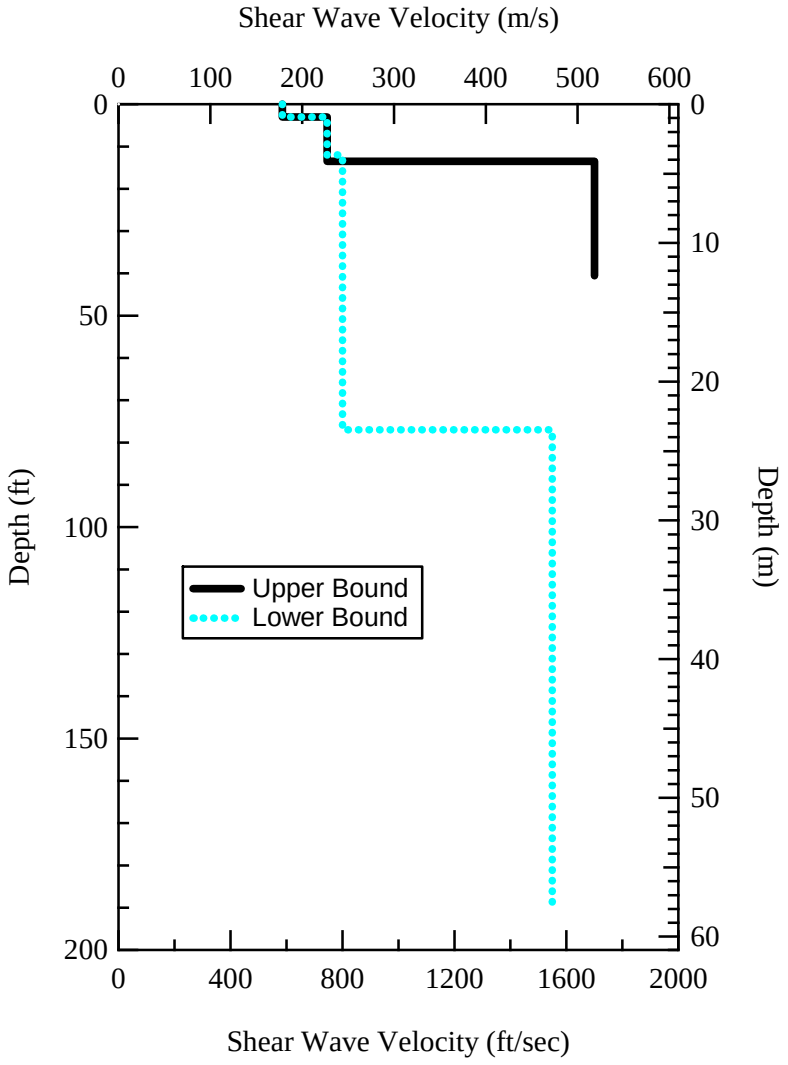


Figure 114 Shear wave velocity profile for Array #1 at Site 29 (WRRC).

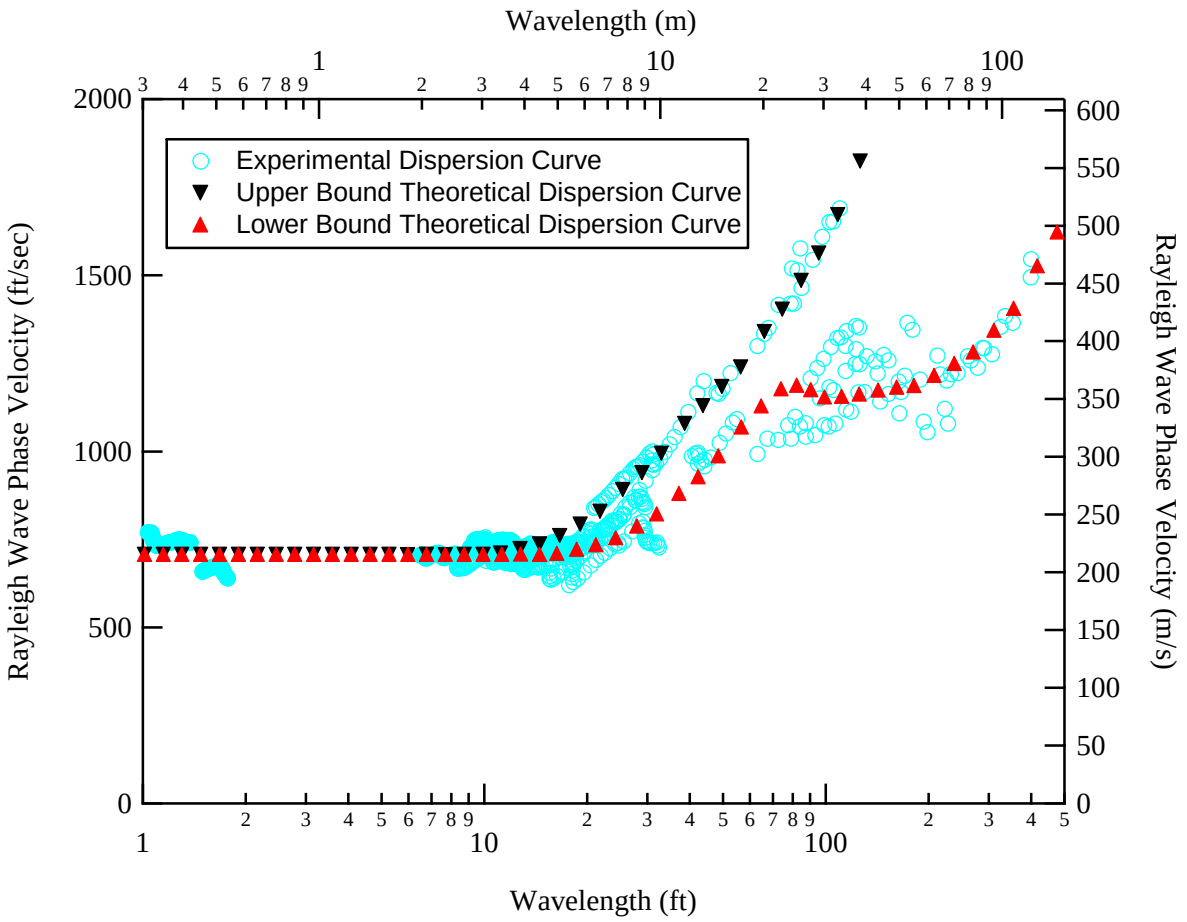


Figure 115 Experimental and theoretical dispersion data for Array #2 at Site 29 (WRRC).

Table 43 Final forward modeling soil profile for Array #2 Site 29 Upper Bound (WRRC).

Layer No.	Thickness (m)	Depth to bottom (m)	P-wave velocity (m/s)	Shear wave velocity (m/s)	Poisson's Ratio	Unit Weight (kN/m^3)	Vs 30 Site Class (m/s)
1	3.0	3.0	430	230	0.30	17	527
2	7.6	10.6	770	410	0.30	18	
3	6.1	16.7	1510	760	0.33	19	C

Note: maximum depth of profile is approximately equal to maximum experimental wavelength/two.

Table 44 Final forward modeling soil profile for Array #2 Site 29 Lower Bound (WRRC).

Layer No.	Thickness (m)	Depth to bottom (m)	P-wave velocity (m/s)	Shear wave velocity (m/s)	Poisson's Ratio	Unit Weight (kN/m^3)	Vs 30 Site Class (m/s)
1	4.6	4.6	430	230	0.30	17	281
2	48.8	53.4	770	410	0.30	18	
3	7.6	61.0	1510	760	0.33	19	D

Note: maximum depth of profile is approximately equal to maximum experimental wavelength/two.

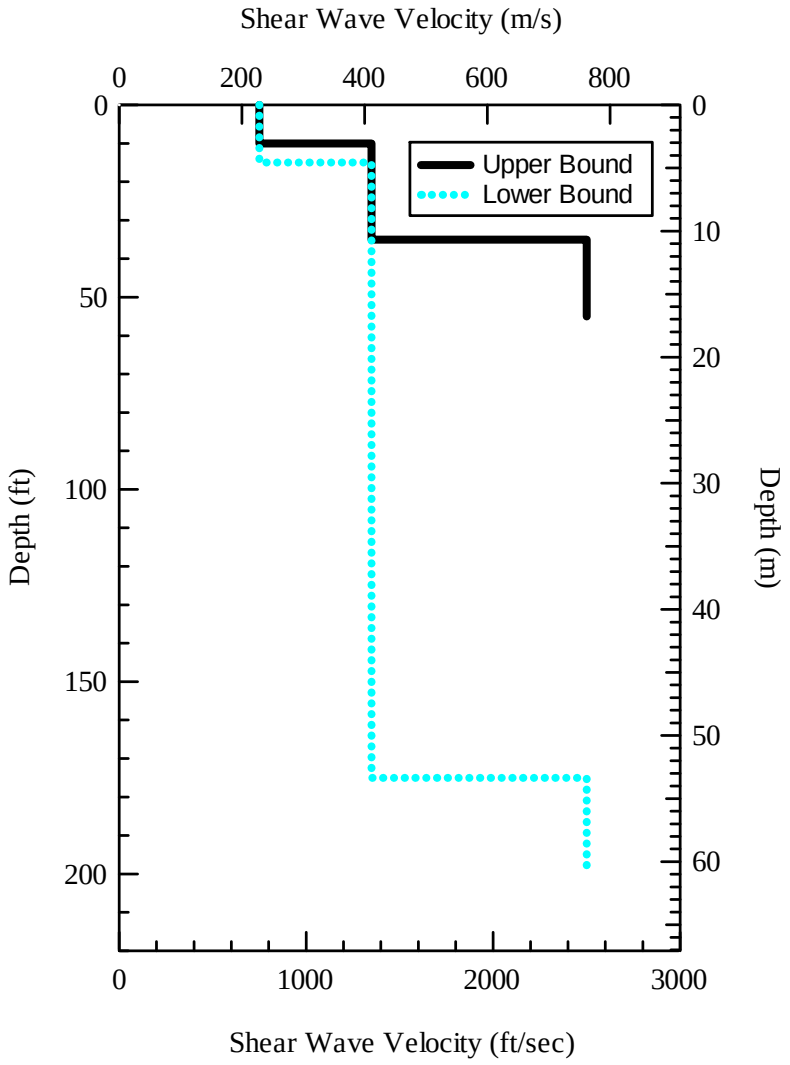


Figure 116 Shear wave velocity profile for Array #2 at Site 29 (WRRC).

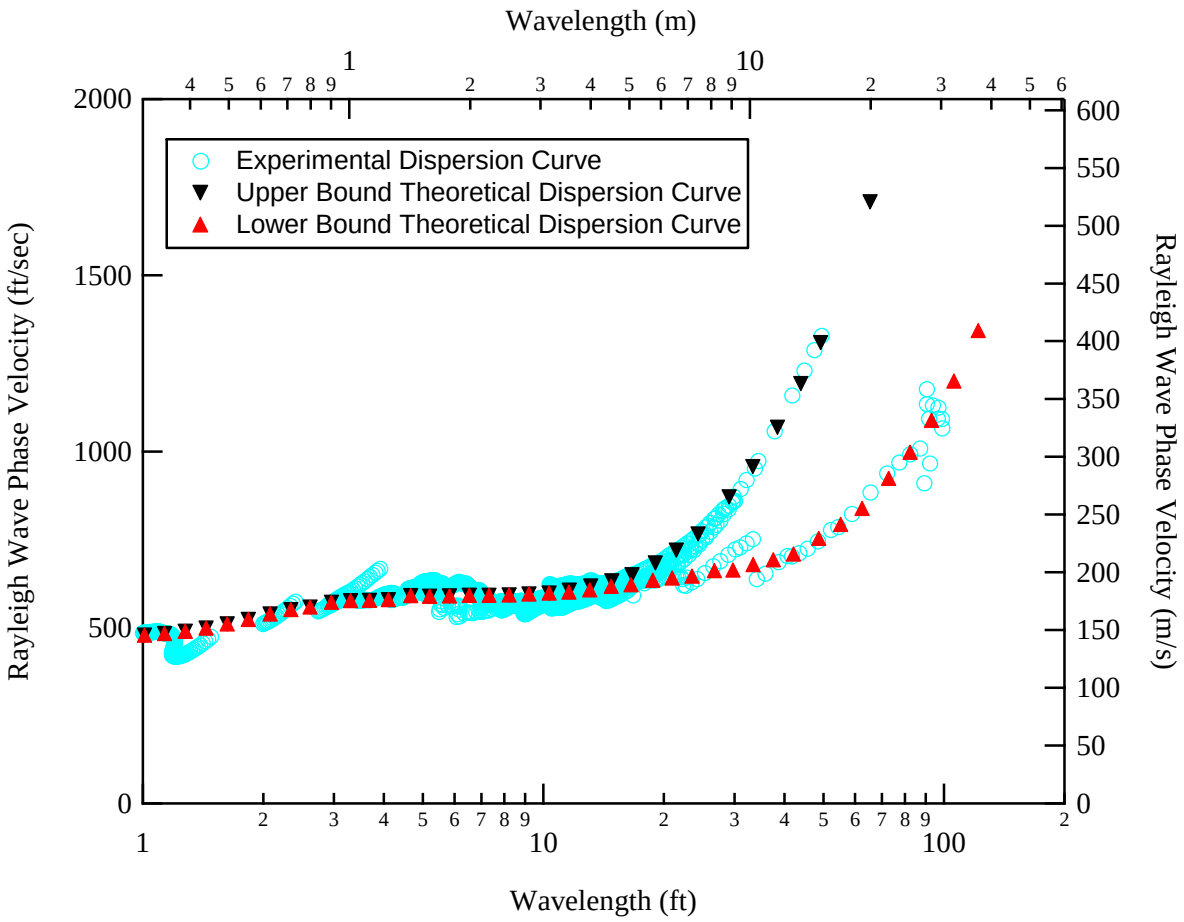


Figure 117 Experimental and theoretical dispersion data for Array #3 at Site 29 (WRRC).

Table 45 Final forward modeling soil profile for Array #3 Site 29 Upper Bound (WRRC).

Layer No.	Thickness (m)	Depth to bottom (m)	P-wave velocity (m/s)	Shear wave velocity (m/s)	Poisson's Ratio	Unit Weight (kN/m^3)	Vs 30 Site Class (m/s)
1	0.2	0.2	290	150	0.30	16	578
2	2.4	2.6	370	200	0.30	17	
3	0.8	3.4	430	230	0.30	17	C
4	4.3	7.7	1510	760	0.33	19	

Note: maximum depth of profile is approximately equal to maximum experimental wavelength/two.

Table 46 Final forward modeling soil profile for Array #3, Site 29 Lower Bound (WRRC).

Layer No.	Thickness (m)	Depth to bottom (m)	P-wave velocity (m/s)	Shear wave velocity (m/s)	Poisson's Ratio	Unit Weight (kN/m^3)	Vs 30 Site Class (m/s)
1	0.2	0.2	290	150	0.30	16	439
2	2.4	2.6	370	200	0.30	17	
3	6.2	8.8	430	230	0.30	17	C
4	6.3	15.1	1510	760	0.33	19	

Note: maximum depth of profile is approximately equal to maximum experimental wavelength/two.

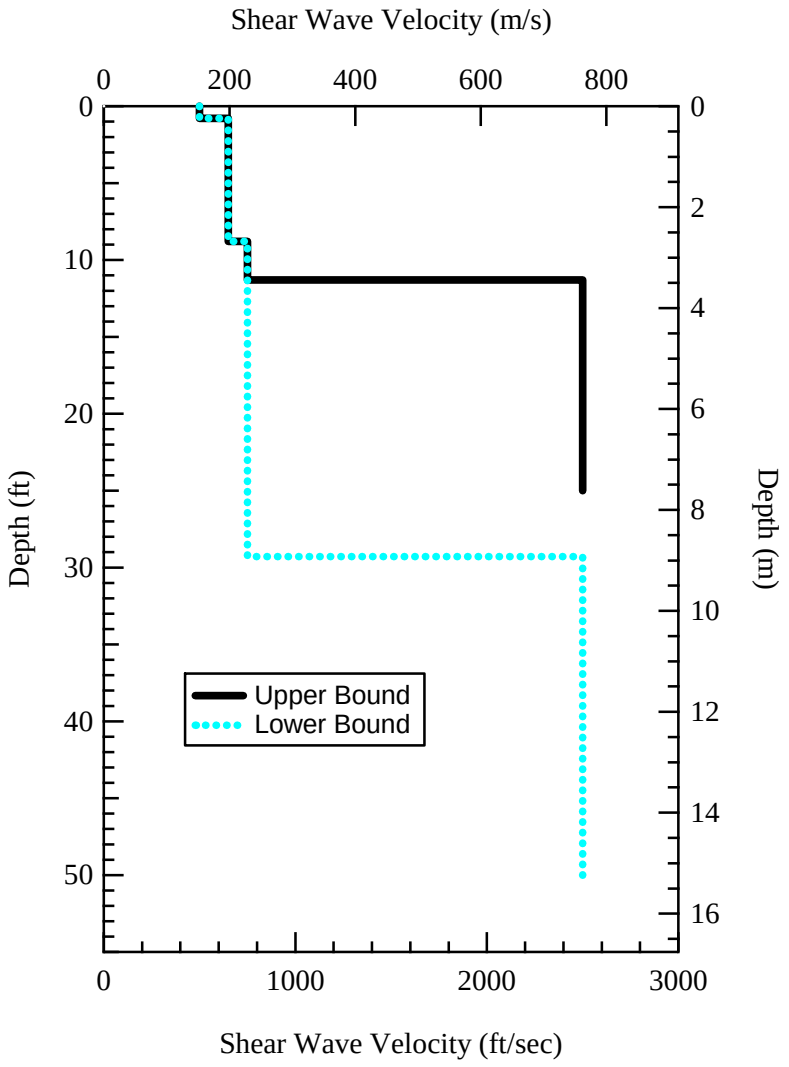


Figure 118 Shear wave velocity profile for Array #3 at Site 29 (WRRC).

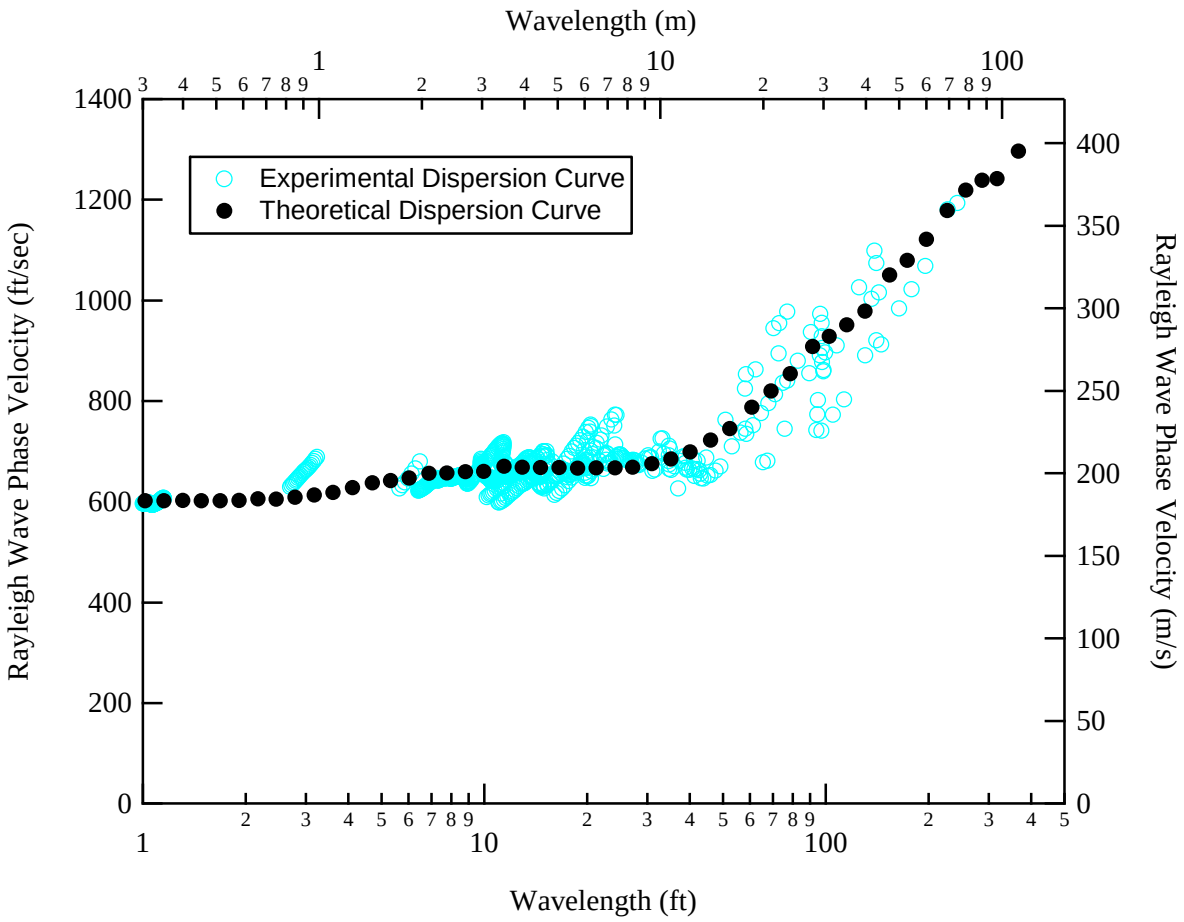


Figure 119 Experimental and theoretical dispersion data for Array #4 at Site 29 (WRRC).

Table 47 Final forward modeling soil profile for Array #4 at Site 29 (WRRC).

Layer No.	Thickness (m)	Depth to bottom (m)	P-wave velocity (m/s)	Shear wave velocity (m/s)	Poisson's Ratio	Unit Weight (kN/m^3)	Vs 30 Site Class (m/s)
1	0.6	0.6	360	200	0.30	16	304
2	7.3	7.9	410	220	0.30	17	
3	18.3	26.2	630	340	0.30	18	D
4	11.0	37.2	910	460	0.33	19	

Note: maximum depth of profile is approximately equal to maximum experimental wavelength/two.

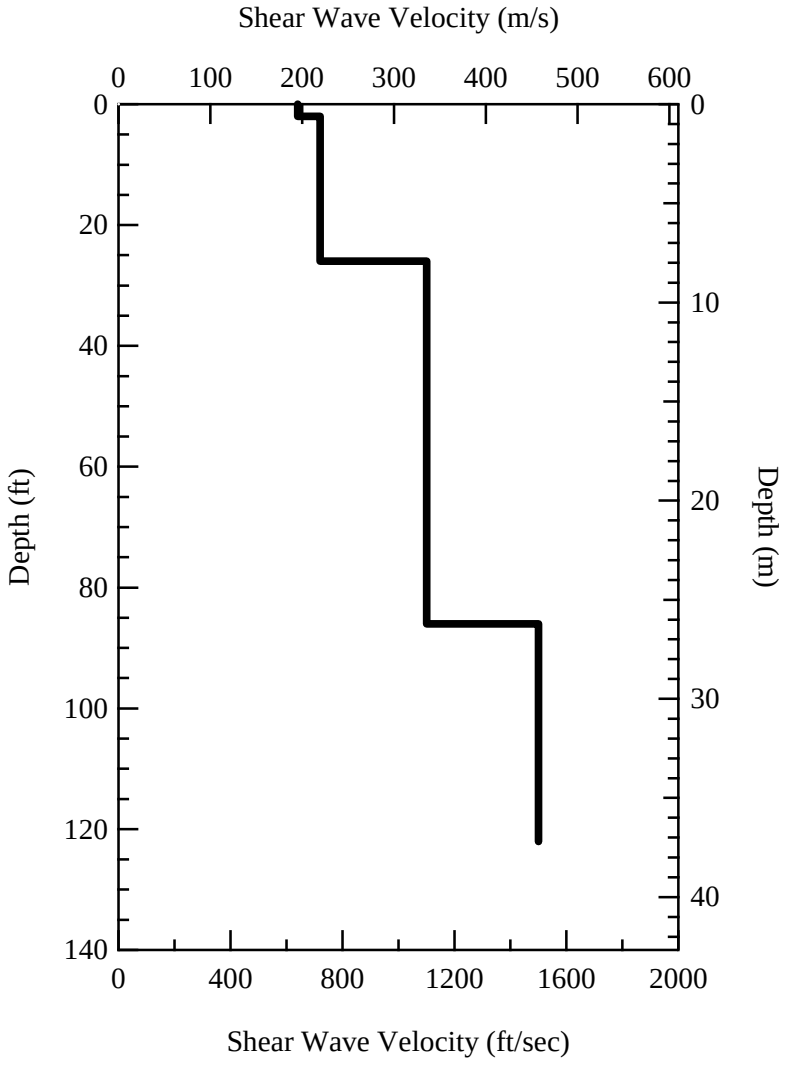


Figure 120 Shear wave velocity profile for Array #4 at Site 29 (WRRC).

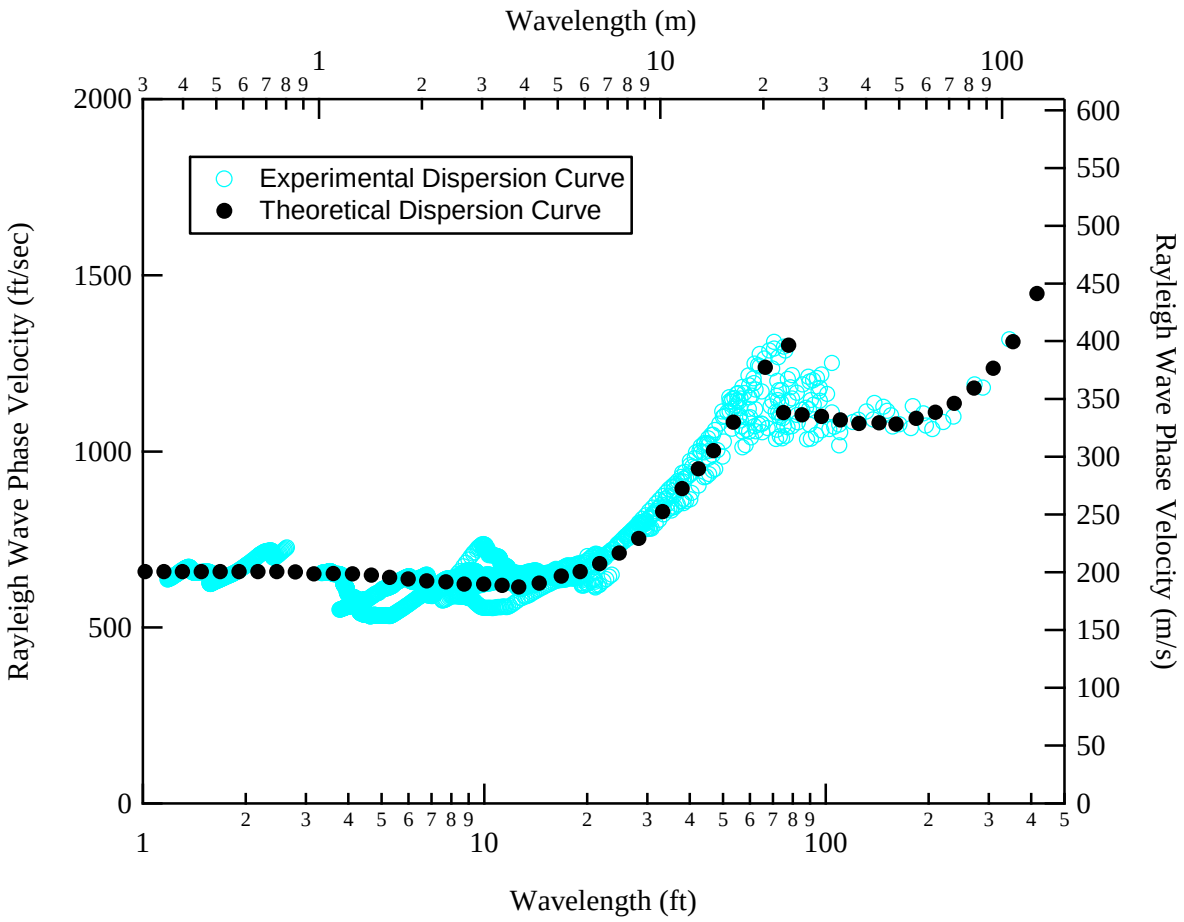


Figure 121 Experimental and theoretical dispersion data for Array #5 at Site 29 (WRRC).

Table 48 Final forward modeling soil profile for Array #5 at Site 29 (WRRC).

Layer No.	Thickness (m)	Depth to bottom (m)	P-wave velocity (m/s)	Shear wave velocity (m/s)	Poisson's Ratio	Unit Weight (kN/m^3)	Vs 30 Site Class (m/s)
1	0.9	0.9	400	210	0.30	17	341
2	2.7	3.6	370	200	0.30	17	
3	7.6	11.2	910	490	0.30	18	D
4	33.5	44.7	640	340	0.30	18	
5	8.5	53.2	1510	760	0.33	19	

Note: maximum depth of profile is approximately equal to maximum experimental wavelength/two.

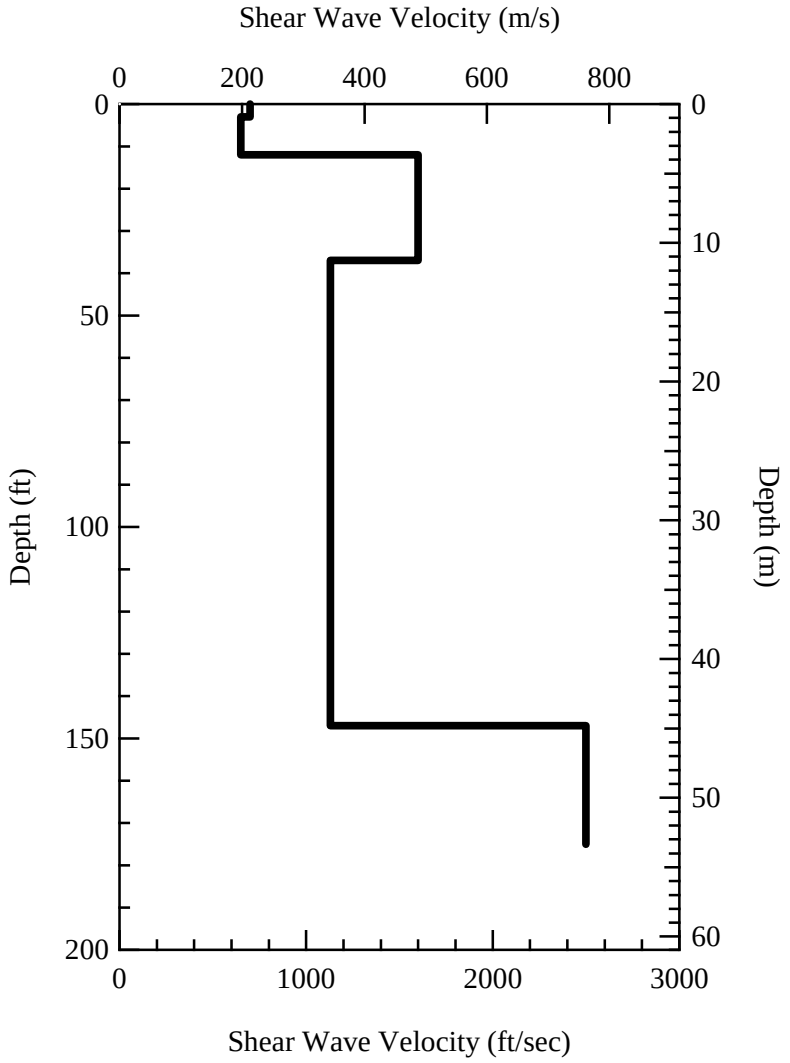


Figure 122 Shear wave velocity profile for Array #5 at Site 29 (WRRC).

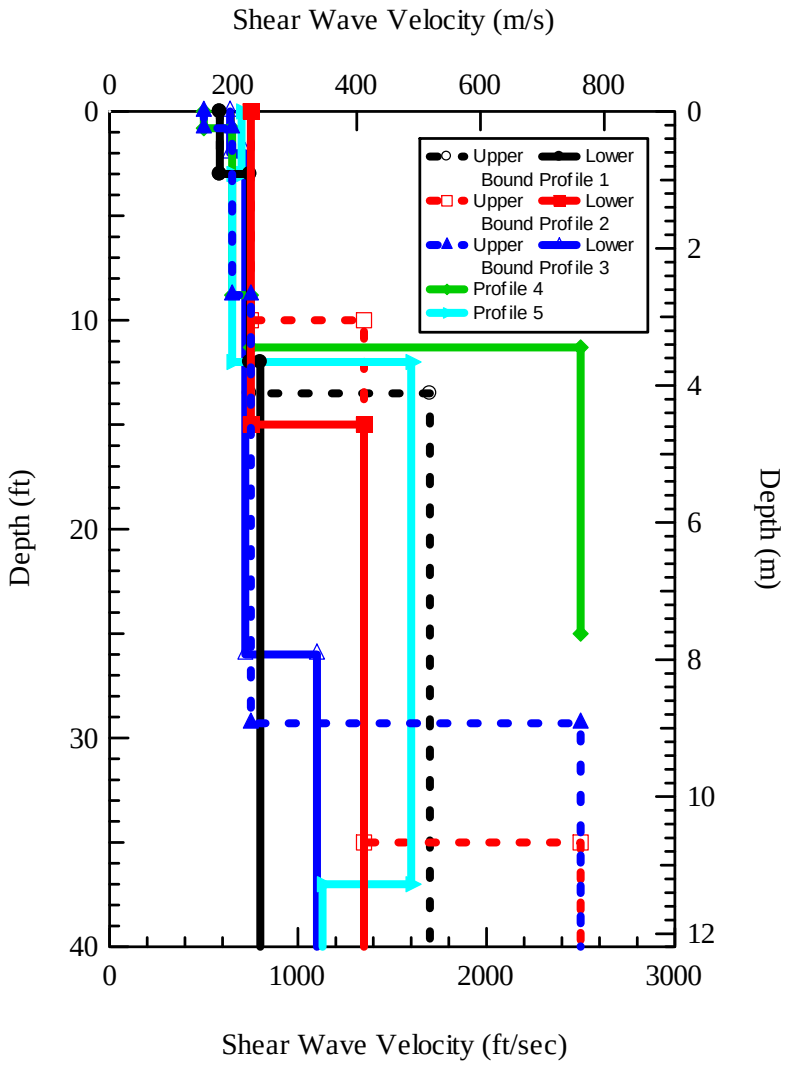


Figure 123 Shear wave velocity profile comparison for Site 29, 0-40ft (WRRC).

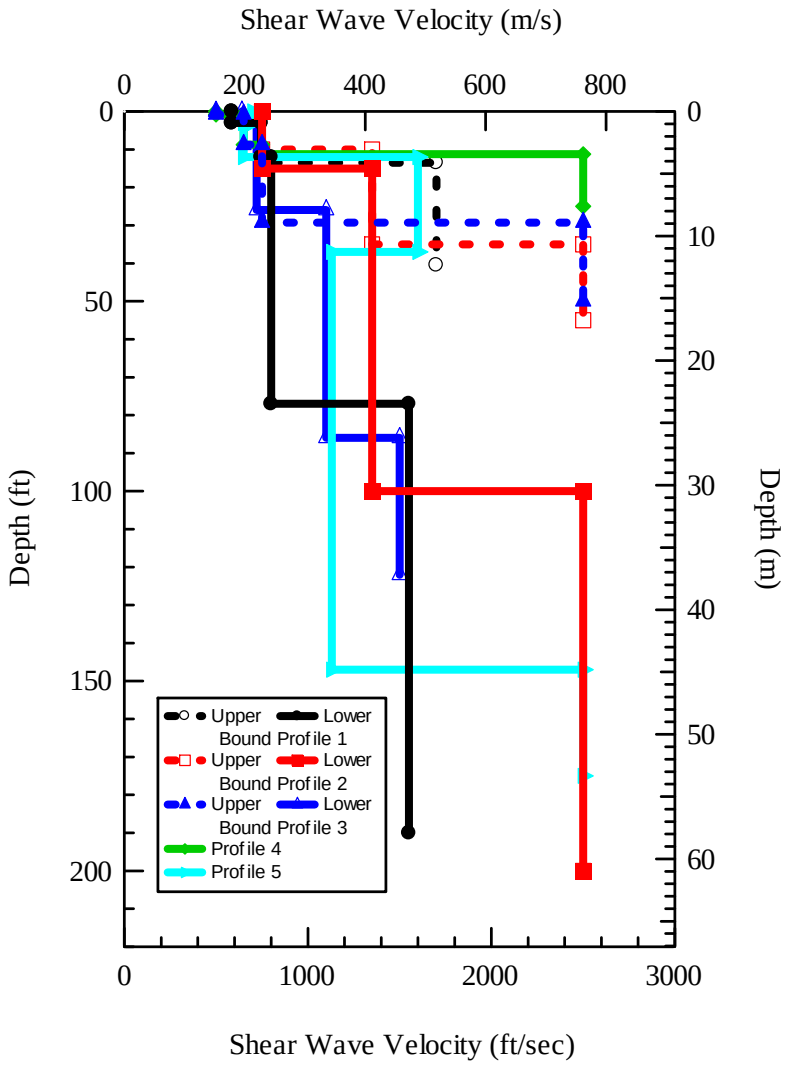


Figure 124 Shear wave velocity profile comparison for Site 29 (WWRC).

Site 30: Zion Lutheran Church

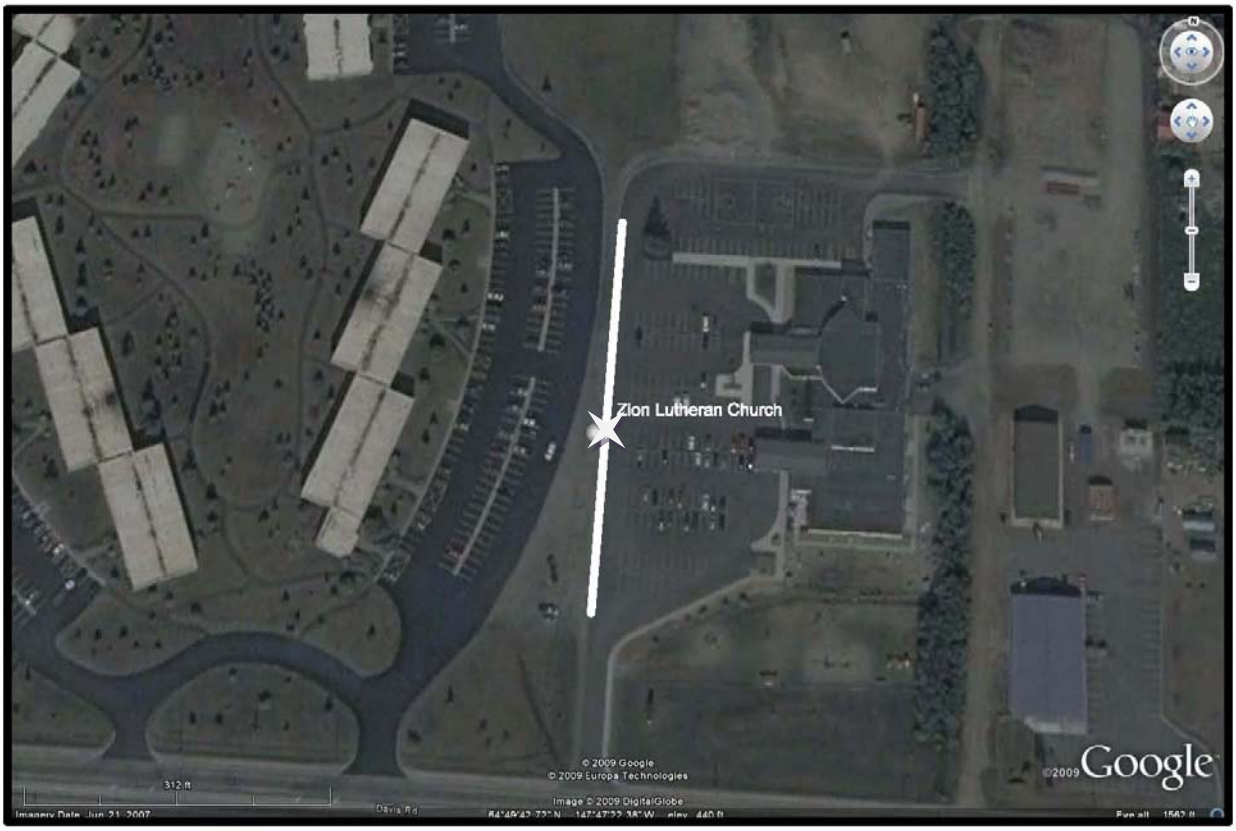


Figure 125 SASW Array location map for Site 30 (Zion Lutheran Church).

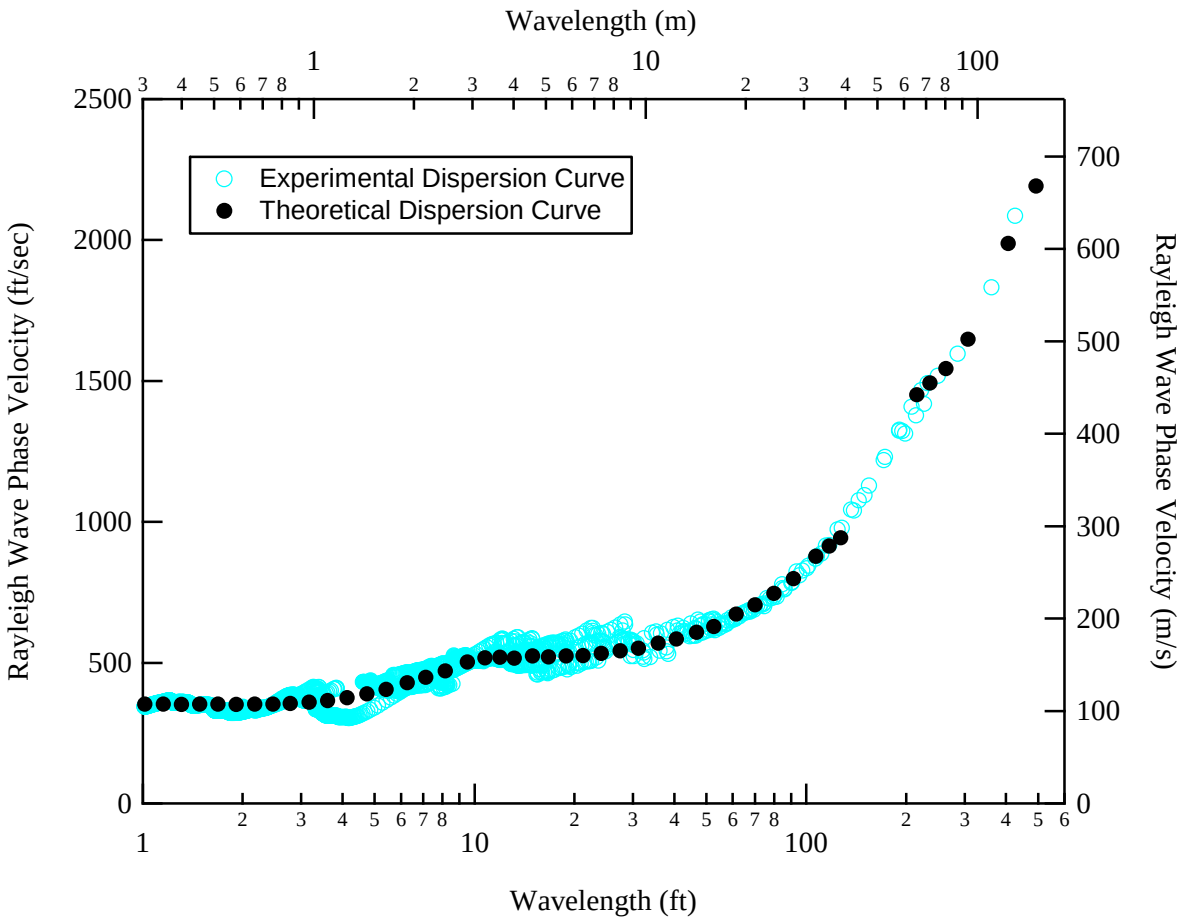


Figure 126 Experimental and theoretical dispersion data at Site 30 (Zion Lutheran Church).

Table 49 Final forward modeling soil profile for Site 30 (Zion Lutheran Church).

Layer No.	Thickness (m)	Depth to bottom (m)	P-wave velocity (m/s)	Shear wave velocity (m/s)	Poisson's Ratio	Unit Weight (kN/m^3)	Vs 30 Site Class (m/s)
1	0.8	0.8	210	110	0.30	16	308
2	5.5	6.3	340	180	0.30	17	
3	7.6	13.9	470	240	0.32	18	D
4	47.1	61.0	1060	530	0.33	19	

Note: maximum depth of profile is approximately equal to maximum experimental wavelength/two.

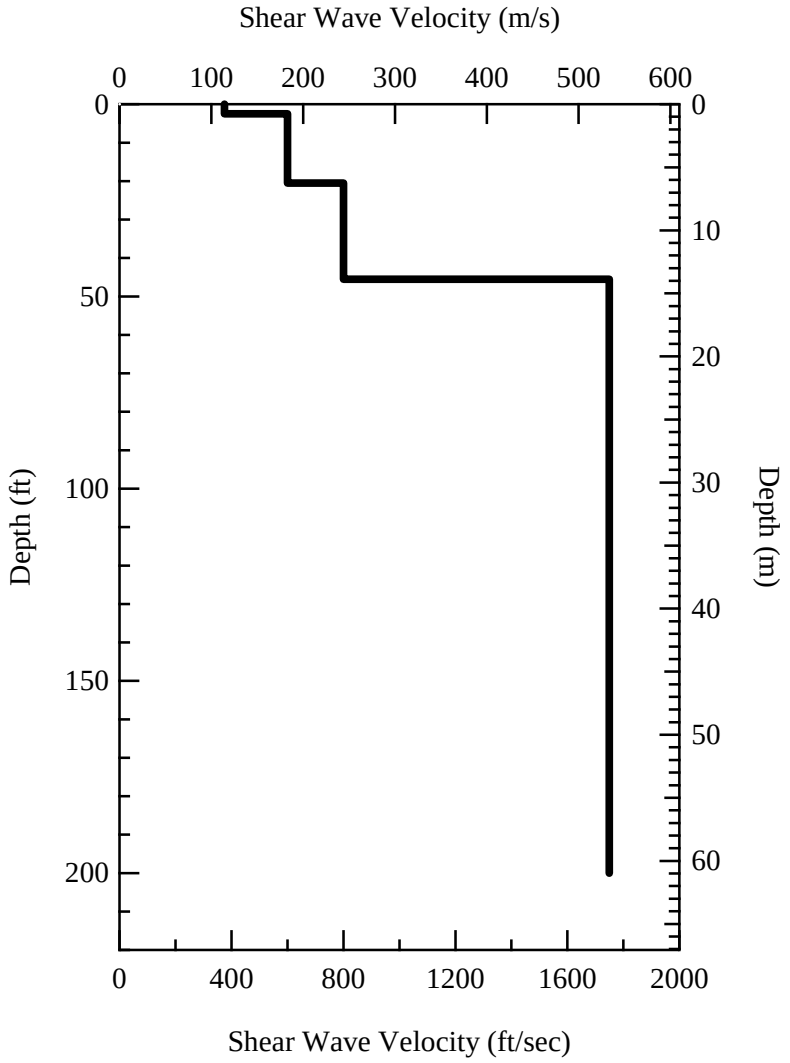


Figure 127 Shear wave velocity profile for Site 30 (Zion Lutheran Church).